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Wayne Orchiston
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Exploring the History of Southeast Asian Astronomy

A Review of Current Projects and Future Prospects and Possibilities

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Exploring the History of Southeast Asian Astronomy

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About the Authors

Rose Ann Bautista resides in the Philippines. She earned a BSc in Astronomy Technology (2015), a Graduate Diploma in Astronomy (2017) and an MSc in Astronomy (2018), all from Rizal Technological University (RTU) in Manila. Currently she is studying for a PhD in Astronomy at the same university. Rose Ann also earned a Certificate of Professional Education in 2016 from the University of Rizal. She was awarded the RTU's Best Thesis Paper in 2019.

She has been writing research papers on astronomy, astrobiology, astronomy education, astrophysics and Philippine ethnoastronomy, and is an author of books in the fields of Earth Science, Earth and Life, and Physical Science.

Rose Ann has attended international training programs and seminars on astronomy education, exoplanets, astrophysics, and ethnoastronomy, and she has presented research papers at local, national and international research forums. She also supervises senior high and undergraduate student research projects.

Currently Rose Ann is a College Instructor and Head of the Department of Earth and Space Sciences and a researcher in the Center for Astronomy Research and Development at RTU. She is the former adviser of the RTU-Astronomy Society and the RTU-Astronomy Rotaract.

Rendy Darma was born in Tanjung Pinang (Indonesia). He was awarded scholarships from the Indonesian Ministry of Research and Technology to complete BSc and MSc degrees in Astronomy from Bandung Institute of Technology (ITB). The title of his MSc thesis was “The Dynamical Evolution and Formation of Binary Star Clusters in the Milky Way and Large Magellanic Cloud from Fractal Stellar Distribution”.

After completing his master degree, he continued his research in ITB until the end of 2018. He was teaching Astronomy for high school students participating in the Astronomy Olympiad in 2019. Since January 2020, Rendy has been working as a back-end developer in the Xtremax Digital Company (in Indonesia).

He is interested in computational astrophysics, galactic dynamics, stellar astrophysics and dynamics, and Indonesian ethnoastronomy. In 2016 and 2018 he participated in astronomy schools and workshops at the National Astronomical Observatory of Japan and the National Research Institute of Thailand.

Rendy has published nine papers in computational astrophysics, stellar astrophysics, and stellar dynamics since 2019. Although he is now working as a web programmer, he is still actively researching binary star cluster formation with his supervisor at ITB and his co-supervisor from the Xi'an Jiaotong-Liverpool University in China.

In 2018 Rendy and some colleagues agreed to establish Warna Bima, as an astronomical group that would contribute to astronomy education in Indonesia.

Suzanne Débarbat was born in 1928 in Montluçon (France), and spent her career at the *Observatoire de Paris*, from 1953. She obtained her Doctorat d’État (1969) ès Sciences Mathématiques. Her last position was *Astronome Titulaire de l’Observatoire de Paris*, being nowadays *Astronome Titulaire Honoraire* (1997), having been Director (1985–1992) of a research group (*Systèmes de Référence Spatio-Temporels*/CNRS) and (1987–1992) of the D*épartement d’Astronomie Fondamentale* (*Observatoire de Paris*), nowadays *Systèmes de Référence Temps-Espace* (SYRTE), having been supervisor of the thesis of M. Toulmonde in 1995.

After working on fundamental astronomy, determining the astrometric positions of the main planets of the Solar System with a Danjon Astrolabe, she was asked by historians of astronomy to research the history of the *Observatoire de Paris*, its astronomers, their instruments, works and discoveries. This is an on-going project.

Over the years, Suzanne has published many papers in the fields of astrometry, geodesy and related sciences and, from 1976, on history of astronomy. For example, there are several about women in French astronomy in. She also has written prefaces for books and worked with collaborators such as Simone Dumont. Suzanne has participated in most of the exhibitions at the *Observatoire de Paris* and small books or brochures concerning special subjects relating to the *Observatoire*, mostly in collaboration with its *Bibliothèque* (Library). She has written chapters of several books, the most recent one in 2019 with Terry Quinn, which was published in the *Comptes Rendus de Physique* of the *Académie des Sciences*.

Suzanne also participated with Antoine Hurtado in a documentary film about the *Système Métrique Décimal* and, with Lilly Hibbed, on her exhibition "First Light - β Persei" (*Conservatoire National des Arts et Métiers-Galerie de Soussan*), for the Year of Light in France (2015). From 2007 to 2009, Suzanne was General Secretary of the *Comité National Français d'Histoire et de Philosophie des Sciences et des Techniques*.

With B. Guinot, Suzanne co-authored the book *La Méthode des Hauteurs Égales en Astronomie* (1970), which was translated into Russian and partly into Chinese.

Among others, SD is a member of: International Astronomical union (Commission History of astronomy, President 1991-1994), *Bureau des longitudes* (President 2004-2005), *Académie internationale d'histoire des sciences*. SD was (1976-1981) *rédacteur en chef* of *l'Astronomie,* monthly publication of the *Société Astronomique de France* (SAF) and responsible of the re-edition of books published by the *Bureau des longitudes*. *Suzannedebarbat* is the name, of the small planet 15671, which was proposed by H. Kosai and K. Furukawa from Japan, discovered in 1977 from Kiso (Japan). She organized and/or edited several colloquia, *Journées*, symposia (IAU, IUHPST, CHST, Observatoire de Paris). SD received *Prix des Dames* (SAF 1977), *Prix Jules-Janssen* (SAF 2013), *Prix Paul Doistau–Emile Blutet de l'information scientifique* (*Académie des sciences 2019*, France) with Dominique Bernard. She is a member of: *Légion d'honneur*, *Ordre national du Mérite*, *Ordre des Arts et des Lettres*, ordre des *Palmes académiques.*

Ruby-Ann Dela Cruz has BEd (General Science) and MSc (Arts in Industrial Technology) degrees, a Graduate Diploma in Astronomy, and MSc (Astronomy) and PhD (Philosophy in Technology Education) degrees, all from Rizal Technological University (RTU) in Manila.

Currently she is an Associate Professor in the Department of Earth and Space Sciences and Graduate School at RTU, where she also served as the Chairperson of the Diploma and Master of Astronomy and Master of Science in Science Education; Assistant Dean of the College of Engineering and Industrial Technology; Assistant Dean of the Graduate School; Assistant University Board Secretary, College Secretary of the Graduate School, and Head of the Department of Earth and Space Sciences. She is an associate member at the

National Research Council of the Philippines and a member of the Asia Pacific Consortium of Researchers and Educators.

Ruby-Ann is the author of books relating to Earth Sciences, Earth and Life Sciences, Zoology, and Astronomy. She has published papers on astronomy education in an international journal, and presented an ethnoastronomy paper in an international forum. Currently she is writing papers on light pollution in the Philippines. In addition, she has supervised research by senior high school, undergraduate and graduate students in astronomy, astronomy education, ethnoastronomy and science education.

Patrick Dumon is a retired army officer who was a Chief Communication and Information Systems Manager in the Belgian Parachute and Commando Brigade. From 1996 he worked as a United Nations Military Observer and Staff Officer in conflict zones such as the Golan Heights, Kashmir and Central Africa.

He retired in 2006 and developed a deep interest in Siamese history. He is committed to researching the ancient temples, historical sites and settlements, ancient roads, canals and water gates, bridges, historical events and ruins of the historic city of Ayutthaya, and in 2009 he and two colleagues launched the project 'Ayutthaya Historical Research' and the web site http://www.ayutthaya-history.com This web site now contains extensive records of Ayutthaya's historical past, including details of more than four hundred temples, and accounts of the early astronomical observations made in Ayutthaya.

Patrick publishes under the *nom-de-plume* 'Tricky Vandenberg', and his aim is to gather and publish a maximum of information on historical sites in and around Ayutthaya in order to facilitate and encourage the level of public awareness and support necessary for the long-term survival of Ayutthaya's cultural heritage. He has gathered information from books, theses, chronicles, documents and reports, and by visiting sites and interviewing local villagers.

J. C. Eade (MA St Andrews, 1963; Adelaide 1966; PhD ANU 1973), after completing his thesis on "Aristotle's *Poetics* in English Literature", became a Research Assistant in the Department of English at the Australian National University (ANU) and then Research Officer in the newly-established Humanities Research Centre at ANU ("Bibliographical Essay on Studies in Eighteenth-Century European Culture since 1958" (1970) and "Eighteenth-Century Studies in Australia since 1958" (1979—where the attached photograph was published).

Then, with the increase of computer assistance in the late 1980s he turned his attention from English writing (*The Forgotten Sky: A Guide to Astrology in English Literature*, Clarendon Press, Oxford, 1984) to the possibilities of dating the inscriptional records of South East Asia, and published two books: *The Calendrical Systems of Mainland South-East Asia* (Brill, 1995) and *The Thai Historical Record: A Computer Analysis* (Centre for East Asian Cultural Studies for UNESCO, 1996).

After his retirement in1988 this interest was extended to include Burma ("On the Temple Walls of Pagan: Early Burmese Horoscopes", *Études birmanes,* EFEO, Paris, 1998, pp. 57–73) and Cambodia ("Dates des Inscriptions du pays Khmer par Roger Billard augmentées par J.C. Eade", *Bulletin del'École française d'Extrême-orient*, Vol. 93 (2006), 395–428). More recently, he has published a series of papers on Burmese astronomy and Southeast Asian calendars, co-authored by Lars Gislén, in the *Journal of Astronomical History and Heritage*.

Ni Putu Audita Placida Emas is a Balinese-Javanese girl who was born in Surabaya, Indonesia, in 1995. She has BSc and MSc degrees from the Institut Teknologi Bandung (ITB). Now, she works at ITB as an academic assistant and is an astronomy communicator at Bosscha Observatory. She also is active in educating senior high school students who will compete in the National and International Astronomy Olympiads. In 2018, she and her colleagues formed 'Warna Bima', which has the goal of supporting astronomy education in Indonesia.

Ni Putu is interested in cosmology research, especially neutrino cosmology and the large-scale structure of the Universe, and soon she will commence a PhD in cosmology.

As a Balinese she has a dream to link the preservation of Balinese culture with astronomy, hence her interest in Balinese ethnoastronomy. She has attended several conferences relating to astrophysics and the history of astronomy, and the results of her research have been published in the proceedings. She also was a student of the 42nd International School for Young Astronomer (ISYA) in Kunming (China) in 2019.

Visanu Euarchukiati was born in Bangkok, Thailand, in 1962. He graduated with a BSc (Eng) in Computing Science from Imperial College, London University, and an MS in Computer Science from Florida Institute of Technology. Visanu has worked as a systems analyst and in other managerial positions with the Shell Company of Thailand, in database analysis for Smart Loyalty (Thailand) and J Walter Thompson, as a communications consultant at ActionAid Thailand, and as an editor and author of Thai books on history of astronomy. Currently he is the General Manager of the CE Foundation.

He produces Thai language podcast programs on star tales, current astronomy news, and news about archeological discoveries. He is also an active member of the Astronomy Dictionary Committee of the Royal Society in Thailand. He holds an executive committee position in the Thai Astronomical Society, and is a committee member of the Siam Society's Siamese Heritage Trust. His interests in astronomy, history, music, literature and photography have led him to many lines of research.

Visanu has edited two series of Thai books on the history of astronomy, the 3-volume "Kings and Astronomy" and the 3-volume "Astronomy Traditions in Thailand". He also is the author of *Chronicle of Astronomy in Siam during the Reigns of Rama V-Rama VIII*, an extension of the former books series. His book *Timeline of Astronomy* was compiled with Thai context added. He edited the Thai and English translation of *Princess of Astronomy*. All of these books were published by the National Astronomical Research Institute of Thailand. Visanu also has edited and translated into English *Heritage Lawyer: Laws for Cultural Heritage Protection*, a publication of the Siam Society.

Siti Fatima (known to all of us as 'Fatim') was born in Sampang (Indonesia) in 1994, and has BSc and MSc degrees in Astronomy from Institut Teknologi Bandung (ITB). Working in collaboration with Dr Kiki Vierdayanti, she continues research in High Energy Astrophysics, on a binary supermassive black hole blazar candidate.

Apart from Astrophysics, Fatim also is very interested in ethnoastronomy and archeoastronomy. She was raised in a small village on the island of Madura and experienced traditional Madurese culture from the time she was very young. When she was at senior high school, she won a gold medal in the 2011 Indonesian *National Science Olympiad* in Astronomy, a silver medal in the 2010 *Asian-Pacific Astronomy Olympia*d (APAO) and bronze medal in 2012 *International Olympiad on Astronomy and Astrophysics* (IOAA) in Rio de Janeiro, Brazil. When she was in the training programme for the IOAA she and the national team were coached by lecturers from the Astronomy Department at ITB. One of the professors there encouraged her to document the traditional Madurese responses to eclipses.

After completing secondary school Fatim was lucky to be able to study at ITB, which was where she met Professor Taufiq Hidayat who supervised her research in ethnoastronomy. She also met Professor Wayne Orchiston through the History and Heritage Working Group of the Southeast Asia Astronomy Network (SEAAN) in Thailand in 2015, who encouraged her to carry out further fieldwork, and then joined Professor Hidayat in helping her write up the research project outlined in this book.

Fatim led a team writing an Astronomy Olympiad book for high school students, titled *Buku Sakti Olimpiade Astronomi* (Yrama Widya, 2015), and together with Mrs Ely Sulistialie (the Bosscha Observatory Librarian), she wrote her second book, a biography of Indonesia's famous astronomer, Professor Bambang Hidayat. It is titled *Derap Langkah Seorang Astronom (Steps of An Astronomer)*, and was published by ITB Press in 2019.

Fatim also actively works on social and public outreach activities about education and child protection. She co-founded Rumah Jamoer, a children protection community in Madura, and she set up the Rampak Naong Library for children in her village. She now lives with her husband, two children and her mother in Depok, West Java, where she co-founded an education and training community named Yaa Bunayya for Mothers and Children.

Alif Husnul Fikri was born in Jakarta. He completed his BSc in Astronomy in 2017 at Bandung Institute of Technology (ITB). The title of his thesis was "Automation of Reduction and Analysis of Chandra X-Ray Satellite Data for Studies of Clusters of Galaxies". He is interested in X-ray astrophysics, cosmology and Indonesia ethnoastronomy. After completing his Bachelor's degree, Alif continued his research in ITB until end of 2017 and presented a poster titled "Estimating Masses of Galaxy Clusters from Automated Analysis of Chandra X-Ray ACIS Data" at a SST Workshop in Vietnam. He currently works as a Data Analyst at Tokopedia (Indonesia).

In 2015 Alif became involved in the IOAA as a Technical Jury Assistant, and in 2016 he participated in an astronomy workshop held by the National Research Institute of Thailand (NARIT).

Alif is also still active in teaching high school students who participate in the Astronomy Olympiad. In 2018 he and his colleagues agreed to form Warna Bima, as an astronomical group that can contribute to astronomy education in Indonesia.

Martin George was born in Ramsgate, United Kingdom, in 1956 and has a BSc (Honours) from the University of Tasmania and a PhD from the University of Southern Queensland (Australia). He is Manager of the Launceston Planetarium at the Queen Victoria Museum in Launceston, Tasmania.

Martin is actively involved in the International Planetarium Society (IPS), being the current Board Member for Oceania, Chair of both International Relations and Elections, and a former President of the Society (2005–2006). In 2018 he was presented with the IPS Service Award. He is a member of the IAU (where he is actively involved in the Historical Radio Astronomy Working Group), and of the Astronomical Society of Australia, and is a former President of the

Astronomical Society of Tasmania. He also served as administrator of the Grote Reber Medal for Radio Astronomy from 2005 to 2014.

Martin's major research interest is the history of Tasmanian astronomy. His PhD research was on low-frequency radio astronomy in Tasmania during the three decades beginning in the mid-1950s and a succession of his research papers, which had been published in the *Journal of Astronomical History and Heritage* (JAHH), were incorporated into his thesis

He has also co-authored several other research papers, on Thai and Australian astronomical history (and published mainly in *JAHH*), and has co-authored two books: *Advanced Stargazing* (Weldon-Owen, 1995) and *Hale-Bopp: Comet of the Century*, (TON OR GRAMMY, 1997), in Thai.

Martin is passionate about communication of astronomy. In addition to his work at the Launceston Planetarium, he presents public lectures, speaks to common-interest groups, and works closely with the media. He speaks about astronomy on several regular radio programmes, and writes astronomy columns for *Astronomy* magazine and Hobart's *Saturday Mercury* newspaper in Tasmania.

In 2009 he was awarded the David Allen Prize for Astronomy Communication by the Astronomical Society of Australia, and the Winifred Curtis Medal for Science Communication by the Science Teachers' Association of Tasmania.

Martin has lived in Launceston, Tasmania, for many years. He is a keen traveller and avid eclipse-chaser, having been to 75 countries, and has included visits to many planetaria and astronomical sites. At home he enjoys making astronomical observations, especially of the aurora australis.

Lars Gislén was born in Lund (Sweden) in 1938, and received a PhD in high energy particle physics from the University of Lund in 1972. He worked in 1970/1971 as a researcher at the Laboratoire de physique théorique in Orsay (France) with models of high energy particle scattering. He has also done research on atmospheric optics and with physical modelling of biological systems and evolution.

He has worked as an Assistant Professor (University Lector) at the Department of Theoretical Physics at the University of Lund, where he gave courses on classical mechanics, electrodynamics, statistical mechanics, relativity theory, particle physics, cosmology, solid state physics and system theory.

For more than twenty years he was a delegation leader and mentor for the Swedish team in the International Physics Olympiad and the International Young Physicists' Tournament.

Lars retired in 1983, and since then his interests have focused on medieval European astronomy and on the astronomy and calendars of India and Southeast Asia. He has published more than 20 research papers in this field. He has also made public several spreadsheet tools implementing a number of astronomical models from Ptolemy to Kepler as well as computer tools for the calendars of India and Southeast Asia. He is a member of the IAU.

Ryan Guido is from the Philippines. He is a product of Rizal Technological University (RTU) in the Philippines, where he earned his BS in General Science, an MA in Education, a Graduate Diploma in Astronomy and MS in Astronomy. Currently he is pursuing a PhD at the Philippine Normal University (the National Center for Teacher Education in the Philippines), working on a country development plan for Astronomy and Space Science Education Agenda in the Philippines.

At RTU Ryan concurrently is an Associate Professor of Astronomy in the Department of Earth and Space Sciences, the founding Program Officer of the Center for Astronomy Research and Development, and the Program Chair of the Master of Science in Astronomy.

After almost fifteen years in academe and research, he has published several research papers on astronomy and science education, solar and space science, research culture, and Philippine ethnoastronomy. Based on Google Scholar, he has a modest 73 citations, an h-index of 3, and i10-index of 2, as of this time of writing.

He has supervised research by senior high school, undergraduate and graduate students in education and astronomy, as well as publishing books on sciences. Moreover, he is keen to seek national and international grants for research, scholarship, community outreach and training programs.

Taufiq Hidayat was born in Surabaya (Indonesia) in 1965, and obtained his Bachelor’s degree in Astronomy from Institut Teknologi Bandung (ITB), Indonesia. His Masters and PhD degrees in Astrophysics were obtained from Université Paris Diderot, Sorbonne Paris Cité, France.

Taufiq has served as Head of the Astronomy Department ITB (1999–2004), Director of Bosscha Observatory (2006–2010), and currently he is Head of the Astronomy Research Division in the Faculty of Mathematics and Natural Sciences at ITB. He is also a member of the National Committee to develop the Timau National Observatory in Timor Island, in the eastern part of Indonesia.

His main interest is in millimeter/submillimeter radio astronomical observations of planetary atmospheres. Recently, he joined a sub-Working Group for star-formation of the East-Asian VLBI Network, and a research group to study the deep field environment of radio galaxies using ALMA data. He also has a strong interest in history of science, and has supervised some undergraduate students to carry out research on archeoastronomical and ethnoastronomical aspects of Indonesian heritage and culture.

Taufiq is a member of the IAU. He has written several textbooks on physics for undergraduate and graduate students and popular books of astronomy for children, as well as editing several conference proceedings. In 2010, the IAU named the main belt asteroid 12179 Taufiq (5030 T-3).

Matthieu Husson was born in France in 1978, and works at l'Observatoire de Paris. His initial training was in mathematics (University of Paris VI), after which he studied the history of medieval Latin sciences at the fourth section of the École Pratique des Hautes Études where he obtained a PhD in 2007 on the mathematical sciences in the fourteenth century.

While continuing his interest in mathematical practices, Matthieu's subsequent research has focused on the history of astronomy as an 'intermediate science' at the end of the Middle Ages (fourteenth to fifteenth centuries). Through an analysis of the tables, texts and diagrams contained in the numerous scientific manuscripts produced during this period, his research attempts to grasp the ways in which the specific astronomical practices attested by these documents, crucial for the development of the discipline in Europe, are part of a global and shared history over the *longue durée*.

Currently this research is developing in the context of the ERC project *ALFA, Shaping a European Scientific Scene: Alfonsine Astronomy* (CoG 723985, 2016, alfa.hypotheses.org) of which Matthieu is the P.I. His research is also deeply engaged in the digital humanities, as attested by the creation of DISHAS, *Digital Information System for the History of Astronomy*, an internationally developed web platform for critical edition and analysis of astronomical tables (dishas.obspm.fr).

Nurul Fatini Jaafar was born in Penang (Malaysia) in 1989, and is a post-graduate student in the Department of Socio-culture/Arts, Academy of Malay Studies, at the Universiti Malaya (UM) in Kuala Lumpur. She received a BSc (Physics and Astronomy) from Universiti Sains Malaysia (Penang) in 2012.

Currently, Nurul's research project focuses on the astronomical knowledge and heritage of the peoples in the Malay Archipelago. Her thesis is on understanding the meaning of the stellar asterisms of the Semelai *orang asli*, and reconstructing their cultural history.

Nurul has served on the Scientific Organizing Committee (SOC) of the History and Heritage Working Group of the Southeast Asia Astronomy Network (SEAAN) since 2015. She has published papers in journals, proceedings and book chapters, and also is actively involved in astronomy education and public outreach.

She has received a number of awards and travel grants during her graduate studies, such as an Honorable Mention Award during the UM Research Carnival Essay Competition 2018; an International Astronomical Union Travel Grant to attend Symposium 358 on "Astronomy for Diversity, Equity & Inclusion: in Tokyo (Japan); and a European Society for Astronomy in Culture Travel Grant to participate in "Road to the Stars", the Oxford XI, SEAC and INSAP Joint Conference in Santiago de Compostela (Spain) in 2017.

Ahmad Hakimi Khairuddin was born in Kuala Lumpur, Malaysia, in 1963, and completed BGS and MA degrees at Wichita State University, Wichita, Kansas (United States), and a PhD in archaeological site management and conservation from the Universiti Malaya (UM) in Kuala Lumpur.

Hakimi is a Senior Lecturer in the Department of Socio-Cultural/Arts, Academy of Malay Studies, at UM, where has served several terms as the Head of Department. He has been teaching anthropology in UM for 28 years.

His areas of expertise and research interests are in cultural theories, cultural anthropology and ethnography of Malay and Austronesian cultures, Southeast Asian prehistory, and anthropological archaeology.

Other than supervising students and publishing his research, Hakimi involves himself as a life member of the Ikatan Ahli-ahli Arkeologi Malaysia (Malaysia's national archaeological association).

Sitti Attari Khairunnisa was born in Jakarta, Indonesia, in 1994. She obtained both her BSc and MSc degrees in Astronomy from Institut Teknologi Bandung (ITB) in 2014 and 2017 respectively with a broad range of research interests, particularly archaeoastronomy and extragalactic astrophysics. Most of the work on the chapter in this book was based on her BS thesis, which was supervised by Professor Taufiq Hidayat.

After graduating, she pursued research that focused on ultraluminous X-ray sources (ULXs) for her MSc thesis. She continued to study the same topic and worked as a Research Assistant in the Department of Astronomy of ITB for the next two years.

Throughout her studies, Sitti has actively participated in the Southeast Asia Astronomy Network (SEAAN) History and Heritage Working Group meetings since 2015, and she has attended several international workshops that cover various topics organised by the National Astronomical Research Institute of Thailand

(NARIT), the Korea Astronomy and Space Science Institute (KASI), Academia Sinica Institute of Astronomy and Astrophysics (ASIAA), and the University of Tokyo.

Roger Kinns was born in Winchester, England in 1944. He read Mechanical Sciences as an undergraduate at Gonville and Caius College, Cambridge and then took an MASc degree in control engineering at the University of Waterloo in Ontario, Canada, before returning to Cambridge to complete a PhD on unsteady aerodynamics.

Roger was Maudslay Research Fellow of Pembroke College, Cambridge, from 1971 to 1975. He then joined YARD Ltd in Glasgow, Scotland to lead development and application of techniques for the acoustic design of ships and submarines. He has worked as an independent consultant since 1999 with principal research interests in underwater noise and vibration due to marine propulsion systems. Until 2019 he was a Senior Visiting Research Fellow in the School of Mechanical and Manufacturing Engineering at the University of New South Wales in Sydney, Australia. He has supervised research students in acoustics at the Universities of Cambridge, Newcastle and New South Wales and has published widely in journals ranging from the *Journal of Sound and Vibration* to the *Journal of Astronomical History and Heritage*. The Maudslay connection led to an enduring fascination with the history of engineering and particularly time signals worldwide.

Presently, Roger is Treasurer of the Maudslay Society and Maudslay Scholarship Foundation, and Chairman of the Younger (Benmore) Trust that has supported development of Benmore Botanic Garden since 1928. He is also a member of the Newcomen Society, the Royal Northern and Clyde Yacht Club, the Tasmanian Philatelic Society and the Incorporation of Gardeners of Glasgow, having been Deacon in 2009-2010. Roger has lived in Clynder, near Helensburgh, Scotland since 1975.

Siramas Komonjinda is a Director of the Astronomy Program at Chiang Mai University, Thailand. She earned a BS (Physics) from Mahidol University, an MS (Physics) from Chiang Mai University and PhD (Astronomy) from the University of Canterbury, New Zealand. She served as an Expert Advisor for the National Astronomical Research Institute of Thailand.

Her research interests are in variable stars, binary stars evolution, and exoplanet search using both photometric and spectroscopic methods. She initiated research on astrobiology in Thailand.

Siramas is also interested in archaeoastronomy, history of astronomy and calendars, especially those that relate to Thai culture and history. She is a member of

Divisions C, F and G of the IAU, and is on the Organising Committee of Commission C4 (World Heritage and Astronomy).

Besides research, she is also very active in education and outreach activities in Thailand. At present, she serves as the Deputy Head of Doi Suthep Nature Center at Chiang Mai University.

Françoise Launay spent her whole career as a research engineer at Meudon Observatory, near Paris, where she was the technical head for a large high resolution vacuum ultraviolet spectrograph installed in the very place where the astronomer Jules Janssen carried out his laboratory experiments.

She was also involved in preservation of artefacts of scientific history. She had joined the team of historians at Paris Observatory as an associate researcher when she published Janssen's biography (Vuibert/ Observatoire de Paris, 2008; Springer, 2012) and went on to research astronomical instrument-makers. She is now concentrating on discovering unpublished material that documents the biographies of unknown or erroneously known Encyclopaedists and people whose names appear in the correspondences of D'Alembert (including himself!), Diderot and Condorcet.

Françoise is a member of the IAU.

Lê Thành Lân was born in Hải Hưng (Vietnam) in 1943. He has a Bachelor of Electrical Engineering from Hanoi University of Science and Technology and a Doctorate in Biomedical and Technological Cybernetics from Ilmenau University of Technology in Germany. For many years he taught at Hanoi University of Technology, before working on Numerical Methods for Dynamic Systems and Information Technology at the Institute of Information Technology, Vietnam Academy of Science and Technology, until his retirement.

For more than three decades Lê has carried out independent research on the ancient calendars of Vietnamese. After finding three old Vietnamese perpetual calendars, he used his computational skills to reconstruct and publish a Vietnamese historical calendar from 1544 in the book: *Calendar for Five Hundred Years of Vietnam (1544–2043)* (Hanoi Publishing House, 2010). In 2020, he published a longer version: *Calendar of Twenty One Centuries (0001–2100)* (Science and Technology Publishing House, 2020).

Along with researching these calendar books, Lê also has used calendars to resolve various issues relating to the dating of events in Vietnamese history that have challenged historians. His research results have been published in many journals and books, but until recently most of these were in Vietnamese and unknown to

Western scholars. For a useful English-language overview of Lê's research see: Lê Thành Lân, and Nguyễn Thị Trường, 2017. Researching Vietnamese ancient calendars. In Nha, I.-S., Orchiston, W., and Stephenson, F.R. (eds.), *The History of World Calendars and Calendar-Making: The International Conference in Commemoration of the 600th Anniversary of the Birth of Kim Dam.* Seoul, Yonsei University Press. Pp. 31–46.

Since 2017 Lê has been a supporter of the History & Heritage Working Group of SEANN, and in 2020 his international standing as Vietnam's pre-eminent researcher on ancient calendars finally was recognised when he was elected a member of the IAU.

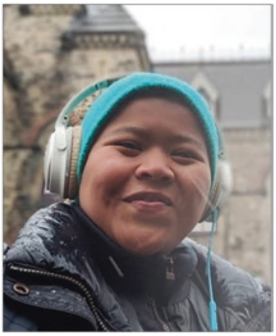
Srikumar M. Menon was born in 1970 in Cochin, India. Trained as an architect at the University of Kerala, he completed his Ph.D in Archaeoastronomy in 2012, from Manipal University. His thesis examined the megalithic monuments of southern India for possible astronomical alignments embedded in their design and layout. This investigation brought to light the nature of a series of menhir sites in southern Karnataka, which were proved to be stone alignments with alignments towards the setting sun on both solstices. After six years in the industry, and 15 years of teaching at Manipal University, he joined the National Institute of Advanced Studies, Bangalore, where he is currently working as Associate Professor.

His academic interests, apart from archaeoastronomy, range from investigating the origins of monumental architecture in the Indian subcontinent, and understanding techniques of quarrying and stone-working from prehistoric to late medieval periods, including tracking ancient artisans. He is also interested in folklore about megaliths and artisans prevalent in the Indian subcontinent. He has recently expanded his study of Indian megaliths from southern India to northeastern India, especially Meghalaya. He is the author of two books – one on Indian megaliths, and another on comets.

Emanuel Sungging Mumpuni was born in Jakarta in 1972, and has a BA in Astronomy and a PhD specialising in solar physics from Institut Teknologi Bandung. Currently he works at the National Space Agency (LAPAN) in the Space Science Center in Bandung, coordinating space weather research and service activities in Indonesia.

Emanuel is member of the IAU, including Commission C4 (World Heritage and Astronomy). Aside from his primary work in heliospheric science, he is also active in various activities relating to the development of space science in Indonesia, including the establishment of a new national observatory in Indonesia. He was a delegation member at the 54th Session of the Scientific and Technical Subcommittee of the 2017 UN Office for Outer Space Affairs, and the 24th Session of the Asia-Pacific Regional Space Agency Forum (APRSAF-24) in 2017. He also was an instructor for the International School for Young Astronomers, Indonesia, in 2013.

Emanuel is interested in the history of Southeast Asian astronomy and has a review paper on Indonesian astronomy (co-authored by Bambang Hidayat and Hakim Malasan) in the book *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe* (Springer, 2017). He also has published on the heritage of Bosscha Observatory (Epifania and Mumpuni, 2012), and co-authored a study of the orientation of Borobudur (Simatupang et al., 2010). He contributed to the "Asian Stars Project/IYA 2009".



Nok Nikeu was born in Subang, Indonesia, in 1990. She completed her Bachelor's degree in Astronomy from Institut Teknologi Bandung (ITB) in 2014. Developing a keen interest in Archaeoastronomy, she wrote her thesis on finding astronomical aspects of the Prambanan temple.

While doing her BSc, she also studied Marketing Management at Padjadjaran University and earned her Bachelor's degree in Economics afterward. She later continued to pursue an MBA at Babson College in the United States, and since then she has been working as a consultant.

Nor Azam bin Mat Noor was born in Sungai Petani, Kedah (Malaysia) in 1971, and studied at Sultan Zainal Abidin Religious College (now Sultan Zainal Abidin University) in Kuala Terengganu and with Terengganu's famous local Muslim astronomer, the late Tuan Haji Abdul Ghani bin Salleh. Nor then completed a Diploma in Land Survey at Ungku Omar Polytechnic in Ipoh, and a 1997 and a BSc (Remote Sensing) at the University of Technology Malaysia (Skudai, Johor) in 2001. He then carried out a solar astrophysics research project for the MSc degree program at the Universiti Sains Malaysia in Penang.

Nor was appointed a Lecturer in Science at Teluk Intan Community College, Seri Manjung (Perak) in 2005. He served in the Brunei Darussalam Government Department of Mufti as an Islamic Astronomical Artifact Investigator for the Sultan Haji Hassanal Bolkiah Islamic Exhibition Gallery, Bandar Seri Begawan in 2007, and was a part-time Science Officer in the Astronomy and Atmospheric Science Research Unit at the University of Science Malaysia for two years from May 2008. Currently he is active in the exhibition of public art astronomy for Malaysian education, arts, culture and unity projects. In 2010 he received the Space Publishing Award from the Malaysia's Deputy Minister of Science, Technology and Innovation.

Noor is experienced in astronomical calculations and is interested in archaeoastronomy and Islamic astronomical studies, including the study of instruments and astronomical phenomena of the Prophet's life. He is lifetime member of the Islamic Astronomical Society of Malaysia. He is frequently invited to give astronomical lectures, and has presented papers on astronomy at the national and international levels. It is now focusing his efforts on reconstructing calendars, and astronomical instruments such as astrolabes, quadrants and sundials.

Yukio Ôhashi was born in Tokyo, Japan, in 1955. After completing BSc (Physics) and MA (Chinese Culture) degrees at Saitama University in Tokyo, he went to the University of Lucknow in India where he completed a PhD on the history of Indian mathematics and astronomy.

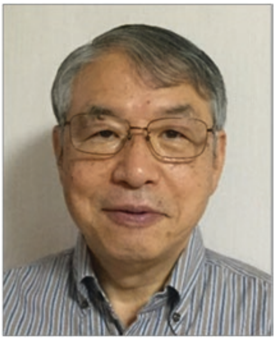
Yukio had independent financial means so after returning to Tokyo did not need to seek an academic or observatory appointment. Instead he taught Chinese language and *ad hoc* courses on the history astronomy, mathematics and science at a number of colleges and universities in Tokyo.

While the history of Indian astronomy remained his prime love, Yukio was quick to include traditional calendars and astronomical instruments in his research portfolio, and over the years he expanded his geographical horizons to include Tibetan, Chinese, Southeast Asian and Japanese astronomical history. One of his last papers was on the ethnoastronomy of the Taiwan aboriginal population, revealing his wide-ranging astronomical interests.

From 1985 onwards Yukio presented a succession of research papers and review papers at national and international conferences, including an IAU Colloquium and a General Assembly, and he published his research in journals and in a number of books and conference proceedings. When he died, he was close to finishing a book on Classical Indian Astronomy for Springer. Supporting Yukio's prodigious research effort was an outstanding reference and reference library that occupied much of his house in an inner suburb of Tokyo.

Yukio was a long-standing member of the IAU and a strong supporter of Commission C3 (History of Astronomy). He was on the Executive Committee of ICOA (the International Conference on Oriental Astronomy), and was active in the History & Heritage Working Group of SEAAN. He also served on the Editorial Board of the *Journal of Astronomical History and Heritage*.

We all were shocked to learn that Yukio had died suddenly on 31 October 2019 at the age of 64, long after submitting Chapter 24 for publication in this book. He was on the SOC of the Third SEAAN History & Heritage Conference, held in Chiang Mai in February 2020, and was down to present a paper. Instead, we ended up dedicating that conference to him. Those wishing to learn more about this remarkable historian of astronomy and a dear friend to many should consult the following obituary: Orchiston, W., and Nakamura, T., 2020. Obituary: Dr Yukio Ohashi (1955–2019). *Journal of Astronomical History and Heritage*, 23, 209–217.



Akira Okazaki was born in Tokyo (Japan) in 1948, and he has a BSc from Tohoku University and a PhD from the University of Tokyo. He is now an Emeritus-Professor at Gunma University in Japan and a member of the IAU. He formerly worked on optical observations of variable stars. He has published some dozens of papers in this field in international astronomical journals. He also engaged in astronomy education with students wanting to be teachers. He has supervised graduate students in optical astronomy and in science education.

Akira has also studied the astronomical records in Vietnamese historical sources. He has presented papers on some of this research at various International Conferences on Oriental Astronomy and at other international astronomy meetings. He has published chapters in *Mapping the Oriental Sky* (2011) and in *The History of World Calendars and Calendar-making* (2018), and a chapter of his will appear in the Proceedings of the 8th ICOA.

Darunee Lingling Orchiston was born in Phrae, Thailand, in 1959. A successful businesswomen (she is the owner and manager of the B-N Shop in Kad Suan Kaew Shopping Centre in Chiang Mai, Thailand), she was taught traditional Lanna astronomy by her father (a medical doctor) and her grandfather (a businessman).

Darunee Lingling also doubles as Professor Wayne Orchiston's part-time Research Assistant and has a special interest in ethnoastronomy. She has participated in research on Philippines and Thai astronomical history; Thai meteorites; and Indian, Maori and Thai ethnoastronomy, and engaged in archival work, data-collecting and fieldwork in Australia, France, India, Singapore and Thailand.

Her research papers have appeared in the *Journal of Astronomical History and Heritage*, in the book *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe*, and in a number of conference proceedings. She will have two co-authored chapters in the forthcoming Springer book, *The Total Solar Eclipse of 18 August 1868: A Watershed Event in the Development of Solar Physics*. Darunee Lingling has co-authored papers presented at conferences and seminars in Austria, India, Myanmar, the Philippines, Singapore, South Korea and Thailand.

Wayne Orchiston was born in Auckland (New Zealand) in 1943, and has BA (First Class Honours) and PhD degrees from the University of Sydney. Formerly he worked in optical and radio astronomy in Australia and New Zealand. He now works at the National Astronomical Research Institute of Thailand and is also an Adjunct Professor of Astronomy in the Centre for Astrophysics at the University of Southern Queensland. Wayne has supervised a large pool of graduate students in history of astronomy through James Cook University and the University of Southern Queensland, in Australia.

He has wide-ranging research interests, and has prepared papers on aspects of Australian, Chinese, English, French, German, Georgian, Indian, Indonesian, Iraqi, Italian, Japanese, Korean, Malaysian, New Zealand, Philippines, South African, Thai and US astronomy. His recent books include *Eclipses, Transits, and Comets of the Nineteenth Century: How America's Perception of the Skies Changed* (Springer, 2015, co-authored by Stella Cottam), *Exploring the History of New Zealand Astronomy: Trials, Tribulations, Telescopes and Transits* (Springer, 2016), *John Tebbutt: Rebuilding and Strengthening the Foundations of Australian Astronomy* (Springer, 2017), *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe* (Springer, 2017, co-edited by Tsuko Nakamura); *Exploring the History of Southeast Asian Astronomy: A Review of Current Projects and Future Prospects and Possibilities* (Springer, 2021, co-edited by Mayank Vahia), and *Golden Years of Australian Radio Astronomy: An Illustrated History* (Springer, 2021, co-authored by Peter Robertson and Woody Sullivan). He has also co-edited a succession of conference proceedings.

Wayne has been very active in the IAU for several decades, and is the current President of Commission C3 (History of Astronomy). In the past, he was responsible for founding the Transits of Venus and Historical Radio Astronomy Working Groups. In 1998 Wayne co-founded the *Journal of Astronomical History and Heritage*, and is the current Managing Editor. He also serves as an Editor of Springer's Series on Historical and Cultural Astronomy. In 2013 the IAU named minor planet 48471 'Orchiston' after him, and more recently he and one of his former American graduate student, Dr Stella Cottam, shared the 2019 Donald E. Osterbrock Book Prize from the American Astronomical Society for their book *Eclipses, Transits, and Comets of the Nineteenth Century: How America's Perception of the Skies Changed.*

Wayne and his wife Darunee Lingling Orchiston live in the Thai countryside one hour's drive from the northern city Chiang Mai.

Phạm Vũ Lộc was born in Hanoi (Vietnam) in 1990. He has an MSc degree from Hanoi University of Science and Technology, with a major in Nanoscience and Nanotechnology.

A passion for astronomy since his childhood led Phạm in 2017 to become a researcher at the Vietnam National Space Center of the Vietnam Academy of Science and Technology. From that time, he has been researching the history of science in Vietnam, but especially astronomy and mathematics.

Because of his proficiency in languages, and especially Classical Chinese, Phạm was able to team up with Associate Professor Lê Thành Lân and present a paper on the history of Vietnamese astronomy and calendars at the second SEAAN History and Heritage Working Group meeting, in Myanmar, and subsequently this was developed into a chapter for this book. This is his first international publication on history of astronomy.

Phạm also attended the February 2020 meeting of the Work Group, where he and Associate Professor Lê presented a paper about the calendars of two Vietnamese ethnic minorities, based on research carried out by their Vietnamese colleagues. Phạm looks forward to conducting further research on Vietnamese astronomical history, and has been discussing collaborative projects with colleagues from other SEAAN countries.

Adli A. Rasyid was born in Makassar (Indonesia) in 1994, the son of a parent with Mandar ethnicity. He completed his BSc in Astronomy in 2018 at Bandung Institute of Technology (ITB).

Adli has a passion for ethnoastronomy, and motivated by his Mandar background decided to carry out research on Mandar navigation.

Currently, he is also interested in astro-tourism and plans to create an astronomy village free from light pollution in Pamboang Majene, West Sulawesi. He really wants to help improve his hometown.

Together with colleagues, in 2018 Adli co-founded Warna Bima, which is an astronomical group designed to provide astronomy education for general public in Indonesia

Orapin Riyaprao was born in Chiang Rai (Thailand) in 1976. She has a BS in Statistics from Chiang Mai University (Chiang Mai, Thailand) and an MA in Applied Mathematics from Long Island University (New York, USA). Formerly she worked as a lecturer in the School of Science, Mae Fah Luang University in Chiang Rai, Thailand.

For the past 10 years, Orapin's research interests have included Lanna and Thai historical records; the history of Indian, Chinese, Burmese and Thai calendars; temple orientations with respect to the azimuth of sunrise-sunset; and the wisdom of astronomy in Lanna Culture and its related kingdoms (i.e. the Kingdoms of Hariphunchai, Sukhothai, Ayutthaya, Lavo, Pagan, and Angkor).

Cherdsak Saelee was born in Chiang Mai (Thailand) in 1970. He has BS (First Class Honours) and MS degrees from Chiang Mai University, and PhD in Physics (in 1999) form Leeds University in the UK. Since 1995 he has worked as a lecturer in the Department of Physics and Materials Science at Chiang Mai University.

For the past two decades he has been interested in archaeoastronomy as well as the Thai calendar, particularly in relation to Northern Thailand. His archaeoastronomical research is an extension of the research conducted by the late Associate Professor Samai Yodinthara, Assistant Professor Mullika Thavornathivas and Associate Professor Sanan Supasai, all three of whom had been researching and gathering information for more than 30 years. Cherdsak has collaborated with them since 1990 in three major areas: an outreach project to unify teaching and learning concepts for teachers and schools in Thailand; the relationship between the orientation of monastery temples and associated cultural traditions; and the Thai lunar calendar.

B. S. Shylaja was born in Keladi (India) in 1953. She obtained an MSc in Physics from Bangalore University in 1973. After short tenures at the National Aerospace Laboratory and the Central Power Research Institute (both in Bengaluru) she joined the Indian Institute of Astrophysics where initially she worked on the instrumentation of telescope controls. Subsequently she began research under the guidance of Professor M.K.V. Bappu, and obtained her PhD with a thesis on Wolf-Rayet stars. Starting with Comet 1P/Halley, she observed many comets, and she also researched Ap stars, novae and dwarf novae.

After a brief stint at the Physical Research Laboratory at Ahmedabad, Dr Shylaja joined the Planetarium in Bengaluru where she taught basics of astronomy and astrophysics to highly motivated students, along with the popularisation activities of the planetarium.

She initiated research in history of astronomy with the unconventional sources of records such as stone inscriptions, which produced very interesting results. She also scrutinises travelogues, temple architecture, art works and literary works for astronomical records. She has been working on unpublished manuscripts of medieval texts and the process of editing and compilation has resulted in an extensive catalogue of over 100 stars with Indian names. She has published more than 300 popular articles and 121 publications in refereed journals. In addition, she has authored or co-authored 15 books, including a book with pop-up pages on the medieval period observatories of Jai Singh.

Dr Shylaja has served on many text book committees, Olympiad training programmes, Boards of Studies of universities and for encyclopaedias. She is a member of Commissions C3 (History of Astronomy) and C4 (World Heritage and Astronomy) of the IAU, and is Chairperson of the C3 Project Group on Indian and Southeast Asian Astronomical Stone Inscriptions. She is keen to expand her work in this field into Southeast Asia through the History & Heritage Working Group of SEAAN.

Boonrucksar Soonthornthum was born in 1952 in Bangkok, Thailand. Apart from a PhD in Astronomy, he has also been awarded an Honorary DSc in Astrophysics by Songkhla Rajabhat University (2008), an Honorary DSc in Physics by Rajabhat Chiang Mai University (2012), an Honorary PhD in Astronomy by Chiang Mai University (2016) and an Honorary PhD in Physics by Rambhai Barni Rajabhat University (2019).

Boonrucksar was the Founding Director of the National Astronomical Research Institute of Thailand (NARIT), Ministry of Science and Technology, from 2004 to 2017, and continues to be associated with NARIT. He was the Dean of the Faculty of Science at Chiang Mai University from 2004 to 2007, and Associate Dean of the Graduate School at Chiang Mai University from 2001 to 2004.

His principle research interests are in Astrophysics, Physics, History and Heritage in Astronomy, and he has published 67 papers and edited five books. He has led many projects setting up astronomical facilities within Thailand, and has received many national awards in recognition of his work. He also serves in an advisory capacity for several institutions.

Boonrucksar is the current Vice President of IAU Commission C1 (Astronomy Education and Development) and since 2007 has been the Chair of the Southeast

Asia Astronomy Network. He was the President of the International Olympiads on Astronomy and Astrophysics (2007–2011), and is the current Chairman of the Thai Astronomy Olympiad Competition. He is a Fellow of the Royal Astronomical Society.

He has been President of the Thai Physics Society since 2017, and is the current Vice-President of The Science Society of Thailand Under the Patronage of His Majesty the King. He is also a member of the Thai Physics Society, the Thai Astronomy Society, the Science Society of Thailand and the Thai Academy of Science and Technology.

Korakamon Sriboonrueang was born in Lamphun (Thailand) in 1979. He earned a BEd in Physics from Chiang Mai Rajabhat University (Chiang Mai), Thailand and an MS in Teaching Physics from Chiang Mai University (Chiang Mai, Thailand).

He works in the Academic Research Division at the National Astronomical Research Institute of Thailand in Chiang Mai.

His research interests focus mainly on archaeoastronomy, including the Lanna map of the lunar mansions and the application of the lunar mansions in daily life.

Wolfgang Steinicke studied physics and mathematics in Germany. He later specialised in General Relativity and Quantum Mechanics. Already in his youth, he observed the sky with telescopes. Later, his interest focused on Dreyer's *New General Catalogue*, which essentially rests upon observations by William and John Herschel. The research on non-stellar objects, their data and historical sources led to comprehensive catalogues, including a revision of the NGC and its supplements.

In 2008, Wolfgang received a PhD from Hamburg University for a thesis on nineteenth century deep-sky observations, and this was published in 2010 by Cambridge University Press as *Observing and Cataloguing Nebulae and Star Clusters: From Herschel to Dreyer's New General Catalogue*.

Wolfgang is a Fellow of the Royal Astronomical Society, Director of the History of Astronomy Section of the German Vereinigung der Sternfreunde (VdS), a Committee Member of the British Webb Deep Sky Society, and he works for international associations. He frequently organizes astronomy meetings and gives talks or courses all over the world.

He is the author of nine books (in German and English) and has published more than 300 research papers. Currently he is writing a comprehensive book about William Herschel's observations.

Jesus Torres is a holder of a Bachelor of Business Administration (1978), a Master of Business Technology (1982) and a Doctor of Public Administration (1986), all from Rizal Technological University (RTU) in Manila (Philippines). He took up a Post-doctoral Fellowship at Chulalongkorn University in Thailand in 2006, and in 2010 he completed a graduate Certificate in Business Economics at the University of Asia and the Pacific in Manila.

Starting with the rank of Assistant Instructor at RTU in 1978, Dr Torres rapidly rose through the ranks, becoming a full Professor in 1986, and was evaluated with the rank of University Professor under NCC 69 in 1993. He became Vice President of RTU that same year and President in 2010. In 2018 he became President of the Technological University of the Philippines.

Professor Torres has taught one hundred and twenty five different subjects in the Tertiary, Master's and Doctorate levels in the fields of Philosophy, Management, Marketing, Filipino, English Literature, Political Science, Education, Physics, Astronomy, Finance, Business Law, Economics, and Psychology. Thus, he has been called a 'Renaissance Man' by the Chairperson of the Commission on Higher Education.

One of only six Filipinos who are members of the IAU, and a member of Commission C3 (History of Astronomy). Professor Torres has written 23 volumes of researches and texts on Astronomy, and his papers have been published in the *Astronomy Education Review*. In 2007 he received the Padre Faura Award from the Philippine Astronomical Society, the highest award for Astronomy in the Philippines. He has attended SEAAN History & Heritage conferences and a NARIT/UNESCO ethnoastronomy workshop. He has a special interest in the history of astronomy in the Philippines, and currently is translating Dante Ambrosio's ethnoastronomy classic, *Balatik*, into English. Apart from astronomy, he has also written books on Philosophy, Political Theory and Filipino Psychology.

Professor Torres is a member of the National Research Council of the Philippines in the Division of Earth and Space Sciences (Division XII), and has served on many different Philippine national committees. In 2009, he also was a member of the DOST-National Organizing Committee for the International Year of Astronomy. On 28 January 2016 he was given the Highest Distinction of Leadership Excellence in Education Asia by the Asian Council of Leaders, Administrators, Deans and Educators in Business (ACLADEB).

Mayank N. Vahia was born in Kutch in India in 1956. He completed his PhD in Astrophysics in 1984 from the Tata Institute of Fundamental Research (TIFR). The title of his thesis was "Charged Particle Emission from Sun". After completing his PhD he continued to work at TIFR until his retirement in 2018 where he rose to the position of Professor. During his research career in TIFR he worked on making and operating space telescopes that were flown on American, Russian and Indian satellites.

For the past two decades he has been interested in history of science and astronomy, as well as impact of science on society and the evolution of civilisations. He has published more than 250 research papers during his career, more than 50 of which are about history of science and astronomy. He has edited three books and written two books. According to Google Scholar, he has 1259 citations; his h-index is 17 and i10-index is 33.

Mayank initiated the Astronomy as well as Junior Science Olympiad programmes in India and guided them for more than a decade. He was also the Director of the Nehru Planetarium in Mumbai for a year. He is a fellow of several academies nationally and internationally and has been on the list of referees for several national and international journals. He has served on the Governing Council of Deccan College, Pune and Ananthacharya Indological Research Institute, Mumbai and has been on the Board of Studies of Yashwantrao Chavan Maharashtra Open University. Mayank is a member of Commissions C3 (History of Astronomy) and C4 (World Heritage and Astronomy) of the IAU, and is on the Editorial Board of *the Journal of Astronomical History and Heritage*.

After his retirement he started an innovative School of Mathematical Sciences, at the Narsee Monjee Institute of Management Studies, a Deemed university in Mumbai.

Part I
Introductory Studies

Chapter 1
Exploring the History of Southeast Asian Astronomy: A Checklist of Recent Research Projects and Future Prospects and Possibilities

Wayne Orchiston and Mayank N. Vahia

1.1 Introduction

This book is a reflection of the success of the History & Heritage Working Group (H&H WG) of the Southeast Asian Astronomy Network (SEAAN). SEAAN exists to foster collaboration among Southeast Asia's professional astronomers (see Fig. 1.1), and it has a number of specialist astrophysical WGs. The H&H WG was formed at the December 2013 Annual Meeting of SEAAN, in order to

- Encourage research on all aspects Southeast Asian astronomical history
- Encourage collaborations
- Encourage publication of results
- Encourage presentations at seminars/conferences
- Organize meetings
- View Southeast Asia in regional context: India, East Asia (mainly China) and Australia-New Zealand

This last bullet point recognizes Southeast Asia's unique geographical position, at the 'cross-roads' of South Asia, East Asia and Australia-Oceania.

Our definition of 'history of astronomy', includes all of these specialist or niche areas recognized by the International Astronomical Union's Commission C3 (History of Astronomy), including archaeoastronomy and ethnoastronomy—both of which have special relevance to Southeast Asia (henceforth SEA), as we shall

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Fig. 1.1 A map showing in green all of the nations affiliated with SEAAN: Myanmar, Thailand, Laos, Cambodia, Vietnam, Malaysia, Singapore, Brunei, the Philippines and Indonesia.

see. Furthermore, while hominids have inhabited SEA for nearly 2 million years, we have no knowledge of early astronomical beliefs and practices, so our studies of ancestral astronomical systems are restricted to the last 70,000 years, since the arrival of anatomically modern man, *Homo sapiens sapiens*, and especially to the last 4000 years, with the appearance of Austronesian and Austro-Asiatic populations (more about them in Chapter 2).

With such archaeoastronomical or ethnoastronomical studies we advocate adopting a multidisciplinary approach and where possible synthesizing data drawn from some (or even all) of the following fields: anthropology, archaeology, genetics, geology, history, linguistics, palaeoanthropology and palaeoageography. And in studying the history of SEAn astronomy during the last 2000 years, we realize the importance of considering the respective influences of different religions (but especially Hinduism, Islam and Christianity) and of Western colonialism on the different astronomical systems.

Since the formation of the H&H WG we have seen an explosion of interest in the astronomical histories of some of the SEAAN nations, but especially Thailand, Vietnam, Malaysia, the Philippines and Indonesia. This is reflected in the publications listed at the end of this chapter: there are 79 SEAn history of astronomy entries dating to the past twelve years (2010–2021 inclusive) and 83.5% of these were published in 2015 or later. Note that we made a conscious decision to only include publications written in English in our literature survey—more on this later, in Section 1.3.4.

In the few short years since the SEAAN H&H Working Group was formed we also have held three 2–3 day mini-conferences, two in Thailand and one in Myanmar, and most of the chapters in this book derive from one (or sometimes more) of these meetings. Originally we planned to publish this book much earlier and Springer was eagerly awaiting the arrival of the manuscript, but we never received some of the promised chapters, which left gaping 'holes' in the book.

As the first-ever book on the history of SEAn astronomy we felt is needed to be representative of the region so we scheduled a second mini-conference, but again with the same sad outcome, and finally a third one, in Chiang Mai in February 2020. Yet when the submission deadline for manuscripts arrived, two key chapters about the Philippines did not, and after much soul-searching we decided to go ahead and publish anyway. But the absence of even one Philippines chapter in a book of 24 chapters continued to haunt us.

In English there is a saying, 'Every black cloud has a silver lining', which means that when something really bad happens often there also will be a positive outcome, and this is precisely what happened with this already long-awaited book. Just three weeks before the Springer submission deadline the authors of Chapter 2—which was already edited and ready to go to Springer—very kindly decided to withdraw their chapter (they had just gone and published it elsewhere!). This created a major dilemma for us: should we reduce the book by one chapter and revise all of the chapters (renumbering headings, figure captions, table titles, text references to tables and figures, etc., etc.) from Chapter 3 on—a very time-consuming and tedious task—or should one of us (WO), assisted by colleagues in Manila, try and write a brand new chapter, about Philippines history of astronomy, in the very little time left?

For better or worse, we chose the latter option, and after far more work that we could ever have imagined was necessary that long well-researched and well-illustrated chapter was finished, and it is now in the book as a Chapter 2 replacement. It is so good to finally see the Philippines represented! Meanwhile, we adopted the aforementioned multidisciplinary approach in order to try and understand the ways in which Philippines indigenous astronomical systems would have evolved and changed with time (just like other areas of culture). This will be a novelty for most of you reading this book, but one we hope will be rewarding for you. We suspect that for most it will be a new way of thinking about history of astronomy.

Because of the decision to prepare a new Chapter 2, and to devote it entirely to the Philippines, we have had to make last-minute changes to our plans for this chapter, which originally was to have been substantial, and was to have included the Philippines (but not in nearly as much detail as in Chapter 2). What we therefore have decided to do in this chapter is to briefly summarise publications from the past ten years relating to each of the SEAAN nations, and then bullet point those areas that we feel most warrant further research. Certainly, there are other areas of research that could be listed, but our bullet points highlight areas where a nation can make an *important contribution* to international scholarship.

So now let us examine the check list, gauge the progress—or lack of it—that has been made on a nation-by-nation basis over the past 10 years and review those areas most deserving of further (or totally new) research. We will start at the regional level, and then discuss the different SEAAN nations individually. With some regret we decided to exclude Brunei from our study since it has yet to establish an international astronomical presence or demonstrate that it can offer history of astronomy projects of international importance. Hopefully, this situation will change in the future.

1.2 A Checklist of Recent Southeast Asian History of Astronomy Projects and Future Research Prospects

1.2.1 Southeast Asia: A Regional View

1.2.1.1 Recent Projects

The late Dr Yukio Ôhashi (see Orchiston and Nakamura, 2020) had arguably the best overview perspective of any scholar on SEAn history of astronomy and the competing elements—India, China, the West, and Islam (see Ôhashi and Orchiston, 2021), and he also has published papers about the special role played by India in influencing SEAn astronomical systems (Ôhashi, 2011, 2017b). This topic is also addressed elsewhere in this book by Shylaja (2021) and Vahia and Menon (2021), while Gislén (2018, 2019) and Gislén and Eade (2019a, 2019e, 2021) discuss Indian calendars and their impact in SEA. For his part, Kinns (2021) reviews the time balls and other systems that were used throughout SEA to communicate accurate time to mariners.

1.2.1.2 Future Prospects

- Astronomical stone inscriptions from Myanmar, Thailand, Laos, Cambodia, Malaysia and Indonesia
- Archaeoastronomy: the sun temples of Southeast Asia (see Fig. 1.2)
- Ethnoastronomy: the Chinese ethnic minorities (the so-called hill tribes) of Myanmar, Thailand, Laos and Vietnam, and their links to China
- Ethnoastronomy: negritos of the Andaman Islands, Thailand, Malaysia and the Philippines
- Ethnoastronomy: from hunter-gathering astronomy to farming astronomy in Myanmar, Thailand, Cambodia, Vietnam, Malaysia, Philippines and Indonesia
- Ethnoastronomy: the relative influences of Buddhism, Islam and Christianity on the traditional astronomical systems associated with rice cultivation
- Ethnoastronomy: astronomy and marine navigation (see Fig. 1.3)
- History of tektite studies in Thailand, Vietnam, Malaysia and Indonesia (Fig. 1.4)

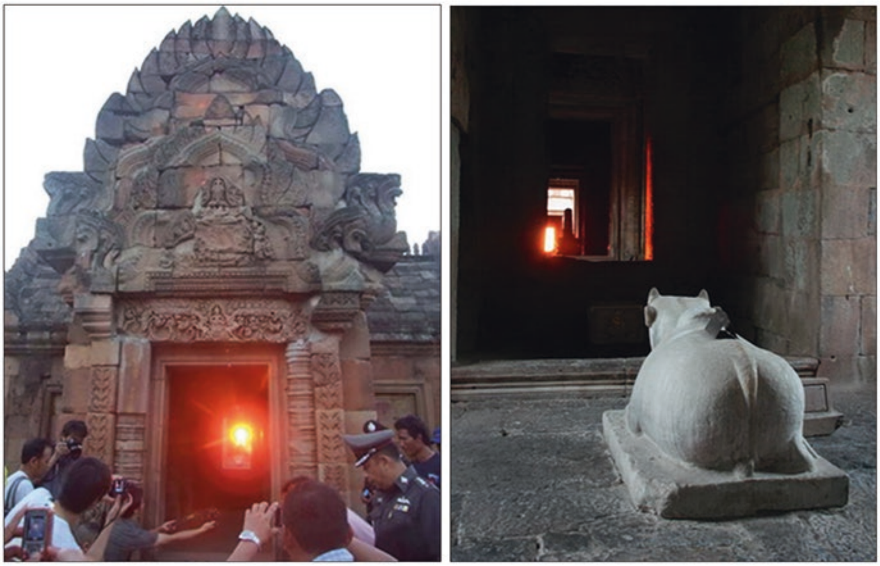

Fig. 1.2 The Khmer temple Prasat Phnom Rung in the north-eastern part of Thailand at sunset on 6 March 2009 at 6.15 p.m. when sunlight penetrates all 15 doorways of the sanctuary (photographs courtesy: Boonrucksar Soonthornthum).

1.2.2 Myanmar

History of astronomy research has yet to blossom in Myanmar. Publications (in English) have been minimal and all were contributed by two Western scholars (from Australia and Sweden). Myanmar offers enormous potential for further research, especially in ethnoastronomy.

1.2.2.1 Recent Projects

There have been papers by Gislén (2015) and Gislén and Eade (2014, 2019b, 2019d), mainly about traditional calendars.

1.2.2.2 Future Prospects

- Archaeoastronomy: astronomical parameters of the temples at Bagan (see Fig. 1.5)
- Ethnoastronomy: individual hill-tribe studies (Fig. 1.6)

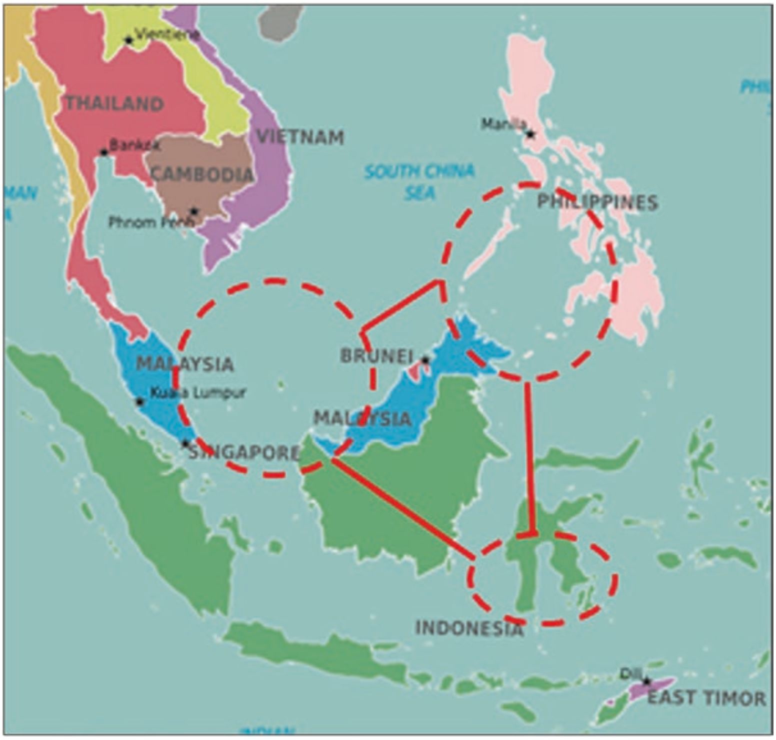

Fig. 1.3 A map showing the three areas of island Southeast Asia with strong maritime traditions. Thus far, only the Mandar and Bugis in Indonesia have been researched, and no attempt has been made to examine the relationships between the maritime astronomical traditions of the three regions, inherited mainly from the Austronesian settlement of island SEA (map modification: Wayne Orchiston).

1.2.3 Thailand

Thailand is particularly active in history of astronomy research, mainly through astronomers associated with the National Astronomical Research Institute of Thailand (NARIT). For some of its historical research NARIT has adopted an international project-team approach. For example, the Seventeenth Century Jesuit Astronomy Project has collaborators from Australia (1), France (3), Sweden (1) and Thailand (3–4). NARIT also has published many books in Thai about the nation's astronomical history, and some of these definitely deserve translation into English for an international audience.

1.2.3.1 Recent Projects

In the past ten years there has been a great deal published in English (and lots more in Thai) about the history of astronomy in Thailand/Siam. There are national overviews by Soonthornthum (2011, 2017); papers about seventeenth century Jesuit

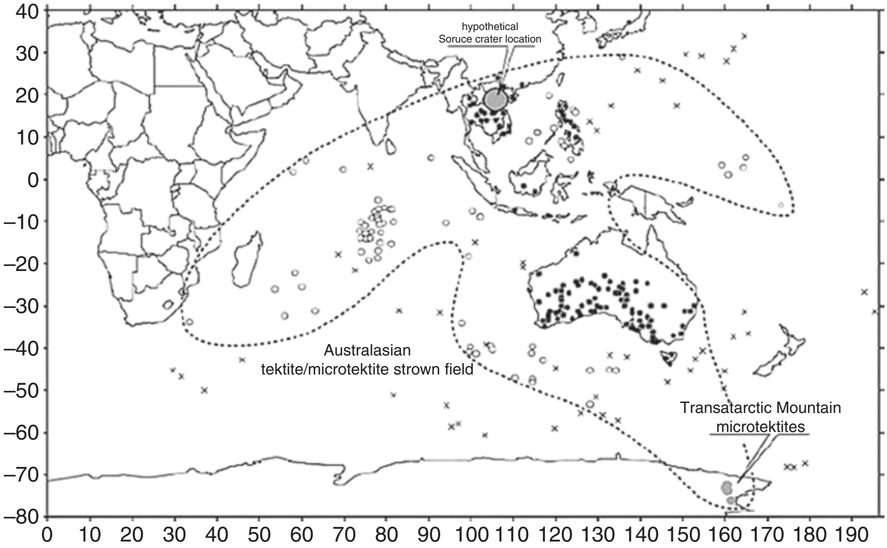

Fig. 1.4 Around 800,000 years ago a major meteorite impact occurred somewhere near the Thai-Laos-Cambodian border, and tektites and microtektites rained down across parts of mainland and island SEA and Australia, as well as areas of the Indian and Pacific oceans, and even as far afield as Antarctica. Tektites from this massive Asian-Australian Strewnfield have been extensively researched in Thailand, Vietnam, Malaysia, Indonesia and Australia, but to date nobody had reviewed these important studies from an historical perspective.

astronomy (Gislén et al., 2018; Orchiston et al., 2016, 2021a, 2021d); about historic solar eclipses (Euarchukiati, 2021a, 2021b; Kramer and Kramer, 2017; Orchiston and Orchiston, 2017; Orchiston et al., 2019a; Soonthornthum et al., 2021); about King Rama V, astronomer and the 'Father of Thai Science (Soonthornthum and Orchiston, 2021); about traditional Thai calendars (Gislén and Eade, 2019b, 2019d; Komonjinda et al., 2017); and astronomical principles associated with the design of Chiang Mai city (Saelee et al., 2021). Meanwhile, Mollerup (2012, 2018) has published two books about Thai Khmer temples, and included astronomical details about some of these.

1.2.3.2 Future Prospects

- Traditional Thai astronomy
- Seventeenth century Jesuit astronomy
- King Rama IV, the 1868 total solar eclipse and astronomical politics (Fig. 1.7)
- Archaeoastronomy: astronomical parameters of Buddhist temples
- Archaeoastronomy: aspects of Hindu and Khmer astronomy
- Ethnoastronomy: studies of individual hill-tribes (see Fig. 1.8)
- Ethnoastronomy: a study of the negritos of southern Thailand
- Ethnoastronomy: astronomical implication of the transition from hunter-gathering to farming

Fig. 1.5 For those wishing to research the astronomical parameters of temples Bagan offers limitless opportunities (https://www.mapsofworld.com/travel/destinations/myanmar/bagan-temples-pagodas).

- The history of Thai tektite studies
- The history of astronomy in Thai universities (e.g. see Fig. 1.9)
- The history of NARIT (which was 10 years old in 2019)

1.2.4 Laos

1.2.4.1 Recent Projects

We know of no recent publications, in English, about Laos history of astronomy, but Laos is mentioned in passing in Gislén and Eade's (2019b) paper about Myanmar and Thai calendars.

1.2.4.2 Future Prospects

- Traditional Laotian astronomy (if there are surviving records)
- Ethnoastronomy: studies of individual hill-tribes
- Archaeoastronomy: astronomical parameters of Hindu temples

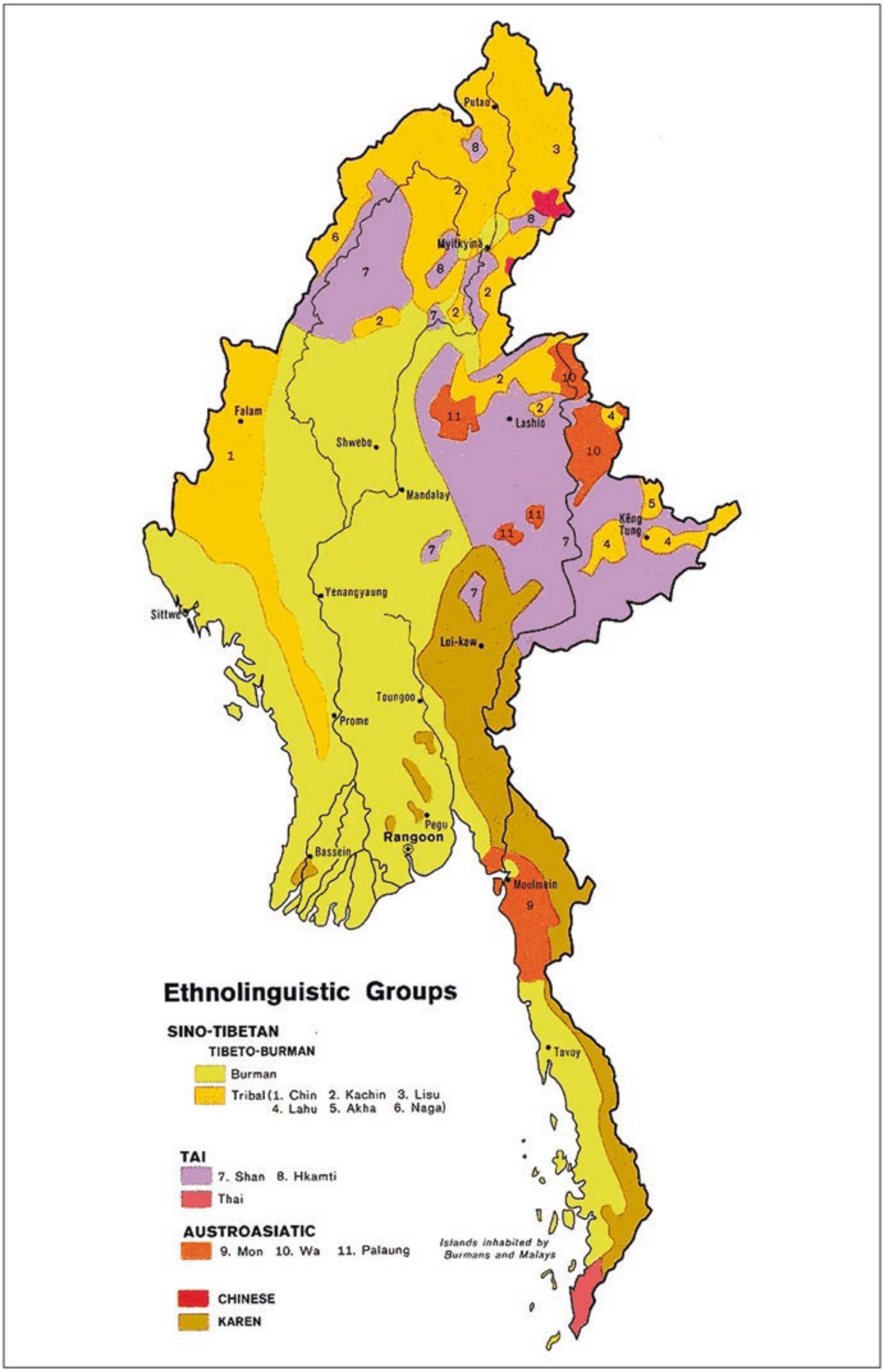

Fig. 1.6 A map showing the plethora of Chinese ethnic minorities in Myanmar, especially near the Chinese and Thai borders (https://upload.wikimedia.org/wikipedia/commons/f/f1/MyanmarEthnolinguisticMap1972.jpg).

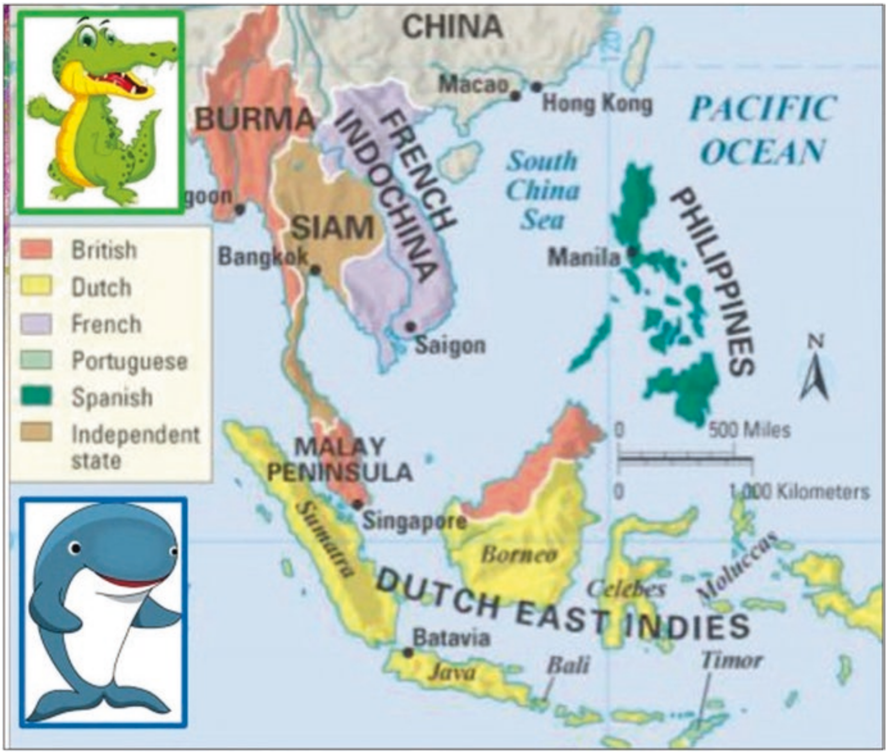

Fig. 1.7 In 1868 Siam's King Rama IV was confronted by Britain and France whose colonies surrounded Siam and who each had colonial ambitions involving Siam. The King wondered whether to swim up-river and make friends with the crocodile (the French) or out to sea and befriend the whale (the British). He ended up choosing both strategies, and he used the 1868 total solar eclipse, visible from Siam, as a political weapon to maintain his nation's independence (map modifications: Wayne Orchiston).

1.2.5 Cambodia

1.2.5.1 Recent Projects

Cambodia also is mentioned in passing in Gislén and Eade's (2019b) paper about Myanmar and Thai calendars, and Mollerup (2018) includes some Cambodian temples in his books about Khmer temples.

1.2.5.2 Future Prospects

- Traditional Cambodian astronomy (if there are surviving records)
- Ethnoastronomy: From hunter-gathering to rice-farming astronomy
- Archaeoastronomy: astronomical parameters of Hindu temples (e.g., see Fig. 1.10)

Fig. 1.8 Northern Thailand has many different Chinese ethnic minorities (‘hill tribes). Here are just two: the Karen (left) and Lisu (right). We know almost nothing about their astronomical systems (https://jetsetbunny.com/are-hill-tribe-tours-in-thailand-ethical/; https://americanexpatchiangmai.files.wordpress.com/2012/01/lisu_12.jpg).

Fig. 1.9 Professor Rawi Bhavalai (1925–2017) from Chulalongkorn University was the first Thai astronomer to establish an international reputation (he was a solar astronomer). He went to two different Australian universities to study for his MSc and PhD degrees (after Knowledge without bounds, 2008).

1.2.6 Vietnam

For many years Associate Professor Lê Thành Lân (an engineer) worked part-time researching ancient Vietnamese calendars and publishing in Vietnamese. Simultaneous, Professor Akira Okazaki from Japan was researching the history of Vietnamese astronomy (e.g. see Fig. 1.11). It is pleasing to now be able to welcome Phạm Vũ Lộc, a new researcher in this field.

1.2.6.1 Recent Projects

Phạm Vũ Lộc and Lê Thành Lân (2021) provide a useful overview paper, and Okazaki (2012, 2014, 2017b, 2019, 2021a, 2021b) has very effectively mined the historic sources, especially for information about eclipses (see, also, Okazaki and

Fig. 1.10 Cambodia has an endless array of Kymer temples (including this one, Preah Kampong Svay Temple) that await astronomical investigation (http://cambodiattak.com/home-stay-01/).

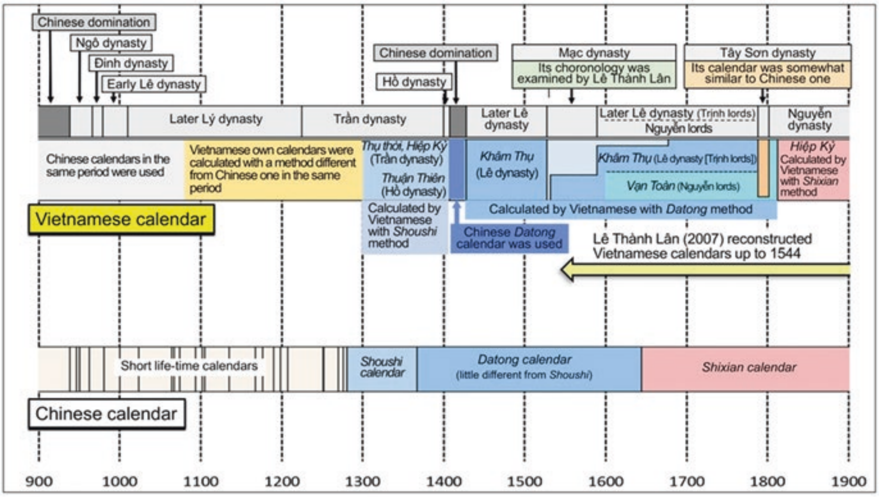

Fig. 1.11 A time-line of Vietnamese luni-solar calendars in relation to the Chinese ones from the tenth to the nineteenth century based on studies by Hoàng (1982) and Lê and Nguyễn (2017a). Calendar names are given in italic type (after Okazaki, 2017a: 48).

Tanokura, 2011). Papers about Vietnamese calendars have been published by Lê Thành Lân (2019), Lê Thành Lân, and Nguyễn Thị Trường (2017a; 2017b) and Okazaki (2017a).

1.2.6.2 Future Prospects

- Traditional Vietnam astronomy
- Seventeenth century Jesuit astronomy
- French colonial astronomy
- Solar Physics: the 1929 total solar eclipse
- Ethnoastronomy: studies of individual hill tribes (see Fig. 1.12)

1.2.7 Malaysia

Although there is a very strong active amateur astronomy tradition in Malaysia, this has not translated into a pool of amateurs intent on researching the history of Malaysian astronomy (although Noor may be able to change this). Currently, there are small groups of researchers at the University of Malaya (in Kuala Lumpur) and the University of Sains Malaysia (in Penang), both involved in ethnoastronomy.

Fig. 1.12 Almost nothing is known about the astronomical systems of the hill tribes of Vietnam. Here top left: Hmong (https://simple.wikipedia.org/wiki/Hmong_people); top right: Tay; bottom left: Dao Do; bottom right: Xa Pho (last three from: https://guide.cmego.com/traditional-clothes-of-ethnic-groups-in-sapa/).

1.2.7.1 Recent Projects

Gislén and Eade (2019c) have published a paper that is partly about traditional Malay calendars, while Jaafar and Khairuddin (2021a, 2021b) and Khairuddin and Jaafar (2021) have written papers on ethnoastronomy and Noor and Orchiston (2021) have discussed an historic solar eclipse.

1.2.7.2 Future Prospects

- Archaeoastronomy: astronomical parameters of Hindu temples in the Bujang Valley
- British colonialism: Did the British use the 1874 transit of Venus to popularize astronomy? (Fig. 1.13)
- British colonialism: Why didn't the British set up an observatory in Penang?
- Ethnoastronomy: further negrito studies (Fig. 1.14)
- Ethnoastronomy: distinguishing Austro-Asiatic from Austronesian astronomical systems
- Ethnoastronomy: researching the astronomy of upland versus lowland rice-growing

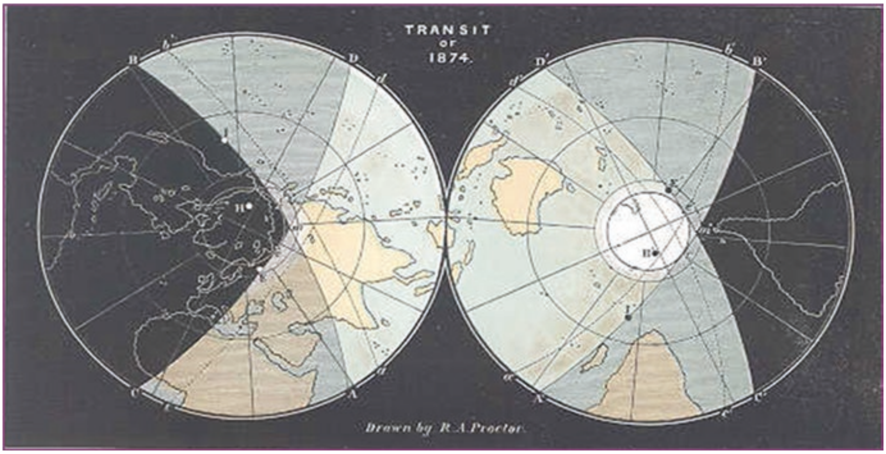

Fig. 1.13 The 1874 transit of Venus was a very rare and important astronomical event that was visible from Malaysia (and other countries, like Japan, China, Indonesia, Australia and New Zealand located in the pale blue sector of these maps). As in Australia and New Zealand, for example, did the British use the transit to popularize astronomy? (map after Proctor, 1874).

Fig. 1.14 Although Nurul Fatini Jaafar has carried out research on the astronomical systems of some of Malaysia's negrito ethnic groups (e.g. see her chapters in this book), further research is warranted.

1.2.8 Singapore

To our knowledge, currently there is no-one in Singapore carrying out historical studies in SEAn astronomy, and given the size of the island and its highly-developed state, the opportunities are severely limited.

1.2.8.1 Recent Projects

Aslaksen and Beltrami (2017) reported on changing the date of Deepavali in 2009, while in February 2020 Dr Fiona Williamson (who researches historic meteorology) gave a paper at an Asian Observatories conference about the non-existence of nineteenth century British colonial astronomy in Singapore.

1.2.8.2 Future Prospects

- Colonial astronomy: the Singapore time ball and a public time-keeping service in Singapore
- Colonial astronomy: publicity surrounding the 1874 transit of Venus
- WWII Royal Navy research on radar (which led to radio astronomy in New Zealand—see Fig. 1.15)
- Astronomical developments at the Singapore Science Centre, Singapore's various universities, and the Astronomical Society of Singapore

Fig. 1.15 Cambridge-trained geologist and physicist Dr Elizabeth Alexander worked on radar at the Royal Navy's base in Singapore during World War II. With the Japanese occupation of the island occurring she and her three young children escaped to New Zealand, where she became involved in radar research and independently discovered solar radio emission. As Orchiston (2016: 629–651) documents, she was the world's first female radio astronomer (photograph courtesy: Mary Harris).

1.2.9 Philippines

There is a very active group of ethnoastronomy researchers at Rizal Technological University in Manila led by Associate Professor Ryan Guido, and the Director of the National Technological University of the Philippines (Professor Jesus Torres) and staff at the National Museum and Manila Planetarium are all interested in history and ethnoastronomy. Dr Kerby Alvarez (University of the Philippines, Diliman) and Professor Patrick Seitzer (University of Michigan, USA) have both been researching the history of Manila Observatory (Fig. 1.16).

1.2.9.1 Recent Projects

Apart from the following chapter in this book, which is about Philippines ethnoastronomy (Orchiston et al., 2021b), we have seen four thesis-related ethnoastronomy booklets (but there may be more) produced by students from the Department of Earth and Space Sciences at Rizal Technological University (Dacula and Demegillo, 2018; Martinez and Dulay, n.d.; Samson and Vitin, 2019; Vicare and Palacois, n.d.), and there is a paper by Ôhashi (2017a) about Taiwan Aboriginal astronomy that relates directly to Philippines ethnoastronomy.

Fig. 1.16 A photograph of the 19-in refractor destined for Manila Observatory mounted and operational in a builder's yard in Washington, D.C., USA (photograph courtesy: Patrick Seitzer).

1.2.9.2 Future Prospects

- Spanish astronomical records
- Colonial astronomy: history of Manila Observatory
- Solar physics: 1929 solar eclipse
- Ethnoastronomy: English translation of *Balatik*
- Ethnoastronomy: studies of individual negrito groups

- Ethnoastronomy: studies of other (non-negrito) groups
- Ethnoastronomy: fishing versus farming astronomical systems
- Ethnoastronomy: negrito versus Austronesian astronomical systems
- Ethnoastronomy: the impact of Islam on traditional astronomical systems
- History of meteoritics: the discovery and recovery of the Bondoc Meteorite (Fig. 1.17) and its loss to the USA
- History of meteoritics & ethnoastronomy: Is there any record of the Late Pleistocene Bondoc Meteorite impact in the astronomical traditions of the nearby Agta, or the more distant Iraya or the Ati?

1.2.10 Indonesia

Two Professor Hidayats, Bambang and Taufiq, have been stalwarts of Indonesian history of astronomy for many years, although they are not related, and Bambang has long been retired. Formerly he was Professor of Astronomy at the Institut Teknologi Bandung (ITB) and Director of Bosscha Observatory, both roles subsequently enjoyed by his younger namesake. Fellow ITB astronomer Dr Hakim Malasan and LAPAN's Dr Emanuel Mumpuni also are actively involved in Indonesian history of astronomy research, joined by the first author of this chapter. So, as in Thailand and the Philippines, Indonesia also has a critical mass of active researchers in this field, and especially in archaeoastronomy and ethnoastronomy.

Fig. 1.17 The main mass of the Bondoc Meteorite, recovered in 1956 from the jungles of the Bondoc Peninsula and now in the Meteorite Museum at Arizona State University in the USA. At 888.6 kg this is by far the heaviest of the Philippines' five known meteorites. It is a rare mesosiderite (stony-iron meteorite).

1.2.10.1 Recent Projects

There have been two overview papers (e.g. Hidayat et al., 2017; Orchiston, 2017); a paper about Houtman's early star catalog (Verbunt and van Gent, 2011); the nineteenth century Dutch astronomer Oudermans (Orchiston et al., 2021c); solar eclipses (Mumpuni et al., 2017; Pearson and Orchiston, 2011, 2017); traditional calendars (Emas et al., 2021; Gislén and Eade, 2019c); archaeoastronomy (Hariawang et al., 2011; Khairunnisa et al., 2021; Rodhiyah and Hidayat 2019), and ethnoastronomy (Ammarell and Tsing, 2015; Fatima et al., 2021; Hidayat, 2011; Rasyid et al., 2021; Retnowati et al., 2014).

1.2.10.2 Future Prospects

- Archaeoastronomy: Astronomical parameters of the Hindu temples in Java
- Archaeoastronomy: Astronomical parameters of the Hindu temples in Bali (Fig. 1.18)
- Colonial Astronomy: Astronomy and the Dutch East India Company
- Ethnoastronomy: Studies of hunter-gatherer versus farming astronomical systems
- Ethnoastronomy: Studies of farming versus fishing astronomical systems
- Ethnoastronomy: Studies of Austro-Asiatic versus Austronesian astronomical systems
- Ethnoastronomy: What impact did Islam have on the traditional rice farming astronomical systems of Java?
- Ethnoastronomy: The relative roles of religion in the rice-farming astronomical systems of Central Java (Islam), Bali (Hindu) and northern Manado (Christian)
- The history of Bosscha Observatory, especially different instruments and research themes (see Fig. 1.19)

1.3 Discussion

1.3.1 How Do We Trigger History of Astronomy Research in Those SEAAN Nations That Currently Are Inactive?

As we have seen above, there is a tremendous range of exciting history of astronomy research projects awaiting our attention. But even in those countries with numbers of active researchers in this field there is a challenge: what criteria should we adopt in deciding on which project to choose when there are many options? And what of those countries with no active researchers in this field. How can we help change this?

Myanmar is a case in point. On 26 July 2015 the first author of this chapter attended a Workshop on the History of Myanmar Astronomy at Mandalay University

Fig. 1.18 The Pura Taman Ayun and Pura Besakih tiered Hindu temples in Bali (photographs courtesy: Darunee Lingling Orchiston).

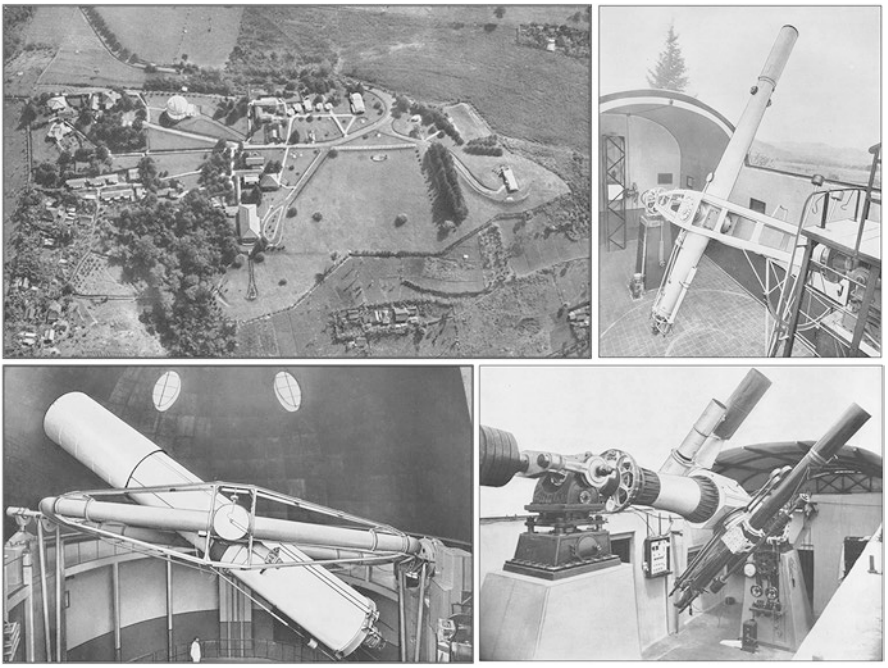

Fig. 1.19 Bosscha Observatory (top left) soon after its founding, and the main early instruments: a 37-cm Schmidt refractor (top right), 64-cm Zeiss double refractor (bottom left), and 19-cm Merz refractor with astrocameras (bottom right). The research accomplishments of these initial instruments have yet to be reviewed (all photographs after Voûte 1933).

and presented a Keynote Paper titled "Studying the History of Myanmar Astronomy: Future Prospects and Possibilities". In this the following eight research areas were discussed as offering research potential of international significance:

(1) Hill-tribe ethnoastronomy
(2) Ancient city design (cf. the chapter by Saelee et al. 2021 later in this book)
(3) Astronomical parameters of Buddhist temple design
(4) The astronomical murals at Kyauktawgyi Pagoda, Amarapura
(5) Any records in traditional Myanmar sources of supernovae, solar eclipses, lunar occultations of stars and planets, comets, meteor showers, or meteorite impacts that can be used in international Applied Historical Astronomy studies
(6) Astronomical beliefs and practices associated with rice cultivation
(7) Any Mynamar evidence of astronomical stone alignments, as found in southern India
(8) British attempts to use the 1874 transit of Venus, visible from Myanmar, to popularize astronomy

At the time, there was a very positive response to this paper from the audience, but the outcome was disappointing. Subsequently, research was only carried out on topic (4), but by the late Dr Yukio Ôhashi from Japan (who presents some of his findings in a chapter in this book). Myanmar scholars have remained remarkably silent, and if they did conduct any research as a result of this Workshop then this has not translated into papers submitted for publication in the *Journal of Astronomical History and Heritage* or presented at the second or the third H&H Conference—and the third conference was held on their 'home turf', in Mandalay.

This raises the issue of how we can inspire new research in countries like Myanmar, or Laos or Cambodia. We believe that there needs to be at least one local 'champion' in each country, who is respected by his and her peers, is dedicated to this type of research and is willing to build up a small group of collaborators. Once there is an active team of three or four researchers there is a good chance of reaching the critical mass that will sustain these studies.

International mentors also can be a great help, so long as they are willing to invest the necessary time and effort. This is one advantage of joining a Working Group or Project Group of Commission C3 (History of Astronomy) of the International Astronomical Union (IAU).

1.3.2 Working Groups and Project Groups of the IAU

Working Groups (WGs) and Project Groups (PGs) of IAU Commission C3 (History of Astronomy) have been set up specifically to foster research, and we know from past experience that they have the ability to accomplish this very effectively (e.g., see Orchiston, 2019). Of the different C3 WGs and PGs, the following will probably be most relevant to those interested in SEAn history of astronomy. Listed also are the names, national affiliations and email addresses of the Chairpersons of these groups (as at June 2020):

Archaeoastronomy and Cultural Astronomy WG (Dr Steve Gullberg, USA, srgullberg@ou.edu)
Asian Astronomy PG (Professor Wayne Orchiston, Thailand, wayne.orchiston@gmail.com)
Astronomical Archives PG (Dr Ileana Chinnici, Italy, ileana.chinnici@inaf.it)
Biographical Encyclopedia of Astronomers #3 PG (Professor Tom Hockey, USA, thomas.hockey@uni.edu)
Ethnoastronomy and Intangible Heritage WG (Associate Professor Duane Hamacher, Australia, duane.hamacher@gmail.com)
Historic Solar Eclipses and the Development of Solar Physics (Professor Wayne Orchiston, Thailand)
Historic Transits of Venus PG (Professor Wayne Orchiston, Thailand)
Historical Instruments and Observatories PG (Dr Sara Schechner, USA, schechn@fas.harvard.edu)
Historical Radio Astronomy WG (Professor Richard Schilizzi, England, Richard.Schilizzi@manchester.ac.uk)
Indian and Southeast Asian Stone Inscriptions PG (Dr B.S. Shylaja, India, shylaja.jnp@gmail.com)

Even if you are not an IAU member you can join one of these groups as an IAU Associate—either contact the relevant Chairperson, or contact Professor Wayne Orchiston (listed above), who is also the current President of IAU Commission C3.

1.3.3 Conference Options

Conducting research on SEAn history of astronomy is all very well, but unreported research is wasted effort, so the ultimate objective of any project must be to present the results of this research at local seminars and at local, national or international conferences, and to publish papers about the research. First let us look at international conferences.

There are two regular conferences that are specifically geared to Southeast Asian history of astronomy research. One is the SEAAN History and Heritage mini-conferences that have resulted in the publication of this book. As mentioned earlier, thus far we have held three of these mini-conferences: 30 November–1 December 2015 in Ao Nang (Thailand); 28–29 November 2017 in Mandalay (Myanmar); and 3–5 February 2020 in Chiang Mai (Thailand). We are now talking about holding the next H&H mini-conference in Bandung, Indonesia, probably in 2023 (because of the virus, 2022 will now be an IAU General Assembly year). Once we are able to make firm plans we will set up a web site; in the meantime, for interim details contact Wayne Orchiston (wayne.orchiston@gmail.com).

The other conference where SEAn papers are welcome is the International Conference on Oriental Astronomy series (or ICOAs). These are held on average every third year in a different city in the 'Greater Asian region'. To date, there have been nine ICOAs, held in Australia, China, India, Japan, South Korea and Thailand. ICOA-10 was scheduled for South Korea in June 2020 but has been postponed because of the COVID-19 Virus. The President of the ICOA Executive Committee is Professor Shuhrat Ehgamberdiev from Uzbekistan (shuhrat@astrin.uz), and either he or Professor Eun-Hee Lee (ehl77@naver.com) from South Korea can keep you up-dated on this conference.

In addition, for some years Drs Mitsuru Sôma and Kyotaka Tanikawa from the National Astronomical Observatory of Japan (NOAJ) in Tokyo have been holding *ad hoc* small 'boutique' mainly Asian-oriented conferences on history of astronomy at the NOAJ. However, both colleagues are now retired, so the future of this conference series is in doubt. For the latest news contact Dr Sôma (Mitsuru.Soma@nao.ac.jp).

1.3.4 Publication Options and Strategies

The end point of any history of astronomy research project must be publication, and we cannot stress enough the importance of publishing in *reputable* international outlets. Apart from *ad hoc* books like this one, there are two major publication options that SEAn historians of astronomy should consider: (1) the ICOA Conference proceedings, and (2) the *Journal of Astronomical History and Heritage*.

To date there has been a proceedings published following every one of the nine ICOAs, and all are meant to have been refereed so (supposedly) they should contain papers of international standard. However the extent to which this actually has happened has depended very much on the editor(s) of the individual volumes, and in some cases their mastery of English. That said, sometimes there have been lengthy delays between the conferences themselves and publication of the associated proceedings. Some of these delays have spanned many years, so by the time the conference papers finally appear in print they are dated. Perhaps this does not matter where little further research is occurring in a particular field, but when this is not the case or for undergraduate or graduate students who were counting on listing ICOA papers in their CVs, this can be a major concern.

We should also mention that the ICOA proceedings vary enormously in appearance, quality and size. Some are produced, usually in A4 format (which helps with large-scale maps and showing photographic detail), by the institutions hosting the ICOAs, and can (but do not always) feature attractive colourful covers that relate to the themes of the respective conferences (e.g. see Fig. 1.20), but the world's leading astronomy publication house, Springer, has also published two ICOA proceedings in its conference series. These have a standard cover format (also see Fig. 1.20), and with smaller page sizes than the in-house A4 proceedings are much thicker tomes than any of the other ICOA proceedings. Thus, *Highlighting the History of Astronomy in the Asia-Pacific Region: Proceedings of the ICOA-6 Conference* (Orchiston et al., 2011) ran to 660 pages, and *The Growth and Development of Astronomy and Astrophysics in India and the Asia-Pacific Region: ICOA-9, Pune, India, 15–18 November 2016* (Orchiston et al., 2019b) to 587 pages (for comparison, the edited and formatted A4 version of this same book was only 336 pages).

If you are looking for a journal in which to publish SEAn history of astronomy, then the *Journal of Astronomical History and Heritage* (*JAHH*; web site https://www.jahh.org) is the ideal venue. Founded by the first author of this chapter in 1998, *JAHH* is now an A4 format e-journal that (from 2021) is produced four times a year (in March, June, September and December) and is posted on the ADS and NARIT web sites. As an open access publication, individual research papers, book reviews and IAU Reports—or, indeed, entire issues—can be downloaded free of charge, so they usually reach a wide international audience. Issues typically range in size from about 160 to 200 pages, and each issue has a dedicated front cover where the feature image relates to one or more papers in that particular issue of the journal. Two examples are shown in Fig. 1.21; both of these issues of *JAHH* contain ethnoastronomy papers. Many papers about SEAn history of astronomy have been published in *JAHH*, along with others about Indian, Australian, New Zealand, Chinese, South Korean and Japanese astronomy that emphasize SEA's key geographical locale in the Asian-Oceanic region. *JAHH* is supported by a distinguished Editorial Board, which includes Professors Bambang Hidayat (Indonesia), Tsuko Nakamura (Japan), Nha Il-Seong (South Korea), Xiaochuin Sun (China) and the second author of this chapter, Mayank Vahia (India). It is an ideal venue for the

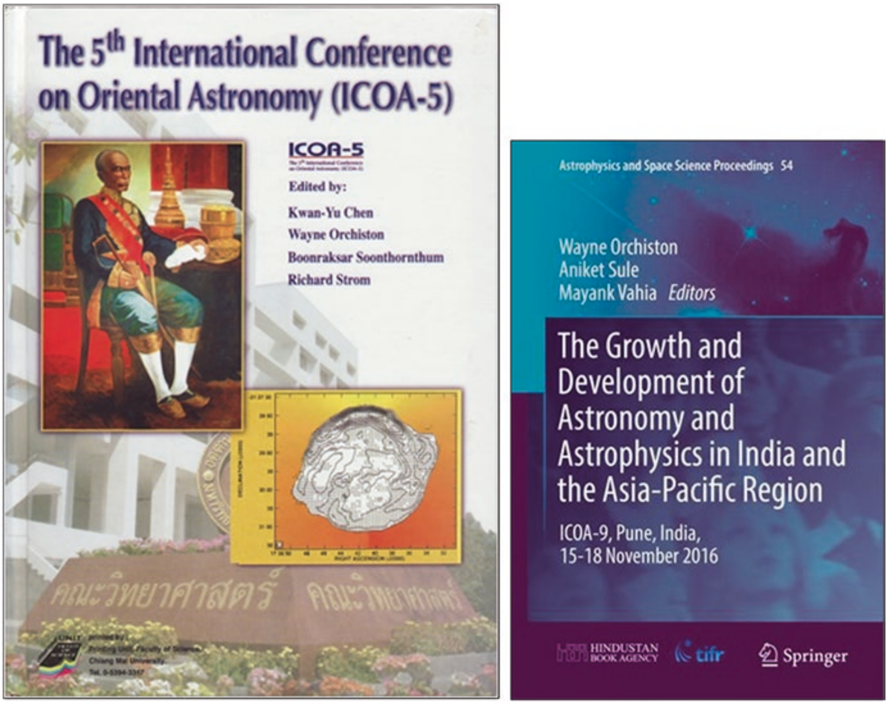

Fig. 1.20 Front covers of the ICOA-5 and ICOA-9 conferences proceedings published respectively by Chiang Mai University and Springer, and showing their respective sizes.

publication of SEAn history of astronomy papers by graduate students. For further details about *JAHH* consult the web site, or contact the first author of this chapter (wayne.orchiston@gmail.com), who continues as the Editor of the journal.

When we reviewed the SEAn history of astronomy publications of each of the SEAAN nations we noticed that many papers, booklets and even entire books are published in Thai, in Bahasa Melayu, in Vietnamese, in Tagalog, and in Bahasa Indonesia and aimed solely at local audiences. Yet some of these are of international importance (such as Ambrosio's (2010) book *Balatik*, for example) and deserve to reach a much wider audience. So by all means continue publishing locally in your own languages, but also try to get into the habit of writing up your most important results in English so that they can be appreciated, and evaluated, by your international colleagues. Whether we like it or not, the reality is that English is now the acknowledged international language of science, and of astronomy.

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Ethnoastronomy of Aboriginal Australians

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Fig. 1.21 The front covers of two issues of the *Journal of Astronomical History and Heritage* that include papers on ethnoastronomy.

1.3.5 Graduate Studies in Southeast Asian History of Astronomy Research

Sometimes we are asked if it is possible to undertake a history of astronomy PhD degree on a part-time basis through an internationally recognised university, and we always mention the Centre for Astrophysics at the University of Southern Queensland (USQ), in Australia. This department inherited the part-time internet-based Master of Astronomy and PhD programs from James Cook University (JCU, also in the Australian state of Queensland) when the latter university closed down its Astronomy program at the end of 2012. The first author of this chapter launched the world's first part-time off-campus research degree in history of astronomy at JCU in mid-2005, and to date 17 students from Australia, Lebanon and the USA have graduated, with a New Zealand student currently part way through his doctorate. Note that the USQ history of astronomy PhD is a science degree: it is a PhD in Astronomy, specializing in history of astronomy, not a History degree specializing in astronomy. Therefore the entry prerequisite is a Masters degree by *coursework and research* in Astronomy, or equivalent work experience. As well as faculty at the main campus in Toowoomba, Australia, the Centre for Astrophysics appoints appropriate adjunct staff to co-supervise new students (the first author of this chapter is an Adjunct Professor). This way, we are able to accept and supervise a wide range of thesis projects.

Fig. 1.22 Dr Clifford Cunningham (USA) has already published four Springer books based on his PhD research—see the front covers above. About half of the JCU/USQ history of astronomy PhD graduates have published books based on their thesis research. Most of the students also published prolifically in research journals whilst still engaged in their thesis research so had an excellent track record of publication by the time they graduated.

A few of those who enrolled in the JCU or USQ doctoral program required Astronomy PhDs for promotion in their current jobs, but most students were serious mature age amateur astronomers, sometimes already retired, intent of conducting researching and publishing at the highest possible international level (see Fig. 1.22), and presenting papers at international astronomy conferences such as the ICOAs and even IAU General Assemblies.

To date, younger students (i.e. those under the age of 40) have not enrolled in the USQ doctoral program, given the tuition fees levied by the University and the paucity of university, observatory or research institute positions in history of astronomy open to them when they graduate. And this despite the multitude of available MSc and PhD research projects, even in SEA alone, as the foregoing lists indicate. We therefore applaud the approach adopted by the Astronomy Department at the Institut Teknologi Bandung (through Professor Taufiq Hidayat) and the Department of Earth and Space Sciences at Rizal Technological University in Manila, Philippines (mainly though Associate Professor Ryan Guido) of encouraging senior undergraduate astronomy students, and post-graduate astrophysics students to conduct small-scale archaeoastronomy or ethnoastronomy research projects, present results at conferences and publish them. This should increase the competitiveness of these students when seeking scholarships or post-doctoral fellowships, and it will enhance their career prospects: apart from universities and observatories, they can also apply for positions in museums, visitor education centres, science centres and planetariums.

1.3.6 A Hypothetical 'Southeast Asian History of Astronomy Hall of Fame'

It is sometimes invidious 'to name names', but we thought it worthwhile at this stage to identify candidates (the authors excepted) whom we feel are worthy of entry into a hypothetical 'Southeast Asian History of Astronomy Hall of Fame', on

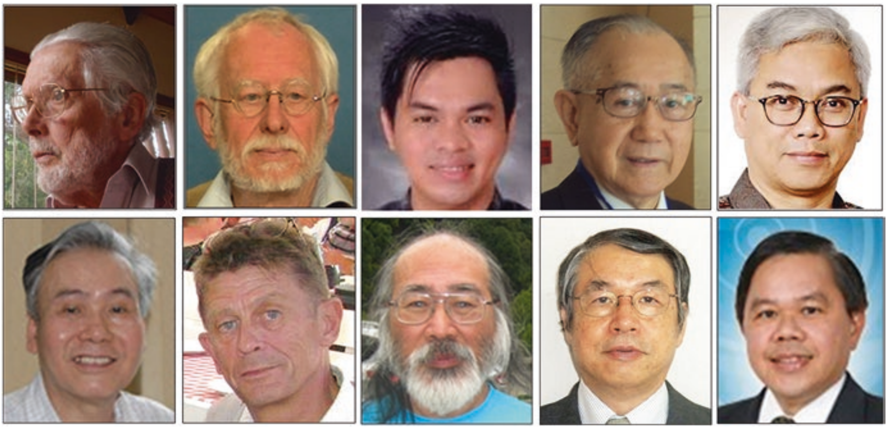

Fig. 1.23 Photographs of the our inaugural ‘Southeast Asian History of Astronomy Hall of Fame’ candidates; top row, left to right: Eade, Gislen, Guido, B. Hidayat, T. Hidayat; bottom row, left to right: Lê, Mollerup, Ôhashi, Okazaki, Soonthornthum.

the basis of their overall contributions to SEAn research and scholarship. They are listed below (in alphabetical order, with their major areas of research listed in brackets), and their photographs appear in Fig. 1.23.

Dr Christopher Eade (Australia: traditional calendars; astronomical inscriptions)
Dr Lars Gislén (Sweden: traditional calendars)
Associate Professor Ryan Guido (Philippines: ethnoastronomy)
Professor Bambang Hidayat (Indonesia: general; ethnoastronomy)
Professor Taufiq Hidayat (Indonesia: archaeoastronomy; ethnoastronomy)
Associate Professor Lê Thành Lân (Vietnam: traditional calendars)
Mr Asger Mollerup (Thailand: Hindu temples)
The late Dr Yukio Ôhashi (Japan: general)
Professor Akira Okazaki (Japan: Vietnamese astronomy)
Professor Boonrucksar Soonthornthum (Thailand: general)

Note that four of the ten are non-locals, from Australia, Japan and Sweden, and that although Mollerup now lives in Thailand he hails from Europe.

All of those featured in Fig. 1.23 are worthy candidates, but there are others ‘in the wings’, such as Thailand’s Visanu Euarchukiati, Indonesia’s Dr Emanuel Sungging Mumpuni, and female graduate students Nurul Fatini Jaafar from Malaysia and Sitti Khairunnisa from Indonesia, who are all building up their lists of English-language publications in SEAn history of astronomy. They will surely be contenders when the next Hall of Fame intake occurs, along with Professor Jesus Torres from the Philippines, if he has finished his English translation of Ambrosio’s *Balatik* and published it.

1.4 Concluding Remarks

The way we ended up structuring this book was to split it into four Parts:

Part 1 (Introductory Studies) contains two chapters, one that you are reading right now, and the other a long chapter about Philippines history of astronomy that focuses mainly on evolving indigenous astronomical systems, viewed in an environmental context.

Part 2 (Southeast Asian Studies: Eclipses, Calendars, Time-keeping and Tropical Astronomy) has ten chapters, about Indonesia, Malaysia, Thailand, and Vietnam (to use 2021 terminology), and is rounded off by a pan-SEAn chapter about time balls and other devices used to indicate time during the nineteenth and early twentieth centuries.

Part 3 (Southeast Asian Studies: Archaeoastronomy and Ethnoastronomy) has eight chapters, about Indonesia, Malaysia and Thailand. All but two of these chapters are about ethnoastronomy, reflecting the enormous potential that SEA holds for such research. More on that theme, also, in Chapter 2.

Part 4 (Southeast Asia in Regional Context) has four chapters, three relating specifically to the influence of India (in archaeoastronomy, calendars and astronomical stone inscriptions). The final chapter looks at the ways in which India, China, Islam and Western culture impacted on SEAn astronomy.

It is interesting to review the different authors of chapters in this book. They total 39, and exactly one third of them (i.e. 13) hail from overseas, from Australia, France, Germany, India, Japan, Scotland and Sweden. This healthy spread of non-local authors reflects the international appeal that SEA has for historians of astronomy. But it also reflects the success that some of the 'local' authors have had in effectively networking with their international colleagues.

This is the first book written specifically on the history of SEAn astronomy, and although it is a sizable tome some of the gaps that we first tried so hard to plug back in 2016 are still there. Thus, despite a lengthy Chapter 2, the Philippines is still seriously under-represented. But this is partly because the infrastructure needed to support student projects in ethnoastronomy has only recently been put in place at Rizal Technological University. It is also sad that there are no chapters specifically about Myanmar, Laotian, Cambodian or Singapore astronomy—although in the case of Singapore this is not really surprising given the severe limitations we outlined in Subsection 1.2.8 above. Myanmar, though, is a totally different story as it has *enormous* potential—in archaeoastronomy and ethnoastronomy. Yet, as we have noted, this has yet to translate into active research.

If the next five years produces the avalanche of new research results that he have witnessed since the founding of the SEAAN H&H Working Group, this will auger well for the publication of a follow-up volume in this series. But Volume 2 will only happen if authors who promise chapters really do deliver them on time, and if Springer is once again interested in supporting us. Time will tell …

Finally we should announce that following this book, and of special interest to SEAn historians of astronomy, is another Springer book, titled *The Total Solar Eclipse 18 August 1868: A Watershed Event in the History of Solar Physics*, edited by the first author of this chapter. Because of delays caused by the virus, this new book will now appear in 2022 instead of 2021, and will contain 17 chapters by 12 different authors, from France, Germany, India, Indonesia, South Korea and Thailand. Five of the chapters will relate SEAn observations of this landmark eclipse, made from Siam, Borneo and the Dutch East Indies.

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Chapter 2
Exploring the History of Philippine Astronomy: Catholics, Comets, Eclipses and Ethnoastronomy

Wayne Orchiston, Ryan Guido, Rose Ann Bautista, Ruby-Ann Dela Cruz, Jesus Torres, and Darunee Lingling Orchiston

2.1 Introduction

The Republic of the Philippines is one of the economic wonders of Asia, and a famous tourist destination. It is also a wondrous place in which to carry out research on the history of astronomy. Located in island Southeast Asia, the Philippine archipelago is surrounded by the Philippines Sea to the east, the Celebes Sea and Sulu Sea to the south and the South China Sea to the west (Fig. 2.1), and its immediate neighbours are the islands of Borneo to the southwest, Sulawesi to the south and Taiwan to the north. As we will see in this chapter, some of these islands played key roles in shaping the nature of the prehistoric astronomical systems found in the Philippine region or transmitting them elsewhere. According to census figures, the Philippines was home to almost 101 million people in 2015. Before independence, in 1946, the Philippines was an American colony, and prior to 1898 a Spanish

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Fig. 2.1 Location of the Philippines, with other Southeast Asian nations also in green.

colony. The Spanish, mainly through Jesuit missionaries and astronomers, left their astronomical imprint on the Philippines.

Currently the Philippine archipelago comprises about 7641 islands (see Fig. 2.2), but this situation was very different during the Late Pleistocene. Then, sea levels were much lower than they are today, and most of the larger islands in the archipelago were linked to other islands. For example, 22,000 years ago Luzon, Samar, Leyte, Bohol and Mindanao all comprised one single long sinuous island, but all this was to change over the next 16,000 years as the seas rose relentlessly, drowning land, forming islands and splitting up human populations. These environmental changes often triggered changes in human ecology, which then were reflected in astronomical beliefs and practices.

This chapter is about the changing astronomical beliefs and practices of the ancient Filipinos. The astronomical system of any ethnic group is simply a part of its culture (for the Philippines see Ambrosio, 2010; Casino, 1967), and cultures typically change with time. Therefore, so do astronomical systems, especially when the ecological basis of the culture is challenged and changes. This may happen because of major environmental changes, or with the arrival of new genetically-distinct populations, or the introduction of new religions, or through colonization. One of our tasks as ethnoastronomers is to investigate these changes, whenever this is possible. We will pursue this task in this chapter, and outline future research projects—and not just in ethnic astronomy—that we feel hold special potential for the history of astronomy in the Philippines.

Fig. 2.2 A map showing the main islands of the Philippines.

2.2 A Changing Environment

2.2.1 Changing Sea Levels

Environmental changes triggered mainly by variations in sea level had a profound influence on the biogeography and human history of the Philippine region. The earliest human inhabitants of the Philippines that have left traces of their astronomical systems were *Homo sapiens* who arrived 70,000–60,000 years ago after anatomically modern humans first left Africa, followed the coastline from ancestral India and moved down into what is now island Southeast Asia and onwards into Australia and New Guinea (Kealy et al., 2016; O'Connell et al., 2018; O'Connor et al., 2017).

At the time these first modern humans settled in the Philippine region the sea was between 30 and 50 m below the present level (depending on the precise date of their arrival). As Fig. 2.3 shows, from that time sea levels continued to oscillate but followed a general downward trend until around 32,000 BP[1] when they began to fall steeply, reaching what is now known as the Last Glacial Sea Level Low at 22,000 years ago, when they stood 125 m below the present sea level.

With the rapid fall in sea level between 32 kyr and 22 kyr areas formerly submerged under the ocean became dry land and the islands of Java, Sumatra and Borneo eventually joined with what is now Peninsular Malaysia forming one large continental landmass known as Sundaland (Oppenheimer, 1998). This is depicted in Fig. 2.4. Sundaland offered a terrestrial land-route, perhaps along a 'savannah corridor' (Bird et al., 2005) to what are now the major islands of island Southeast Asia, except that challenging water-crossings were required, even at times of low sea level to enter the Philippine region, or Sulawesi and Indonesian islands in the Moluccas group.

Let us now examine the Philippine region in more detail. If we use the sea level curve shown in Fig. 2.3, we can plot the coastlines of the numerous islands of the Philippine archipelago as the seas oscillated during the period of human habitation. The critical time was when the sea level was lowest, islands were linked to one another by 'land bridges' and the archipelago reached its maximal extent. This occurred at 22 kyr when seas were at –125 m. Unfortunately, we do not have a map of the Philippines at this exact time, but Fig. 2.5 is a good approximation. It shows what the Philippine region looked like 20,000 years ago when the seas stood at –120 m. The difference between the –120 m and the –125 m coastlines on the scale used for this map is

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[1] We need to explain some geological and archaeological terms that are used throughout this chapter. 'BP' (= 'Before the Present'), which is rather similar to 'years ago', except that by international definition the 'Present' is the year 1950 CE. Geological time, for the period discussed in this chapter, is covered by two epochs, the Pleistocene (from 2.58 million years BP to 11,700 BP) and the Holocene (from 11,700 BP to the present day). The Pleistocene has Early, Middle and Late stages, with the Late Pleistocene from 126,000 to 11,700 BP (Gibbard et al., 2010). Sometimes it is convenient to express these dates as 126 kyr BP and 11.7 kyr BP, while the Pleistocene began at 2.58 myr BP. Note that some authors use ka and ma in lieu of kyr and myr.

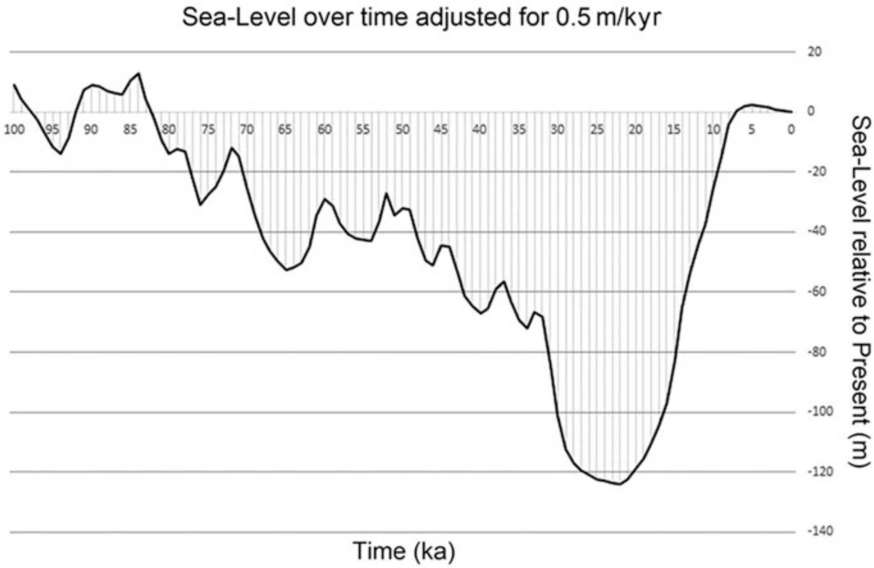

Fig. 2.3 A plot showing the changing sea levels in the Southeast Asian region over the past 100,000 years (after Lambeck and Chappell, 2001, but incorporating an isostatic uplift of 0.5 meters per thousand years, as calculated by Kealy et al. 2017).

negligible. What is particularly noticeable is that apart from around Palawan, Panay, Negros, Cebu, Sulu Islands and one section of coast between the islands of Polillo and Catanduanes, very little new land was exposed around Luzon or around much of Mindanao, where steeply sloping beaches plunged into marine trenches (see Fig. 2.6).

Upon examining this map there are several important points to note. Firstly, Luzon, Polillo, Marinduque, Catanduanes, Samar, Leyte, Bohol, Dinagat, Siargao and a greatly enlarged Mindanao were all connected, forming one continuous sinuous landmass. For want of a better term let us call this large island 'Lusanao'. Secondly, note that Panay, Negros, Cebu and Masbate were all joined, forming one large irregularly shaped island that was never connected to Lusanao, although only one short water crossing was required to access it from what is now Leyte. It is significant that even when the seas were at their lowest, numerous smaller Philippine islands never joined up with others, but remained isolated; the largest of these was Mindoro which had steeply sloping sea-floors on all sides. Note, also, that 'Greater Palawan' (Heaney, 1985) was never directly connected to Greater Borneo (and hence to Sundaland) or to Lusanao, so any humans wishing to migrate to the Philippine region had to negotiate two water-crossings. There was a short one at what is now Balabac Strait (near Borneo), then at least two much longer more hazardous crossings to the north-east if they wanted to reach the 'mainland', Lusanao. Meanwhile, accessing Lusanao from further south, via what was then an enlarged Sulu Island Group, also involved two water-crossings, first to get to this Sulu Island area and then to cross to the 'mainland' via the south-western extension of what is

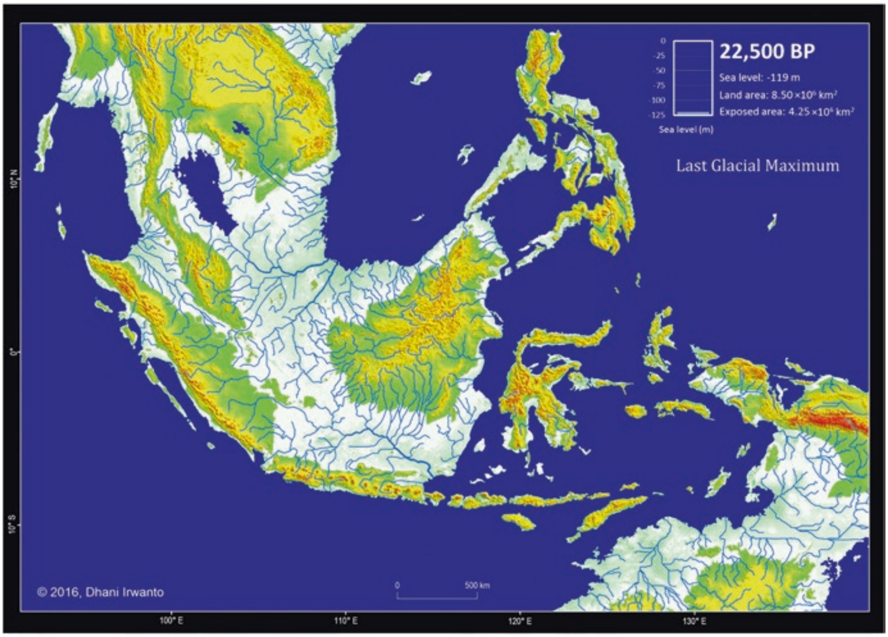

Fig. 2.4 Sundaland at the time of the last inter-glacial low sea level, showing the major riverine systems and the Philippines' isolation from this Southeast Asian continental land mass (https://atlantisjavasea.files.Wordpress.com/2015/05/last-glacial-period-of-sundaland.gif).

now Mindanao. And all of these described water-crossings were 'best case' scenarios, when the sea level was lowest and the water-crossing distances were minimized. To try to negotiate these water-crossings at other times would have been much more challenging. So we can see that for the entire time-interval over which anatomically modern man occupied the Philippines the area was geographically isolated from other parts of island Southeast Asia. This placed emphasis on maritime technology, and the ability to successfully make open-ocean crossings. Navigation therefore was critical, and as a corollary so too was astronomy.

The final phase in the changing biogeography of the Philippine region occurred when the sea rose rapidly, and for the most part steadily, from the Last Glacial Sea Level Low to reach its current level at around 6000 BP (see Fig. 2.7). There is currently debate about this date, with some academics favouring 7000 BP (as reflected in the Fig. 2.3 curve). While this post-glacial sea level rise had a profound effect on Sundaland and led to its disappearance (see Sathiamurthy and Voris, 2006), its impact in the Philippine region was more localised, with shorelines migrating inland so that by around 10,000 BP many of the current islands in the archipelago had been formed. These environmental changes would have had a profound impact on human populations, leading to major ecological changes. These would, in some instances, have astronomical implications.

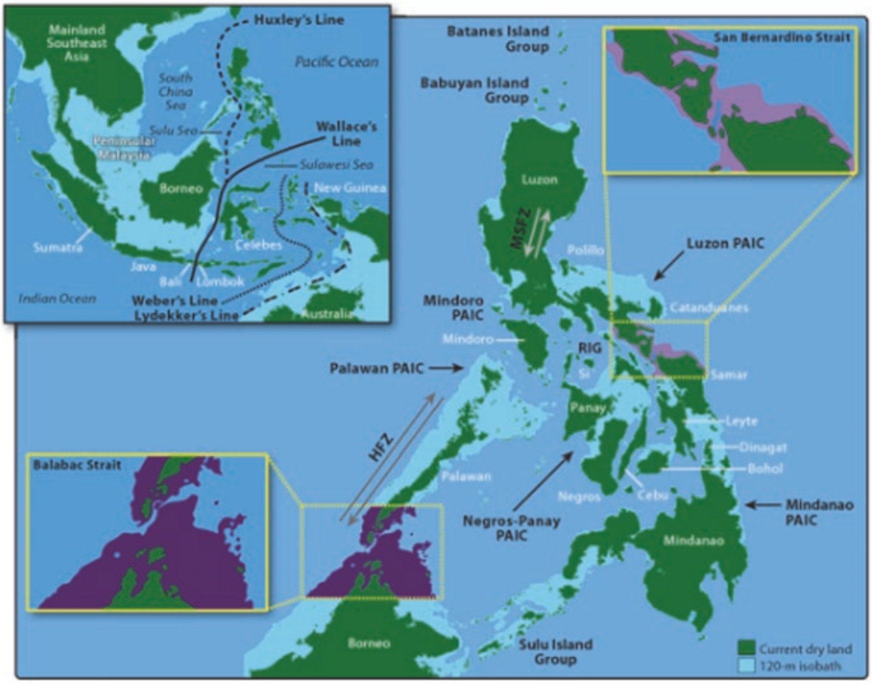

Fig. 2.5 The effect of sea level change on the Philippines. The pale blue areas indicate the areal extent of the Philippines 20,000 years ago when the seas were 120 m below the present level (after Brown et al., 2013: 413).

While sea level changes over the last 70,000 years in the Philippine region would have been on-going, even if unpredictable, they were, nonetheless, basically non-threatening, except where major habitats and their resources were inundated.

2.2.2 *Changing Temperatures and Rainfall*

The sea level changes outlined in Sub-section 2.2.1, above, occurred because of temperature variations that the Earth experienced during the Late Pleistocene as a result of glacial and interglacial episodes. During the period from 70 kyr to the end of the Pleistocene (11.7 kyr) for the most part sea level changes were directly correlated with global temperature changes, so as sea levels rose and fell temperatures followed suit. Thus, the sea level plot in Fig. 2.3 can be taken as a proxy for global temperature oscillations and changes.

However, this convenient correlation ceased as the seas began to close in on their present levels and instead there were global temperature oscillations throughout the Holocene. These led to on-going environmental changes that affected human

Fig. 2.6 A map of the island Southeast Asia showing bathymetry and the existence of submarine trenches off the coasts of many of the islands in the Philippine archipelago (The satellite image was obtained from the Google Maps application [Google Maps attribution: Imagery (2019) Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Landsat/Copernicus, Map data (2019) Google; https://www.google.co.uk/maps/@10.0038529,108.7048144,3313765m/data=!3m1!1e3].

populations, but their effects would "… depend on population size, distribution and density and on a range of other historical, social, economic and political factors …" (Rowland, 1999: 11), not just on the magnitude of the environmental change itself.

The nature of the Holocene temperature oscillations experienced by the negritos in the Philippines, and from 4000 BP on also by the Austronesian settlers, is shown in Fig. 2.8. If we initially ignore the small-scale oscillations and focus on the general trends we can see that from 12.5 kyr to about 10.2 kyr temperatures rose slowly, only to level off from around 10 kyr to 8.8 kyr. Then they rose rapidly, oscillated markedly over the next 4000 years while gradually trending downwards. From 4.2 kyr there was a major drop in temperature, reaching a level that had not been experienced for more than 8000 years, followed by an even more substantial rise to a temperature level comparable to those experienced between 7 kyr and 6 kyr.

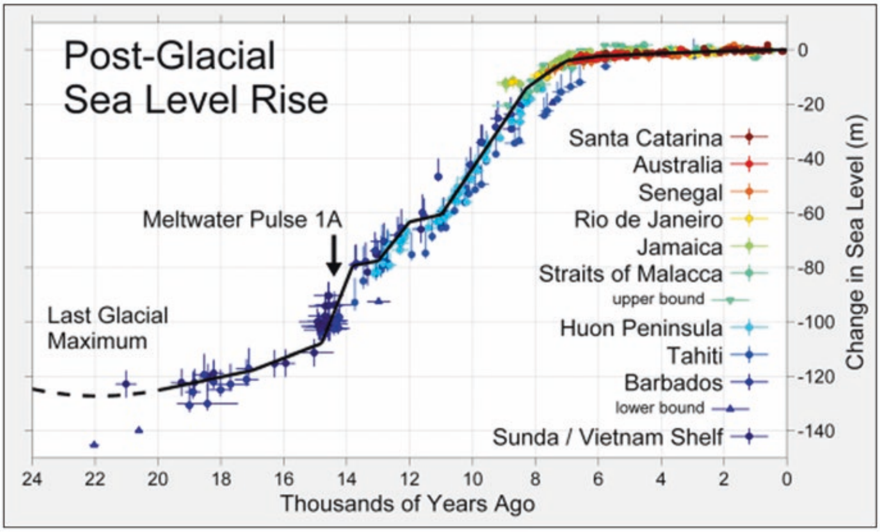

Fig. 2.7 A plot showing the way in which the sea level rose more-or-less steadily between 22 kyr and 6 kyr (https://commons.wikimedia.org/wiki/File:Post-Glacial_Sea_Level.png).

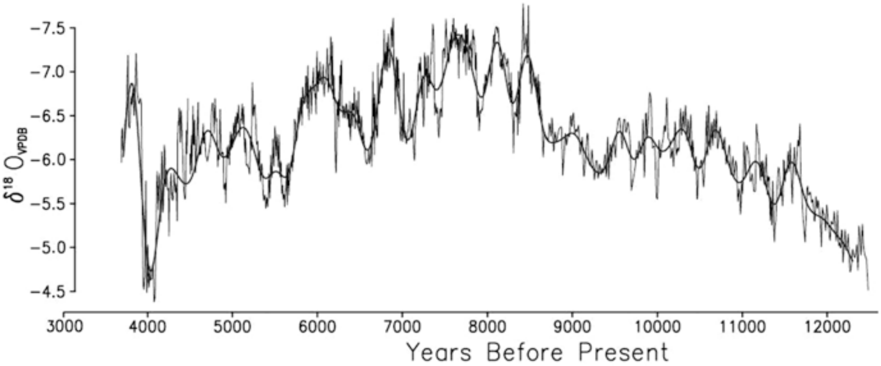

Fig. 2.8 A plot showing temperature variations between 12.5 kyr and 3.5 kyr (after Berkelhammer et al., 2012).

The extreme low temperature at around 4.2 kyr is referred to internationally as the ‘4.2 ka Event’, and its timing *vis-a-vis* the settlement of the Philippines by the Austronesians will be discussed later in this chapter.

The 4.2 ka Event has been generally described as “… an approximately 2- to 3-centuries-long interval of drought (e.g., Berkelhammer et al., 2012; Dixit et al., 2014; Nakamura et al., 2016) … [that was] associated with a series of cultural and societal changes in the Mediterranean, Middle East, Africa, and South and East Asia …” (Kathayat et al., 2018: 1869–1870). In a recent study that expanded on the original study by Berkelhammer et al. (2012), Kathayat et al. (2018) provide fine details of the 4.2 ka Event, based on ($\delta^{18}O$) oxygen isotope levels in two ^{230}Th-dated speleothems (ML.1 and ML.2) from Mawmluh Cave in north-eastern India. Studies have shown (e.g. see Kathayat et al., 2018; Midhun and Ramesh, 2016) that $\delta^{18}O$ is a good indicator of changing prehistoric rainfall levels. Kathayat et al. (2018: 1875) were primarily interested in tracking changes to the intensity of the Indian summer monsoon (which they term ISM), and they summarise their findings:

> (Fig. 8) illustrates the ISM variability between ~3.8 and 4.6 ka …The interval marking the onset of the 4.2 ka event in our record (~4.255 ka) is indicated by a transition from pluvial (inferred by the lower $\delta^{18}O$ values) to variable ISM (dry–wet) conditions, with the latter superimposed by a few short-term (<decade) droughts (Fig. 8). Subsequently, the period between 4.07 and 4:01 ka is marked by persistently lower $\delta^{18}O$ values, implying stronger ISM (Fig. 8). The latter was terminated by a rapid increase in the $\delta^{18}O$ values (~1.0‰, Fig. 5), suggesting an abrupt weakening of the ISM at ~4.01 ka that occurred within a period of ~10 years. Notably, as discussed above, the ML.1 and ML.2 $\delta^{18}O$ profiles show gradual increasing trends over the entire length of the record, which was punctuated by two multi-decadal weak monsoon events centered at ~3.970 (~20 years) and ~3.915 ka (~25 years), respectively (Fig. 8). These aspects of our ISM reconstruction differ from previous proxy records from the ISM domain, which typically portray the 4.2 ka event as a multi-century drought (e.g., Berkelhammer et al., 2012; Dixit et al., 2014). Our new data, however, demonstrate that prominent decadal to multi-decadal variability, together with the intermittent occurrence of multi-decadal periods of low rainfall, was the dominant mode of ISM variability during the period coeval with the 4.2 ka event …

The Fig. 8 ferred to by Kathayat et al. (2018) in the above quotation is reproduced here as Fig. 2.9.

As Kathayat et al. (2018: 1876) note, superimposed at a micro-level on the general pattern of temperature changes outlined in Fig. 2.8 were the drought and pluvial conditions depicted in Fig. 2.9, and these can be attributed to

> … the El Niño–Southern Oscillation (ENSO), and/or dynamical processes intrinsic to the monsoon system, such as quasiperiodic episodes of intense ("active" and reduced ("break") monsoon rainfall, [which] are key processes that are known to produce multi-decadal periods of drought over large parts of Asia.

This is the first evidence of the occurrence of individual ENSO events, which in general terms are known to have profoundly influenced climate at a local level over the past 3000 years. Precisely when they began in SE Asia is not known, though Donders et al. (2008) believe they were unlikely to have played a key role in climate modification prior to 7 kyr BP.

Apart from climate change, the ancient Filipinos faced three different kinds of environmental hazard that could not be anticipated. The first were volcanic eruptions, the second were cyclones, and the third were earthquakes.

2.2.3 Volcanoes

Lying astride the notorious 'Rim of Fire', the Philippines is over-endowed with active volcanoes. Depending on the definition of 'active volcano' and which sources one accepts, there would have been at least 50 Philippine volcanoes that were active

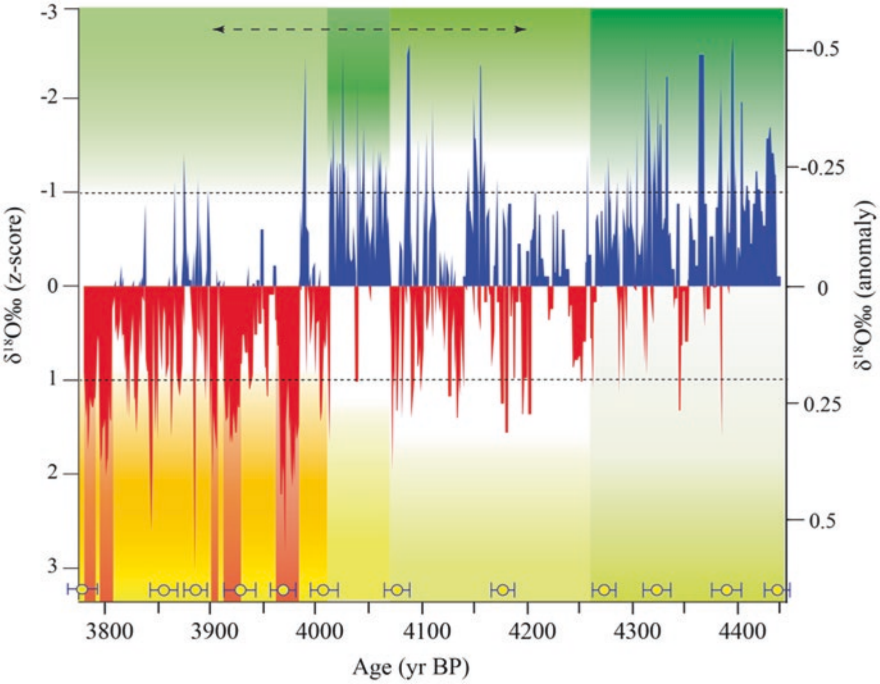

Fig. 2.9 The inferred pattern of Indian summer monsoon variability during the 4.2 ka Event. The horizontal dashed double arrows show the commonly-accepted duration of the 4.2 ka Event. Periods with yellow shading experienced drier conditions while those in green had wetter conditions. The red bars show periods of multi-decadal drought (after Kathayat et al., 2018: 1876).

at least once within the past 70,000 years. The most significant of these are shown in Fig. 2.10. Even when they are not erupting, most volcanoes are physically distinctive, so the ancient Filipinos would quickly have learnt to stay well away from those areas with many volcanic cones concentrated in a relatively small area. One of these was the region in Luzon south of Manila, centred on the currently active Mt Banahaw and Taal Volcano (see Fig. 2.11). Another area of potential threat with the string of volcanoes in the very south-eastern sector of Luzon, from Mt Isarog to Mt Bulusan. A third possible 'no-go' zone, initially at least, was the extensive group of volcanoes in central Mindanao, and the final area to avoid was the Sulu Islands.

Experience would soon have shown that some are these areas appeared safe in live in, while other isolated volcanoes (such as Mt Pinatubo) were to be avoided at times. But despite the attraction of abundant food stocks, looks could be deceiving, as those who settled round Taal Lake found in Spanish times. The towns of Bauan, Caysasay, Lipa and Tanauan, along with churches and cemeteries, are now under water following eruptions of the volcano (see Hargrove, 1991).

Major volcanic eruptions also have an interesting widely-observed atmospheric side effect that has astronomical implications. Because of the concentration of particulates blasted into the atmosphere, intense red sunrises and sunsets are visible,

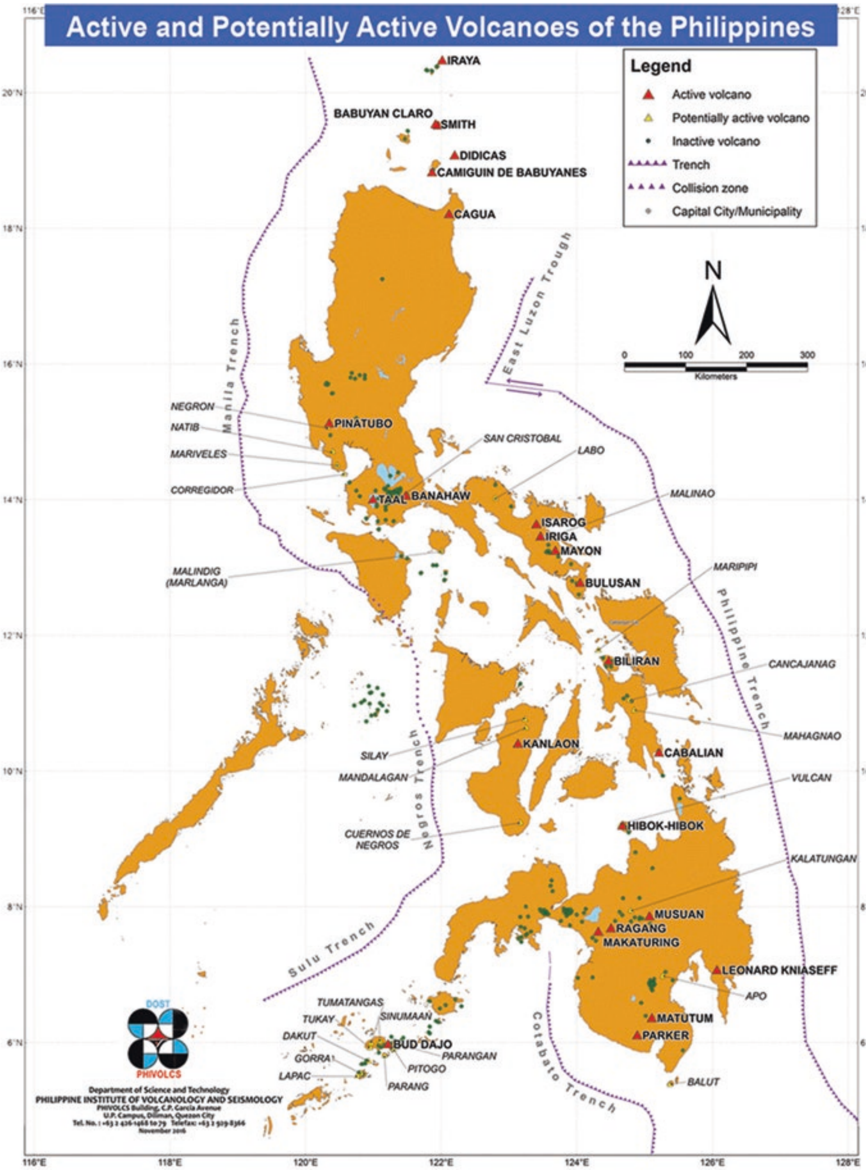

Fig. 2.10 A map showing major volcanic areas in the Philippines (https://www.google.com/search?q=philippines+volcanoes&client=firefox-b-d&sxsrf=ALeKk017fUSths7guMjRN2xYOTGT6K6u-w:1591851171930&source=lnms&tbm=isch&sa=X&ved=2ahUKEwiJkY3d-_jpAhWe4X-MBHXNPBvQQ_AUoAXoECBMQAw&biw=888&bih=660#imgrc=p_hnWa919VebgM).

Fig. 2.11 An aerial view of Taal Volcano, on a lake not far south of Manila. One of the Philippines most active volcanoes, it is known to have erupted at least 35 times in the past 450 years (https://www.newsweek.com/future-taal-volcano-eruptions-could-cause-tsunamis-dangerous-lava-mixture-flows-experts-warn-1482095).

and the Moon may take on a distinctly reddish glow. For example, following the major eruption of Mt Pinatubo in 1991, one of the authors of this chapter (JT) observed these effects for about three years. Earlier eruptions during historic and prehistoric times would have offered ancient Filipinos similarly spectacular views.

2.2.4 *Cyclones*

Although they occurred during specific seasons (i.e., 70% within the four consecutive months from July to October; see García Herrera et al., 2007: Fig. 4), the occurrence of individual cyclones could not be predicted, and their impact on human lives

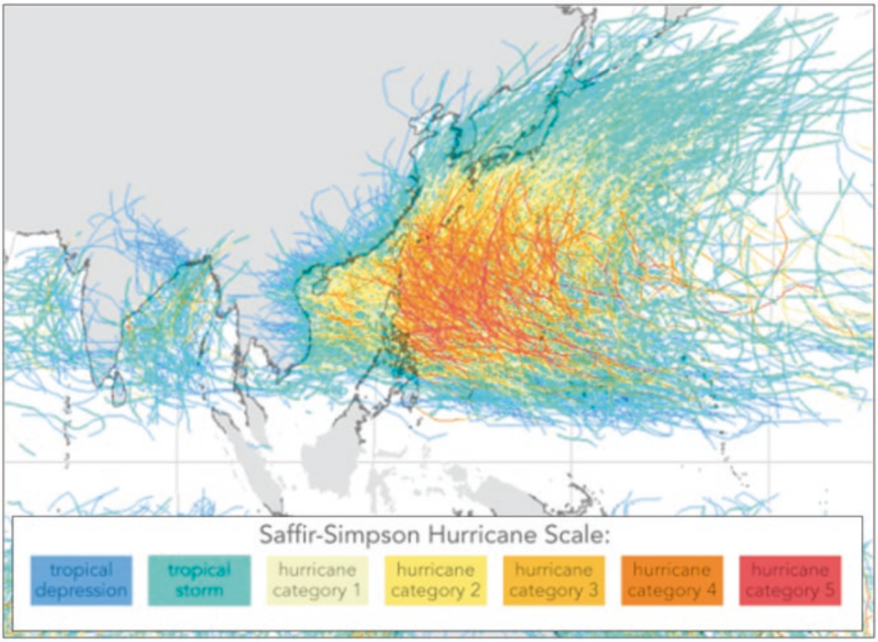

Fig. 2.12 Philippine cyclones recorded between 1945 and 2006 (https://en.wikipedia.org/wiki/Typhoons_in_the_Philippines#/media/File:Tropical_cyclones_1945_2006_wikicolor.png).

and on habitat often was (and continues to be) disastrous. Cyclones also usually are associated with torrential rainfall, leading to floods and landslides. The ancient Filipinos quickly learnt to keep away from flood-prone coastal areas during each cyclone season, but this was difficult if their economic base relied on fishing and coastal resources and there was population pressure on land so they could not easily relocate to safer areas. Cyclones develop over ocean, but unfortunately the incidence of Philippine cyclones probably was not reduced in any substantial way during the existence of Sundaland or at other periods of low sea levels in the island Southeast Asian region because we know that almost all of the cyclones that make landfall in the Philippines originate from the Philippines Sea or the Pacific Ocean to the north and north-east of the archipelago (see Fig. 2.12). Currently, the Philippines is widely recognised as one of the world's most cyclone-prone nations, and this situation probably was no different in prehistoric times. Cyclones, like volcanic activity were hardly sympathetic to observational astronomy.

2.2.5 Earthquakes

Like cyclones, earthquakes could not be predicted, and there was not even an 'earthquake season' in the Philippines when prehistoric people could at least be on the alert. Earthquakes could occur at any time day or night, and could cause severe damage and even loss of life, and there are many examples of devastating Philippine earthquakes mentioned in the historical records (e.g., see Bautista and Bautista, 2004: Figure 2). But while Philippine earthquakes could occur anywhere, as Fig. 2.13 illustrated there were two regions of the archipelago that were especially at risk: in the northern half of Luzon and throughout much of Mindanao.

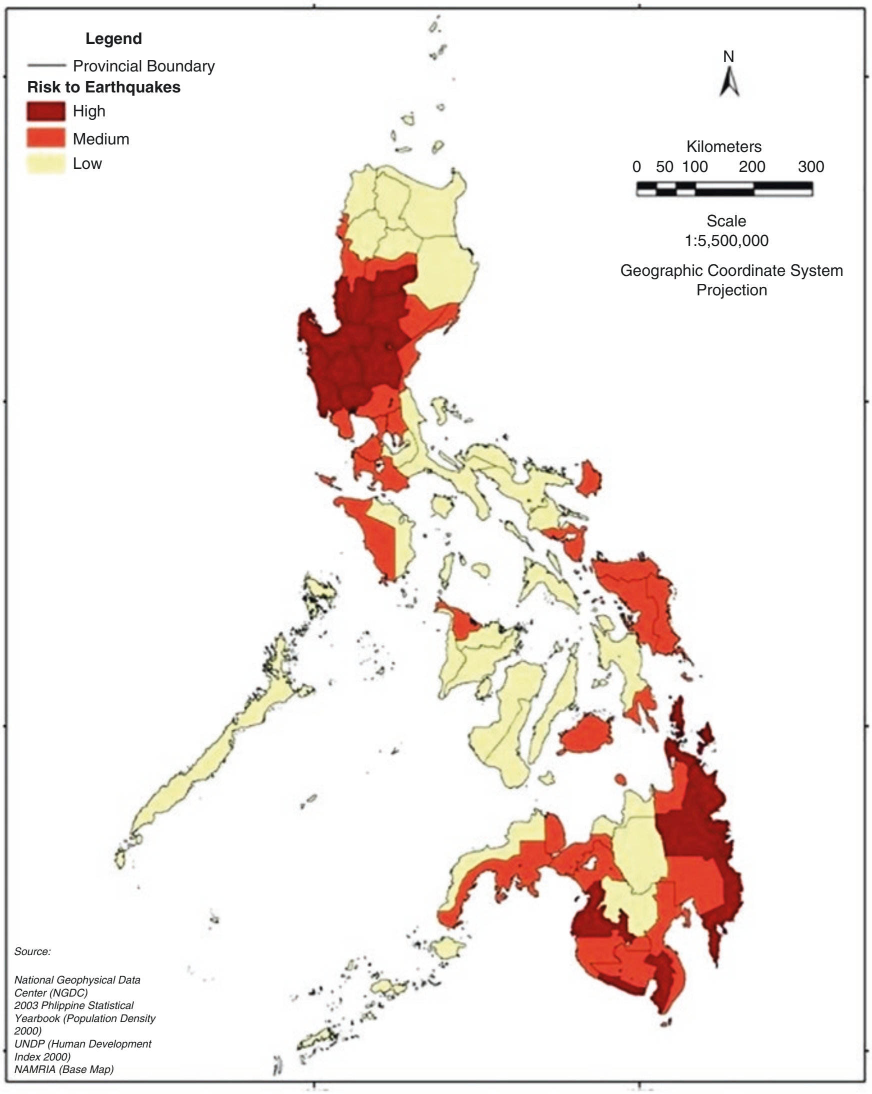

Fig. 2.13 A map showing the risk of earthquakes throughout the Philippines (courtesy: Manila Observatory).

Tsunamis were a special feature of some earthquakes, and they could claim many victims and destroy crops and coastal and near-shore marine resources. As with cyclones, this was particularly devastating for coastal communities that were dependent upon local resources for their survival, but whether prehistoric people felt that the threat of cyclones and tsunamis was adequate grounds for choosing inlands sites for their settlements or elevated sites along the coast has yet to be determined. Obviously the location of a settlement and its specific environmental setting were key factors in encouraging or inhibiting astronomical observations.

The foregoing review provides an all-too-brief environmental canvas upon which to paint the different ethnic groups that settled the Philippine region and then sketch their astronomical systems. Let us begin …

2.3 Placing People in this Changing Environment: The Nature of the Evidence

In order to research the history of Philippine astronomy, and particularly the current and past astronomical systems of different prehistoric ethnic groups, we first must place people in that changing landscape outlined above in Section 2.2. There are five basic types of data we can use:

(1) Archaeological Evidence. Stone (and sometimes bone and shell) artefacts, ornaments, and pottery allow us to identify different prehistoric cultures, while floral and faunal remains at their settlements provide information on their ecological orientations (which often are linked to their astronomical systems), and radio carbon and other dating techniques allow us to track the migrations of people and their cultures over space and time (see Bellwood et al., 2011). We must remember that cultures are dynamic and change with time, and it is important for us to document these changes as they may trigger changes in astronomical beliefs and practices.

(2) Palaeoanthropological Evidence. Three different types of hominids are known to have inhabited island Southeast Asia over the past 1.8 million years or thereabouts: (a) *Homo erectus*, (b) *Homo floresiensis*, and (c) *Homo sapiens* (also referred to as ‘anatomically modern man’). All three species can be easily differentiated on the basis of skeletal, and especially cranial, features. We know nothing about the astronomical practices and beliefs of the first two hominids, and it is debatable anyway whether they were ever in the Philippine region (but see Detroit et al., 2019). The first *Homo sapiens* to settle in the Philippines are thought to have arrived in the archipelago 70,000–67,000 years ago.

(3) Anthropological Evidence. Studies of the cultures of existing indigenous ethnic groups in the Philippines can provide information about their astronomical systems. Their ecological orientations sometimes link to astronomical beliefs and practices, and their morphological characteristics, when combined with archaeological, genetic and linguistic evidence allow us to identify two very different

groups of *Homo sapiens* that made the Philippines home: the initial settlers, referred to as Australo-Melanesians and now represented by negrito populations scattered throughout the archipelago, and the Austronesians, who arrived about 4000 years ago.

(4) Genetic Evidence. Over the past two decades, genetics, and especially mitochondrial DNA (mtDNA, inherited through females) and the Y chromosome (inherited through males), have revolutionised our understanding of prehistoric populations. We now have information about the origins, movements, founder population sizes, and growth rates of different cultures and can trace relationships between different populations. However, as astronomers, we must be carefully when utilising mtDNA evidence since some earlier findings no longer stand up to scrutiny in light of the more advanced analytical techniques used nowadays. For example, as Gunnarsdóttir et al. (2011) has pointed out, a study reported by Abdulla et al. and published in 2009 "… concluded that Filipino Negrito and non-Negrito groups are descended from the same single primary wave of colonization to East Asia." We now know this to be totally incorrect. Another example relates to sampling bias. A recent paper on "The early peopling of the Philippines based on mtDNA" (Arenas et al., 2020) purportedly examines the different routes that anatomically modern humans took to reach the Philippine region. But all those who contributed DNA samples were Filipinos living in Spain! There were no negritos or other distinctive indigenous ethnic groups included in this study. Although genetic studies have opened new doors for us to explore the past, mtDNA data must be used with care in any studies of Philippine astronomical systems.

(5) Linguistics Evidence. Most of the current inhabitants of the Philippines speak variants of an Austronesian language (Bravante and Holden, 2020) that is found not just throughout island and parts of mainland Southeast Asia but also as far afield as Madagascar in the Indian Ocean (near Africa) and among the Polynesians in the Pacific Ocean (see Fig. 2.14; Blust, 2013). It is thought that the ancestral Austronesian language was introduced to island Southeast Asia from Taiwan by the initial Austronesian settlers of the Philippines about 4000 BP, and spread from there. We know that the earlier Australo-Melanesians did not speak an Austronesian language (Reid, 1994a, 2013), so one of our challenges will be to examine astronomical word lists of the different Southeast Asian negrito groups to see if we can identify elements of their ancestral language(s).

Let is now synthesize data from archaeology, anthropology, palaeoanthropology, genetics, and to a lesser extend linguistics, and examine the humans who have inhabited the Philippine region.

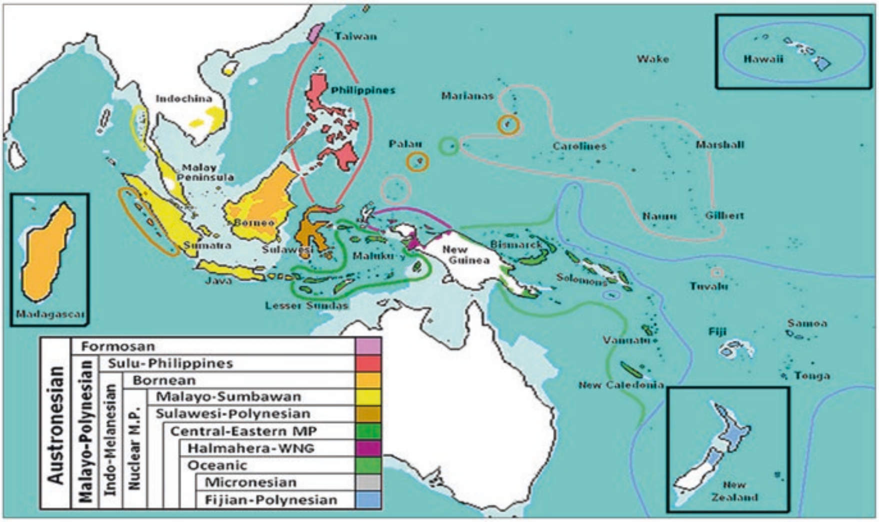

Fig. 2.14 A map showing the widespread geographical distribution of Austronesian speakers (http://www.ksc.kwansei.ac.jp/~jed/MultilingMulticult/Austronesian-expansion.png).

2.4 Changing Populations

2.4.1 The Australo-Melanesians

As mentioned above, the first humans to venture into the Southeast Asian area were *Homo erectus* populations, and their skeletal remains and/or stone tools have been found in southern China, Thailand, Laos, Vietnam, Malaysia and mainly in Indonesia. There are also stone tools in the Cagayan Valley in northern Luzon that may be associated with *Homo erectus* (Ingicco et al., 2018; Pawlik, 2017), but their dating needs to be confirmed. If the Cagayan Valley evidence does indeed disclose the present of *Homo erectus* in the Philippines, then they would have had to make major water crossings in order to get from Sundaland to the Philippine area. Regretfully, we have no knowledge of the astronomical practices and beliefs of *Homo erectus*.

The earliest indisputable evidence of humans in the Philippines dates to 67,000 BP from Callao Cave in northern Luzon (Mijares et al., 2010). Excavations in 2003 produced evidence of human occupation dating back to 25,000 BP but further excavations, in 2007, pushed the date of the earliest occupation back beyond 60,000 BP. Further excavations took place in 2011 and 2015. In all, six small human bones (e.g., see Fig. 2.15) and seven teeth were recovered representing three individuals. All remains are reminiscent of negritos, but—controversially—Détroit et al. (2019) have assigned them to a new species, *Homo Luzonensis*.

This is part of a comprehensive suite of archaeological sites throughout mainland and island SE Asia and Australia and New Guinea dating between 40,000 and

Fig. 2.15 Dorsal view of an MT3 foot bone (left) from Callao Cave, compared with comparable bones of a Philippine negrito (centre) and of *Homo habilis* from Africa (right) (after Mijares et al., 2010: 129).

67,000 and documenting the first settlement of this region by anatomically modern man, *Homo sapiens* (e.g. see O'Connell et al., 2018; O'Connor et al., 2017; etc.). Some of the archaeological and human skeletal sites are plotted in Fig. 2.16, and the genetic evidence is summarised by McColl (2018).

The people represented in Fig. 2.16 were linked to the so-called 'Out of Africa' movement, when groups of anatomically modern humans, with cranial features unlike their earlier genetic ancestors, migrated from northern Africa to the SE Asia and Australia-New Guinea region, along the coasts of the Indian subcontinent at times when the sea levels were 30–40 metres lower than at present, and land-bridges made pedestrian access to this region easier (see Fig. 2.17). That said, they must also have made use of canoes, rafts or other watercraft not just for fishing but also to explore the coastlines, because in order to get from Sundaland to the Philippine region and to Sahul (the enlarged Australian-New Guinea island continent) there were major water-crossing to negotiate (e.g., see Kealy et al., 2016), proof that these early humans had oceanic technology that made them amongst the world's first great mariners.

We refer to these ancestral populations of SE Asia as Australo-Melanesians, and they survive today as the indigenous inhabitants of Australia and New Guinea, and in Southeast Asia as scattered populations of negritos, on the Andaman Islands (in the Indian Ocean, off the coast of Myanmar), in far southern Thailand, throughout the inland mountainous regions of adjacent Malaysia (see Carey, 1976) and on various islands in the Philippines (see Fig. 2.18). Collectively, the negritos are distinguished by their short stature (see Fig. 2.19), black to dark brown skin, and sparse body hair, but there are regional variants of this theme (see Fig. 2.20). For example, African-like 'peppercorn hair' is usual in the Andaman islands, and some of the women there exhibit steotopygia (excessively enlarged buttocks). As might be expected, all of the post-cranial human skeletal remains from Malaysia, Indonesia and the Philippines that date between 67,000 BP and 6,000 BP (including individuals in Callao Cave) are consistent with negrito stature.

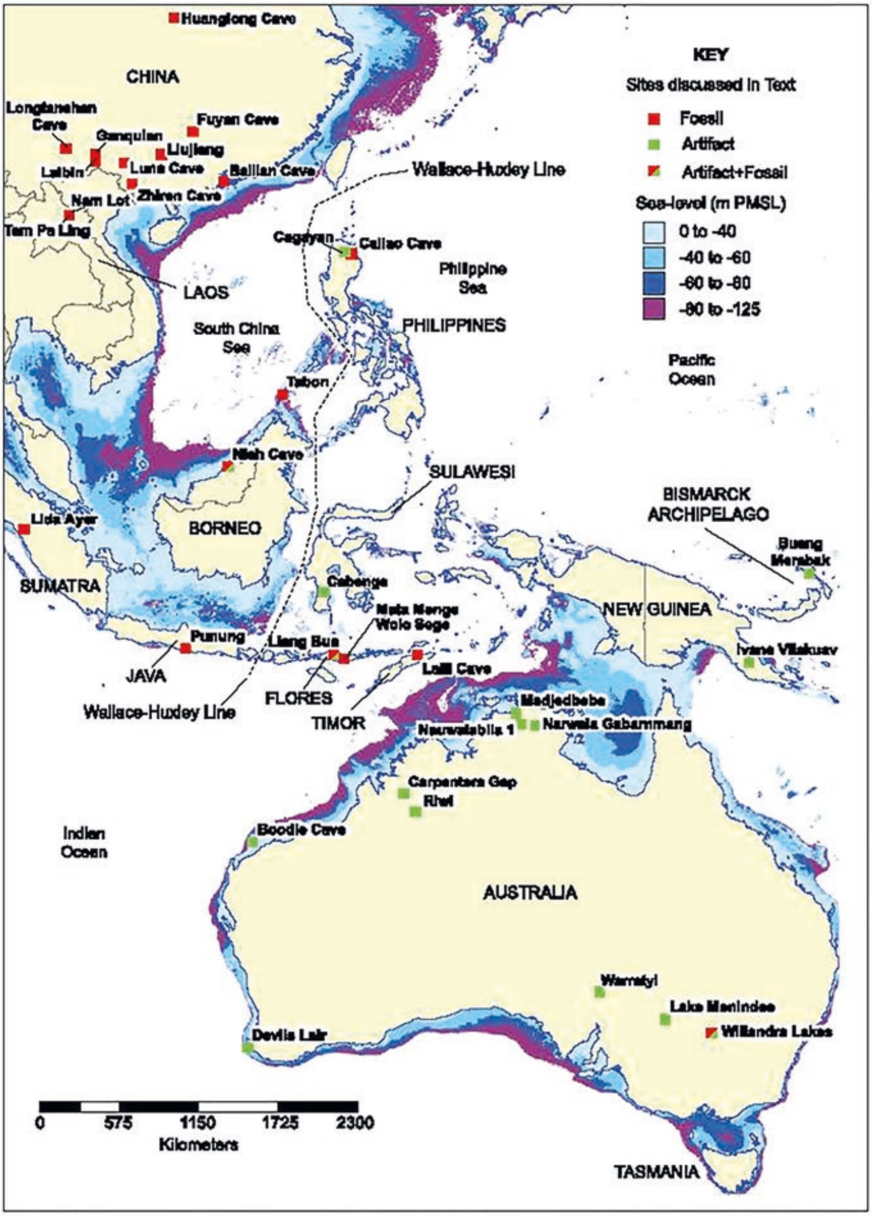

Fig. 2.16 A map showing some of the archaeological sites and human skeletal remains older than 40,000 BP that document the early exploration and settlement of the Southeast Asian area (Sundaland) and Australia-New Guinea (Sahul). Note that if most of these people lived on or near the coast, as would be expected, then their settlements are now submerged under the ocean, if indeed they have survived marine scouring or off-shore sediment deposition and drift following floods and storms (map after O'Connell et al., 2018: Fig. 1).

Fig. 2.17 A map showing the proposed coastal route of the ancestral *Homo sapiens* who first settled Southeast Asia and Australia-New Guinea around 70,000–50,000 BP (https://www.abroadintheyard.com/wp-content/uploads/SE-Asia-and-Australia-50-60000-Years-Ago-Migration-Routes.jpg).

The Southeast Asian Australo-Melanesians were hunter-gatherers and had to utilize the resources offered by marine, coastal and inlands environments for their sustenance and survival. Although they certainly made some use of the rain forest (e.g. see Barker et al. 2007, 2020; Storm et al., 2005), O'Connor et al. (2011) and Samper Carro et al. (2016) have suggested that most Australo-Melanesian local groups preferred the more luxurious resources offered by coastal environments. If this was so—and the argument does make sense—then those Austro-Melanesians living around the shores of Greater Palawan or on the giant island encompassing Panay, Negros, Masbate and Cebu (which we shall call Greater Panay-Negros), or the much-enlarged Sulu Islands must have found life challenging at times, as the seas rose and fell, first drowning and then exposing new habitats. Some of these sea level changes also revealed or drowned major dietary resources, thereby demanded changes to human ecological systems. These changes became even more challenging from 32,000 BP, once the seas began to plunge from their then-current level, falling by about 57 m in the course of the next 10,000 years before leveling off. This resulted in continuous increases in habitat and exploitable resources, while populations also continued to rise, thereby demanding changes to ecological systems. Khairuddin and Jaafar (2021), Halkare et al., 2019), among others how shown how human ecological systems were intricately linked to indigenous astronomical

Fig. 2.18 The current geographical distribution of negrito ethnic groups in the Southeast Asian region; the larger circles in Malaysia and the northern Philippines indicate the presence of many negrito groups in these two areas (map: Wayne Orchiston).

systems. Significant environmental changes could trigger major changes to astronomical systems (see Orchiston and Orchiston (2017, 2018) for examples).

But sea level changes were to prove far more challenging from 22,000 BP, when seas began their rapid rise towards the present level, especially since there is now some controversial genetic evidence (Trejaut et al., 2014) suggesting that successive human populations from the Asian mainland may have migrated to the Philippine region between 20,000 BP and 12,000 BP. Meanwhile, the seas continued to rise relentlessly, drowning habitat after habitat, reducing the territories and resources available to local groups. Around 10,000 BP the seas were 30–40 metres below their present level, and it was at this time that Lusanao disappeared forever, and most of the current islands in the Philippine archipelago were formed. This would have been the first time that sea level changes would have impacted directly on the early Filipinos living round the coasts of northern Luzon, Samar, and much of Mindanao, where previously coastlines had changed hardly at all over tens of thousands of years. Now people could actually see the sea level change within their own lifetime (just as those living in Metropolitan Manila will see the landscape of their city

Fig. 2.19 A southern Thailand negrito man posing with a Western man of average height (Orchiston collection).

change unbelievable in the next 30 years as the seas now rise rapidly in the Philippine area—see Fig. 2.21). For the very first time the Australo-Melanesians saw islands formed, human populations split up, and new ethnic groups take root. Although these scattered populations started with their 'ancestral astronomical systems', with the passage of time, cultural evolution, and further influxes of humans and ultimately religions, astronomical beliefs and practices were subject to change.

2.4.2 The Austronesians

A major new influx of humans took place about 4000 BP, soon after the present shorelines of the islands were established, when Austronesian people from Taiwan migrated to northern Luzon via the intermediary Batanes Islands (Bellwood and Dizon, 2005), and then spread throughout the Philippine archipelago (Bellwood, 2017) and eventually out into the Pacific (Bellwood and Dizon, 2008; Carson et al., 2013). In the Philippines we see evidence of them in archaeological sites (Hung,

Fig. 2.20 Examples of Southeast Asian negritos. From top left, clockwise: Andaman Islands, southern Thailand, Malaysia, Malaysia, Philippines (adapted from https://www.google.com/url?sa=i&url=http%3A%2F%2Findianstatesandculture.blogspot.com%2F2009%2F09%2F&psig=AOvVaw21UpPuYwaDZ5Tnn6iE7MXI&ust=1600251989332000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCICVyMD56usCFQAAAAAdAAAAABAJ; https://kwekudee-tripdownmemorylane.blogspot.com/2012/10/mani-peopleone-of-african-natives-of.html; https://www.pinterest.com/pin/492370171735972897/visual-search/?cropSource=6&h=369&w=530&x=16&y=11; https://says.com/my/lifestyle/indigenous-groups-in-malaysia; https://www.tapatalk.com/groups/anthroscape/the-different-races-of-the-philippines-and-their-r-t92567.html).

2005; Hung et al., 2011; Piper et al., 2009) and in distinctive genetic signatures (Ko et al., 2014). Although back in Taiwan the Austronesians had cultivated rice and millet (that had been perfected in China—see Bellwood, 2005; Chi and Hung, 2010; Lu, 2006) and had other domesticated plants such as the banana, breadfruit, coconut, pineapple, taro and yam, as well as domesticated chickens, dogs and pigs, there

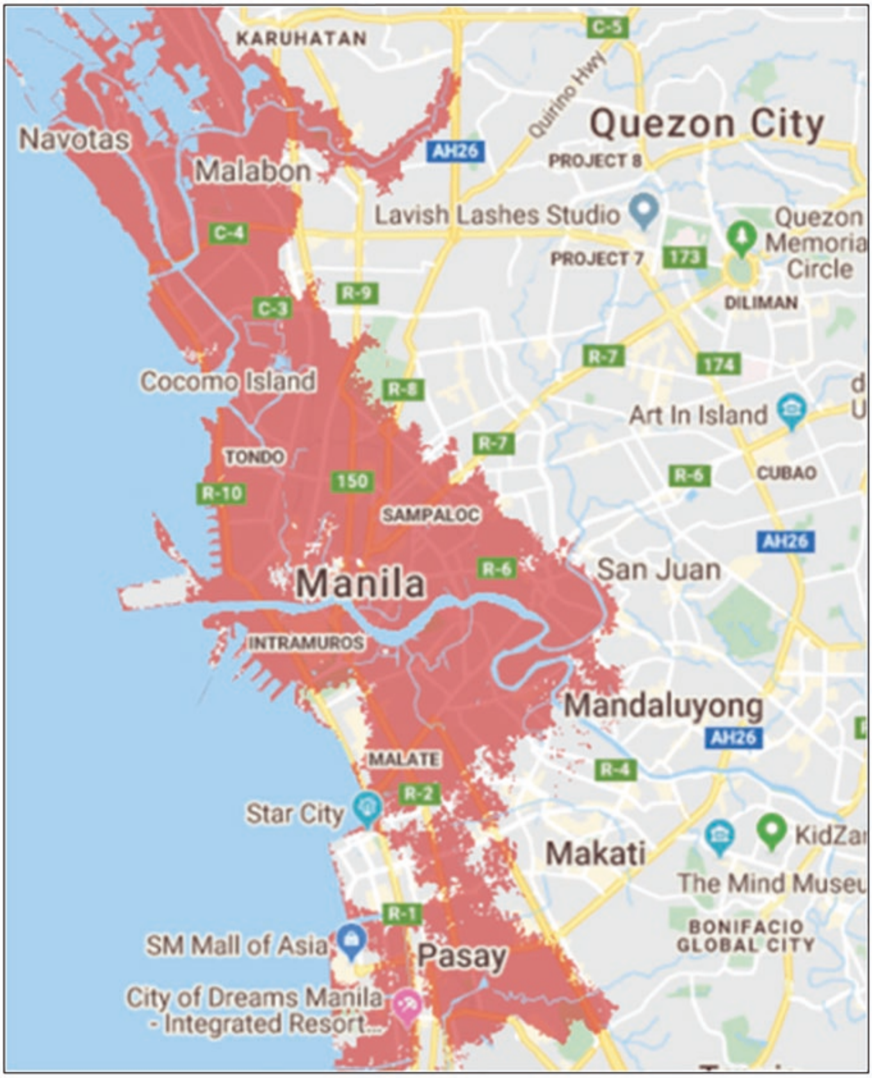

Fig. 2.21 A map showing the expected inundation of parts of metropolitan Manila over the next 30 years. Areas of the city shown in red will then be submerged, and there will be a number of sizable off-shore islands. This map is not included in this book to cause panic, but rather to illustrate that it is possible for humans to actually experience substantial sea level changes in the course of their own lifetimes. The very same situation would have occurred in parts of the Philippines at selected times in the past (map after coastal.climatecentral.org).

is no evidence that they relied on these resources when they occupied northern Luzon (Bulbeck, 2008). Instead, just like the Australo-Melanesian inhabitants, they relied primarily on coastal resources and daily hunting and collecting regimes for their survival. It was only after they had been settled in Luzon for about 1,500 years that the Austronesians began to cultivate rice, and ultimately abandon their hunter-gatherer lifestyle (Barker and Richards, 2013; Snow et al., 1986). It was probably at about this time that the Austronesians laid claim to the fertile alluvial soils near the coast and up the river valleys and drove many of the Australo-Melanesian negrito populations inland into the less hospitable mountains and the rainforest. This is reflected today in the distribution of some of the Philippine negrito groups.

If the astronomical system of the Austronesians was intimately linked to their terrestrial ecological setting, we can assume that they must have made major adjustments when they adopted a hunting-gathering lifestyle in northern Luzon, and abandoned those elements that focused on the cultivation of rice and other plants. Then, when they reverted to rice cultivation they had to revise much of their newly-developed astronomical system and replace it largely with the ancestral system of Taiwan.

Once the Austronesians finally began cultivating rice and other crops it is likely that many of the negritos probably decided to combine hunting and collecting in the rain forest with slash-and-burn agriculture, which was likely to lead to an easier lifestyle than relying solely on forest products. So to what extent did they also adopt aspects of Austronesian astronomy? Khairuddin and Jaafar (2021) have postulated that hunting/gathering and slash-and-burn horticulture are associated with different astronomical systems. We can test this proposition for the Philippines.

The Austronesian newcomers to the Philippines also made a distinctive red-slip pottery (Fig. 2.22), which has proved a valuable ‘marker’ in tracing their movements throughout island Southeast Asia and elsewhere (e.g. see Carson et al., 2013), and they were master mariners and navigators (hence astronomers). They had developed an advanced maritime technology, and sophisticated water-craft capable of carrying humans, edible food, fresh water, domesticated plants and domesticated animals on successful oceanic crossings. Even today in island Southeast Asia we see reflections of this maritime technology among the Mandar, the Bugis and the Madurese of Indonesia (Ammarell, 1999; Fatima et al., 2021; Rasyid et al., 2021).

The Austronesians also spoke a language that differed markedly from those originally spoken by the negritos, and with the passage of time the negritos decided to adopt the language of the newcomers (Reid, 1987). Through an intensive study of surviving negrito languages, Reid (2013: 342) has found that the different languages indicate “… patterns of continuous close interaction …” with their newly-arrived Austronesian neighbours, as well as “… extensive periods of isolation …” both from the Austronesians and other negrito groups. He believes that the Austronesian propensity for head-hunting, which was linked to horticultural rituals and beliefs, may go some way towards explaining the isolationist policies of the more peaceful negritos. But Reid (1994b: 471) believes that before this happened, there were amiable relations between negritos and the newly arrived Austronesians, which made it easy for the negritos to adopt the languages of the newcomers:

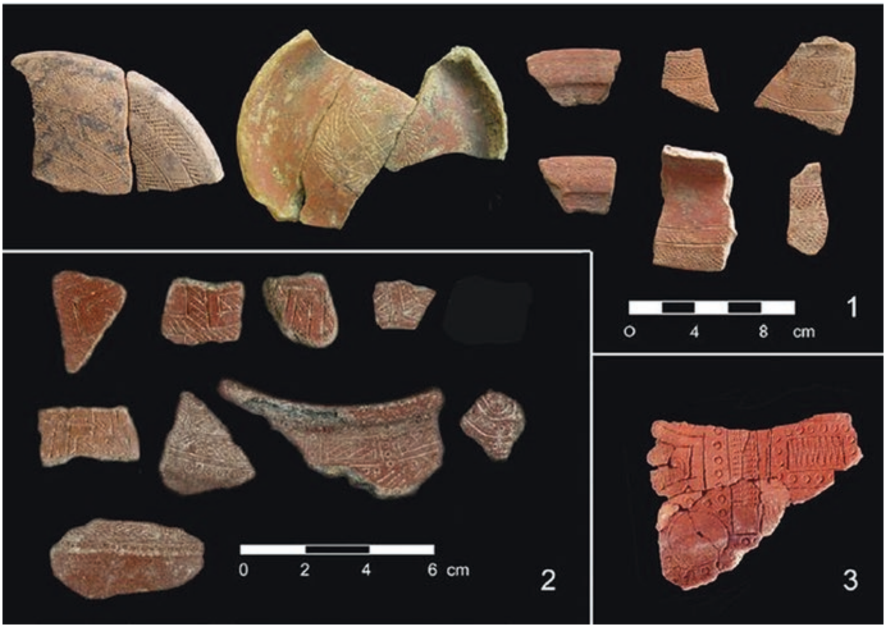

Fig. 2.22 Examples of red slip pottery with punctate/dentate and circle-stamping, in combination with incision, from (1) Nagsabaran (northern Philippines); (2) Achugao (Saipan, Mariana Islands); and (3) Site 13 at Lapita (New Caledonia). Similar pottery has also been found in Taiwan and on Batanes Island between Taiwan and the Philippines (after Hung et al., 2011).

> Negrito and non-Negrito must have lived together in their villages, worked together and played together. The children of the community would have grown up speaking the same language, regardless of what their parents spoke at home, and after a couple of generations, it was the Austronesian language that prevailed.

Although challenged on the likelihood that the two groups would have lived and worked together, Reid (2013: 345) points out:

> However, at some point, whether after a few generations or after a longer period, it is clear that each negrito group was speaking the language of its neighbors, and probably intermarrying with them, given the recent genetic evidence of the affinities of negrito and non-negrito groups …

After they were settled in the Philippine area some Austronesian groups then chose to move southwards down through Sulawesi (Simanjuntak, 2017; Tabbada et al., 2010) until they reached the Lesser Sunda Islands where they split into two groups, one moving eastwards and the other westwards (Karafet et al., 2010; Lipson, et al., 2014; Mona et al., 2009; Spriggs, 2000). Those who chose to head westwards eventually settled in Java, Sumatra and Borneo. Meanwhile, another group of Austronesians residing in the southern Philippines and the eastern Indonesian region chose to migrate further eastwards, settling on the coast of New Guinea and islands off the north coast of New Guinea (Kayser et al., 2008; Skelly et al., 2014; Tumonggor, et al., 2013).

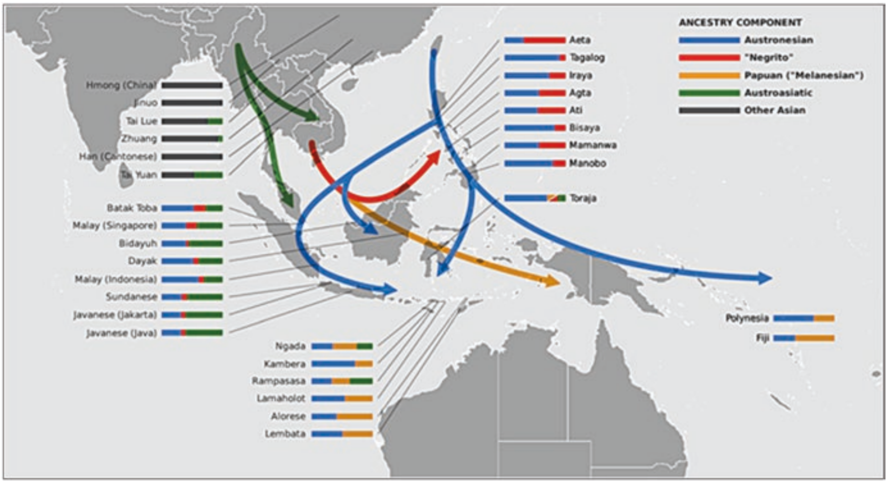

Fig. 2.23 Genetic evidence from island Southeast Asia that clearly identifies the Australo-Melanesian (orange and red), Austronesian (blue) and Austro-Asiatic (green) ancestral populations. Their genetic imprints are now preserved in the present-day populations of island Southeast Asia (after Lipson et al., 2014: Fig. 2).

These latter Austronesians changed their ecology yet again as they once more abandoned rice cultivation but this time in favour of taro, yam and other domesticated crops. Then once they evolved into proto-Polynesians and subsequently settled the scattered islands of Polynesia further changes were required as they adapted to different environmental conditions. For example, in the temperate climate of New Zealand the ancestral tropical dietary staples of taro and yam had to abandoned in favour of the kumara, and this demanded substantial experimentation and a total reorientation of their ancestral astronomical system (see Orchiston and Orchiston, 2017).

Throughout island Southeast Asia the Austronesians are easily recognised by their distinctive genetic signatures, as best revealed by mitochondrial DNA (mtDNA) and the distinctive blue bands on the 'ancestry bars' shown in Fig. 2.23. However, we feel that some of the blue migration arrows in this map are misleading and do not reflect the latest archaeological and genetic results. Specifically, we suggest that Austronesians may have settled Borneo by way of Java and/or Sumatra, rather than directly from the Philippines.

2.4.3 *The Austro-Asiatics*

Fig. 2.24 shows that the next phase in the occupation of island Southeast Asia was by Austro-Asiatic speaking people—ancestors of the current inhabitants—who migrated from Southwest China, via Vietnam, Thailand and the Malayan Peninsula into Sumatra and Java, and northwards into Borneo and Sulawesi (Simanjuntak,

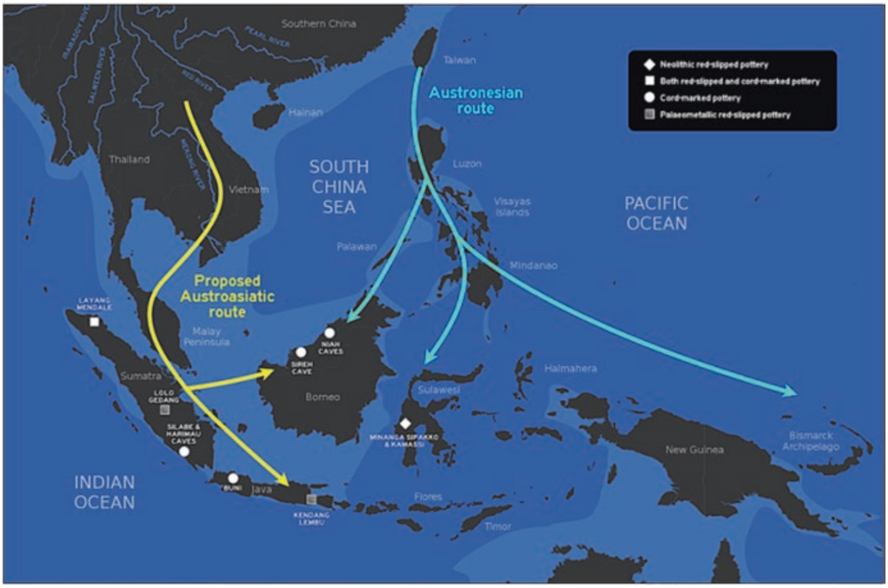

Fig. 2.24 A map showing the proposed routes of the Austronesian (blue) and Austro-Asiatic (yellow) migrations into the Java-Madura region about 3500 and 3000 BP, respectively. We believe the precise routes shown here need to be revised, as discussed in the text of this chapter (based on Simanjuntak, 2017).

2017), but not as far as the Philippines (Corny et al., 2017; Matsumura et al., 2011, 2018, 2019; Yew et al., 2018). Their arrival in Java can be dated to about 3000 BP and is strongly supported by genetic evidence (e.g., see Karafet et al., 2010; Lipson, et al., 2014). We see this represented in Fig. 2.23 by the green components of the 'ancestry bars', where interbreeding with Austronesians and negritos occurred in Sumatra, Borneo and Java, but not in the Lesser Sunda Islands. However, interbreeding with Austronesians occurred throughout the Greater and Lesser Sunda Islands. Meanwhile, we believe that the map in Fig. 2.24 is misleading, and needs to be revised: instead of showing the Austro-Asiatic group migrating down through Vietnam and Cambodia, then sailing across the Gulf of Thailand to the Malayan Peninsula, we believe that they used a land route throughout, as evidenced by the latest archaeological and genetic evidence.

The Austro-Asiatic settlers also grew rice and manufactured pottery, and they quickly merged with the inhabitants of the Greater and Lesser Sunda Islands, forming the ancestors of the present-day populations of this region. However, in most areas of Southeast Asia where they settled (except in some parts of Peninsular Malaya) the Austro-Asiatic groups decided to abandon their original mainland Southeast Asian language and adopt the Austronesian languages that already were widely spoken and accepted throughout Island Southeast Asia.

Note that because the Austro-Asiatics never ventured north of Borneo and Sulawesi in any appreciable numbers, they are not part of the human history of the Philippines.

2.5 Religion and Astronomy in the Philippines

Three different world religions have left their mark on the astronomical systems of the various ethnic groups in the Philippines: Hinduism-Buddhism, Islam, and Christianity (but especially the Catholic faith). These are discussed separately below.

2.5.1 *Hinduism*

While the Hindu religion was very strongly supported in Indonesia and especially Java during the ninth to fifteen centuries CE (see Fig. 2.25), it only took hold in two localized areas of the Philippines, in central Luzon and northern Mindanao. The design and construction of Hindu temples and even entire cites involved complex

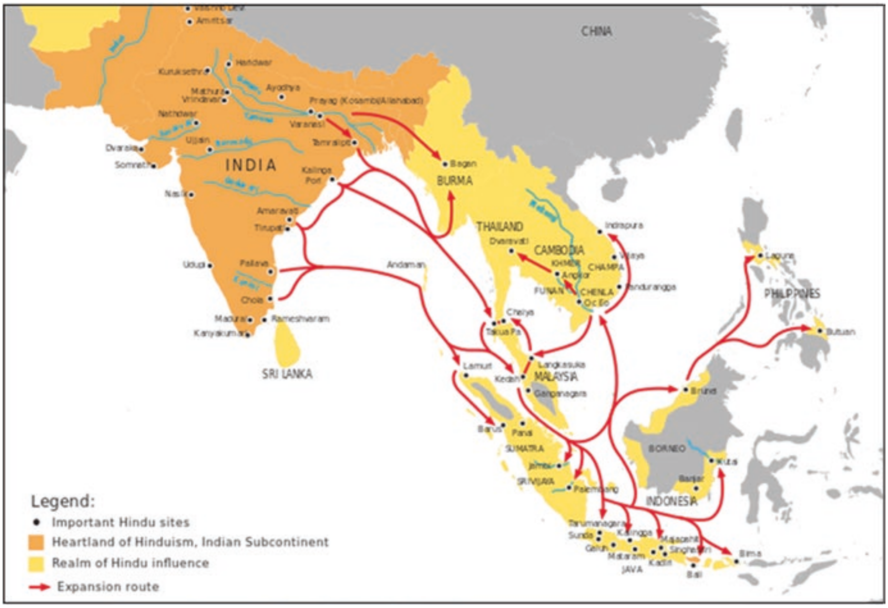

Fig. 2.25 A map showing the spread of the Hindu religion (sometimes in tandem with Buddhism) from the Indian Subcontinent throughout mainland and island Southeast Asia in the last 1200 years. It only impacted on two localized areas of the Philippines (https://commons.wikimedia.org/wiki/File:Hinduism_Expansion_in_Asia.svg).

Hindu cosmological beliefs and practices (e.g. see Khairunnisa et al., 2021; Saelee et al., 2021) that would have been followed religiously in any temples or Hindu cities built in the Philippines. Unfortunately, we are not aware of any surviving ruins of Hindu temples.

2.5.2 Islam

As Fig. 2.26 illustrated, Islam first came to the Philippines in the fifteenth century, when it took root throughout Mindanao. Then in the sixteenth century is found converts in the southern part of Palawan. As a religion, Islam has astronomical requirements in terms of the timing of prayers and the direction of Mecca, but in other parts of island Southeast Asia we sometimes find that pre-Islamic astronomical beliefs and practices are incorporated into Islamic lore and come to the fore during certain astronomical events, such as the occurrence of lunar and/or solar eclipses. Fatima et al. (2021) have clearly documented how this still happens on the island of Madura, in Indonesia. It is important that similar studies are carried out in the Philippines, and it is pleasing that the second author of this chapter and some of his graduate students have made a start in this direction (Guido et al., n.d.).

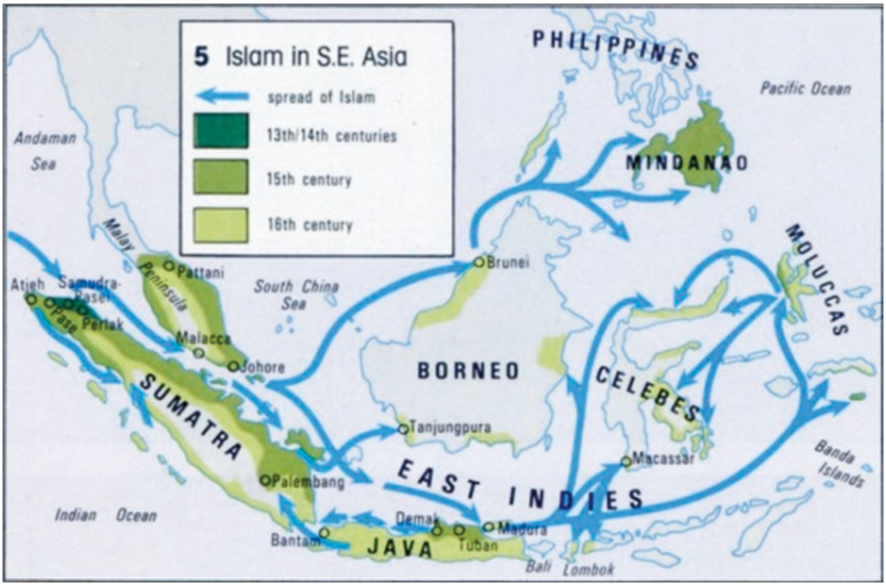

Fig. 2.26 A map snowing the spread of Islam into island Southeast Asia, including the Philippines, during the thirteenth to sixteenth centuries (xenohistorian.wordpress.com).

2.5.3 Christianity and Colonization

The role of Christianity in Philippine society is intricately linked to colonization, and the succession of Western nations that wished to propagate their religion and their political control over the archipelago. As Fig 2.27 illustrates, during the eighteenth and nineteenth centuries in particular, Southeast Asia was a European colonial battleground, with only Siam (present-day Thailand) managing—with considerable difficulty—to maintain its independence. The Philippines, for its part, only had two colonial powers to deal with: the Spanish (until 1898) and the Americans (thereafter, until independence in 1946).

Fig. 2.27 This colourful map shows the territories of the different colonial powers in Southeast Asia. Code: red, purple and blue is British (Burma = Myanmar; Malaya, Sarawak and British North Borneo = Malaysia, and Singapore); green (top-left) is French (Indochina = Cambodia, Laos and Vietnam); orange is the Netherlands (Dutch East Indies = Indonesia); yellow is Spanish up to 1898 and American thereafter (the Philippines—the only colony shown here that subsequently did not change its name); and dark green (bottom, right of centre) is Portuguese (Timor) (https://www.ehm.my/about/history-of-malaysia).

2.6 Priority Research Projects for Philippine History of Astronomy

2.6.1 *Introduction*

The following represent what we believe are the *main* research projects that should be carried out in order to further elucidate the history of astronomy in the Philippines. In defining 'history of astronomy' we adopt the catholic definition employed by the International Astronomical Union (Commission C3: History of Astronomy), and include ethnoastronomy and archaeoastronomy.

The following listing, which reflects our collective view, is given in priority order. Others, with different research interests and backgrounds, are of course welcome to assemble (and action) their own lists.

2.6.2 *Prepare an English Translation of Dante Ambrosio's Book* Balatik

Balatik (Fig. 2.28) was prepared by the late Professor Dante Ambrosio (1951–2011) and was based on his doctoral dissertation. It was published in 2010, and to date is indisputably the most important book ever written on Philippine history of

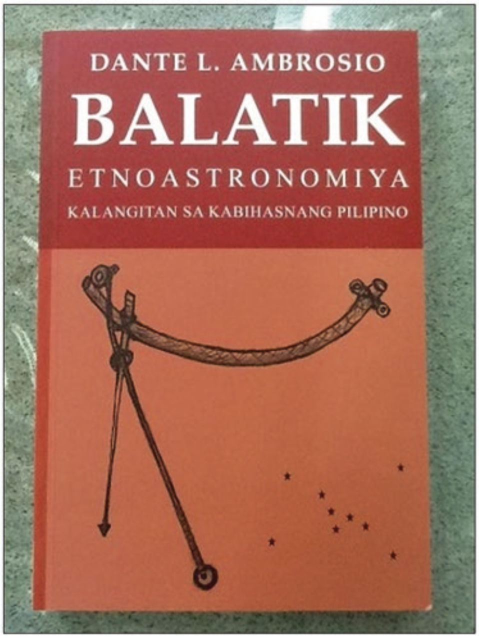

Fig. 2.28 The cover of Dante Ambrosio's *Balatik*.

astronomy. It is the logical starting point for any current and future studies in Philippine ethnoastronomy. But, it is in Tagalog, and urgently deserves an English translation so that it can be enjoyed by an international audience, and expanded on through further research.

We are delighted that one of the authors of this chapter (JT) has taken on this long and challenging task and currently is translating *Balatik*. We look forward to its ultimate publication in English.

2.6.3 Document, Compare and Contrast the Astronomical Systems of the Negritos in the Philippines and Elsewhere in Southeast Asia

2.6.3.1 Introduction

This is a colossal project that will take much time and effort, but it promises to produce an avalanche of research results that will broaden our astronomical (and anthropological) horizons and contribute immeasurably to international history of astronomy scholarship. At very least it will provide accounts of the astronomical systems of all of the main negrito groups in the Philippines and the ways in which they are (or were) linked to human ecology. At best it will provide data that allow us to trace the evolution of some of these astronomical systems over the past 4000 years (since the arrival of the Austronesians), while astronomical word-list from the Philippines and elsewhere in Southeast Asia may allow us to start reconstructing elements of the ancestral languages that were spoken by the Australo-Melanesians.

Currently, there are reputed to be about 20 different negrito ethnic groups in the Philippines (see Gordon and Grimes, 2005), and they are mainly found on Luzon (the Aeta and Agta), Mindoro (Iraya), Palawan (Batak), Panay (Ati), Negros (Ata) and Mindanao (Mamanwa) (see Fig. 2.29). There are various sub-groups that help bring the total number of ethnic groups to 20, and with various groups merging with or splitting off from other groups, and a plethora of different names used, there is confusion in the extensive literature on the Philippine negritos. Nowhere is there a single recent authoritative publication that documents the key physical and cultural characteristics—let alone the geographical locations—of all major Philippine negrito groups, although there are good overviews of some individual groups—e.g. see Griffin and Estioko-Griffin (1985) for the Aeta and Vanoverbergh (1925, 1929, 1930, 1937, 1938) for the Agta. Thus, producing Fig. 2.29 proved a challenge, and we should note that it differs, but in minor ways only, from the distribution published by Reid (2013). Apart from what is mentioned in *Balatik*, very little has been published on the astronomical systems of the Philippine negrito ethnic groups (although some Rizal Technological University astronomers have made a useful start, as we shall see).

When comparing the Philippine negritos with other indigenous ethnic groups in the Philippines it is convenient to treat them as a coherent group, but an examination

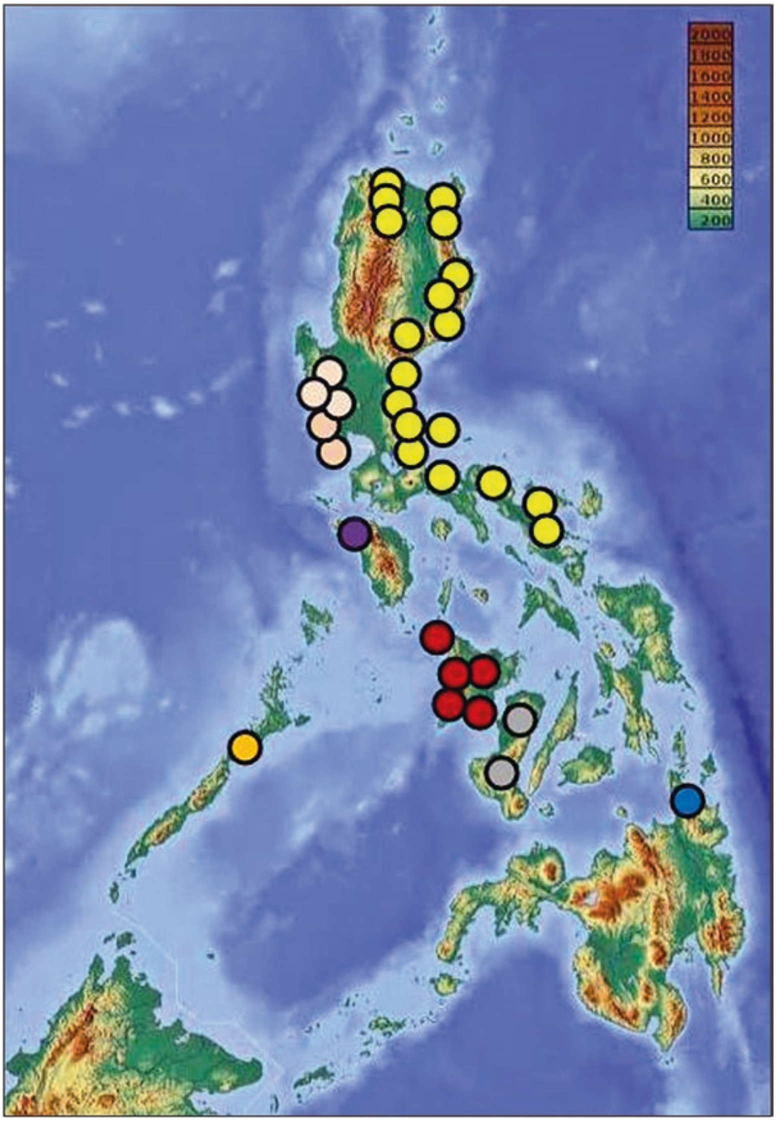

Fig. 2.29 The geographical distribution of the main Philippine negrito groups (Aeta = pink; Agta = yellow; Ata = grey; Ati = red; Batak = orange; Iraya = purple; Mamanwa = blue; map: Wayne Orchiston).

of the physical attributes of the negritos quickly reveals that there are notable differences, especially in skin colour and hair form (e.g. see Fig. 2.30). These are even obvious at a localised level—as shown by the Aeta negritos who feature in Fig. 2.31.

These visual physical differences between the various Philippine negrito groups are also supported by genetic studies. At the same time, these studies allow us to distinguish

Fig. 2.30 (**a**) Examples of different Philippine negritos, showing diversity of skin and hair colour and hair type. Top left: Aeta (https://global-geography.org/af/Geography/Asia/Philippines/Pictures/Pinatubo/Aeta_Kinder_2); Top right: Batak ((https://www.pinterest.com/pin/384494886912041239/); Bottom: Agta (https://www.clbxg.com/dressimage/pkooby.html). (**b**) Examples of different Philippine negritos, showing diversity of skin and hair colour and hair type. Top left: Mamanwa (http://mamanwa.blogspot.com/2007/); Top right: Ati (http://blog.thecheaproute.com/loboc-river-cruise-what-to-do-bohol-philippines/ati-tribe-children/); Bottom left: Iraya (https://www.ayalafoundation.org/a-young-iraya-mangyan-woman-beads-her-way-to-her-dreams/); Bottom right: Batak (https://storymaps.arcgis.com/stories/d14560bce7fa4c2b9701ef4ceee6091d).

Fig. 2.30 (continued)

Fig. 2.31 Portraits showing the diversity of hair and skin colour and hair type among the Aeta. Top row, left to right: http://www.trekkingpinatubo.com/aeta-people-gallery/; https://global-geography.org/af/Geography/Asia/Philippines/Pictures/Pinatubo/Aeta_Kind_4; https://www.filipinotravel.com.ph/photo-guided-tour/; http://www.trekkingpinatubo.com/aeta-people-gallery/). Bottom row, left to right: cropped from https://kwekudee-tripdownmemorylane.blogspot.com/2012/10/aeta-people-one-of-first-natives-of.html; all others from the same web site.

Philippine negrito from non-negrito ethnic groups, but gene-sharing to varying degrees over the past 4000 years, since the Austronesians arrive in the archipelago, has made it difficult on islands like Mindoro, Panay, Negros and Mindanao to identify 'pure' negritos as there are so many 'hybrid' individuals. We see this reflected in many photographs of indigenous people from these islands, and in some recent genetic studies.

For example, Delfin et al. (2011) "… surveyed Y-chromosome … variation in 390 individuals from 16 Filipino ethnolinguistic groups, including six Negrito groups …" from throughout the archipelago. The Y chromosome derives from the male line of inheritance, whereas mtDNA is inherited from females. Delfin et al. found "… extreme diversity in the Y-chromosome lineages of Filipino groups with heterogeneity seen in both Negrito and non-Negrito groups, which does not support a simple dichotomy of Filipino groups as Negrito *vs* non-Negrito." This extensive heterogeneity is shown by the pie charts in Fig. 2.32. Delfin et al. saw this as evidence of widespread gene-sharing and genetic drift following the Austronesian settlement of the archipelago.

Instead of only looking at Y-chromosome details, Heyer et al. (2013: 189) adopted a wide-ranging approach involving "… mitochondrial DNA (mtDNA) hypervariable segment 1 haplotypes and haplogroups, Y-chromosome haplogroups and short tandem repeats (STRs), autosomal STRs, and X-chromosome STRs." But they restricted their investigation to just two negrito groups, the Aeta and the Agta (even though the total number of individuals studied was a respectable 120, drawn from four different locations in northern Luzon). They wanted to examine the genetic diversity and structure of these two negrito groups at a local, regional, and interregional level. They found

> … a high level of autosomal differentiation, combined with no significant reduction in diversity, consistent with long-term settlement of the Luzon region by the ancestors of the Agta and Aeta followed by reduced gene flow between these two ethnolinguistic groups. (*ibid.*).

This reduced gene flow between the Aeta and Agta groups is understandable if they were physically isolated from one another, as appears to be the case from their locations shown in Fig. 2.27, but we will return to this topic later in this chapter.

As a follow-up to their Y-chromosome study, Delfin et al. (2014: 228) looked at the mitochondrial DNA (mtDNA) genomes of 14 different Philippine ethnic groups. This new study revealed

> … genetic differences between ethnolinguistic and regional center groups … consistent with the Y-chromosome, namely: diversity and heterogeneity of groups, [and] no support for a simple dichotomy between Negrito and non-Negrito groups …

This heterogeneity of negrito and non-negrito groups is shown in Fig. 2.33.

Lipson et al. (2014) offer another way of visually comparing the genetic signatures of Philippine negrito and non-negrito ethnic groups, in terms of their ancestral relationships. Thus, in Fig. 2.34 the relative contributions of Australo-Melanesian (= 'negrito') and Austronesian genes are indicated by colour-coding them red and

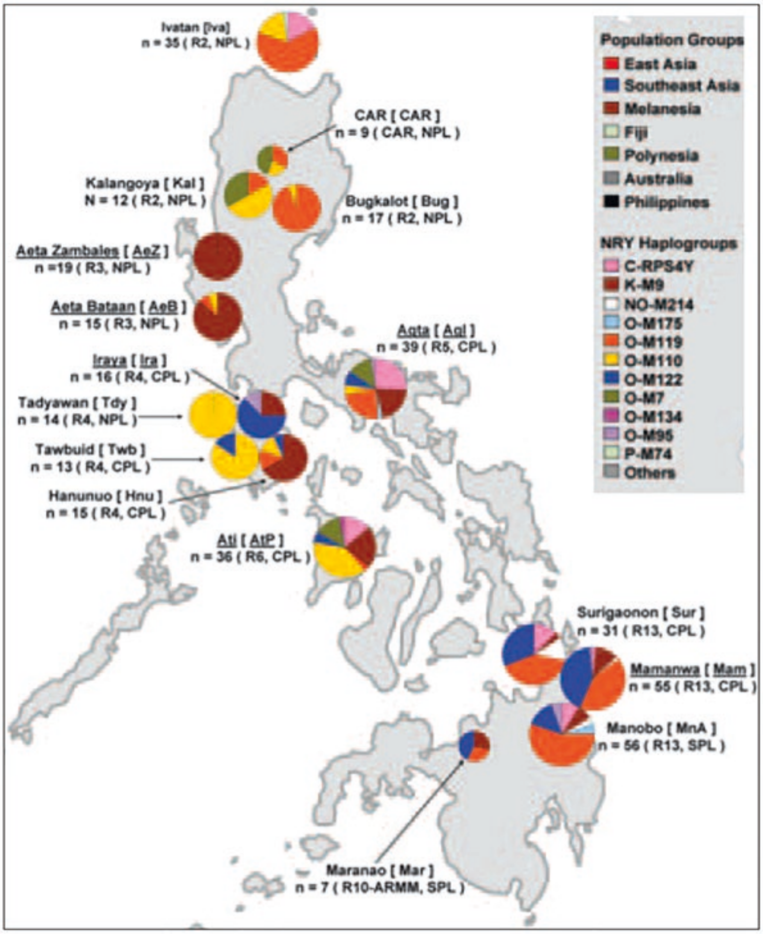

Fig. 2.32 The genetic differentiation of different Philippine indigenous groups based on Y chromosome data (after Delfin et al., 2011: 225).

blue respectively in the 'ancestry bars' of the different ethnic groups. We have marked the negrito groups with red asterisks. The 'ancestry bars' of the negritos are mainly red, with some recent Austronesian interbreeding, while the Austronesians have mainly blue ancestry bars. Note that apart from a very small green Austro-Asiatic component displayed by the Toraja from Indonesian Sulawesi Island, this third genetic population to enter island Southeast Asia is absent from our map. However, as we already saw when we viewed Fig. 2.23, the Austro-Asiatic genetic signature is very obvious in Sumatra, Java, Borneo and in some of the islands in the Lesser Sunda group, along with Austronesian and negrito (i.e. Australo-Melanesian) genes.

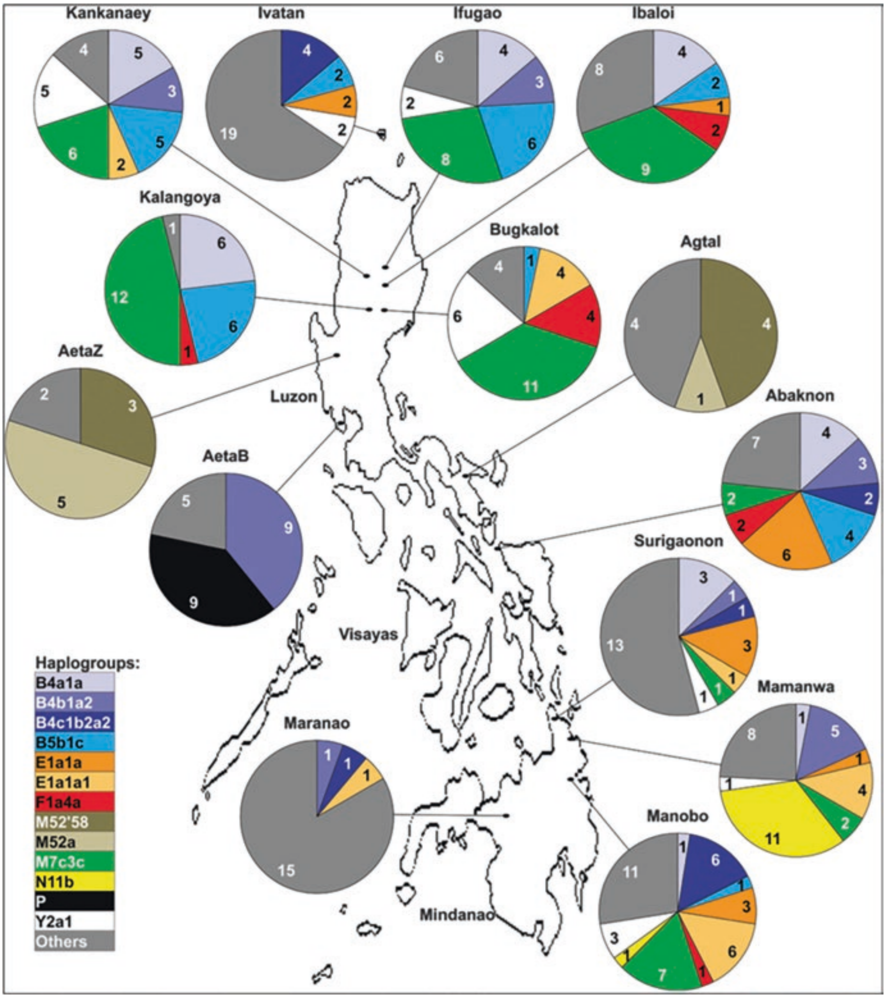

Fig. 2.33 A mtDNA analysis of negrito and non-negrito groups in the Philippines, showing the genetic heterogeneity of both groups. Note the very different pie charts of the two Aeta populations (after Delfin et al., 2014: 232).

It now remains for us to compare the genetic signatures of the Philippine negritos with negritos from other parts of Southeast Asia, and there are two research papers we should discuss. However, both of these present problems—as we shall see. Reich et al. (2011) examined the incidence of Denisovan genes in Asian, Southeast Asian, Australian, New Guinea and Pacific Island populations, and they included two Philippine ethnic groups in their study: the Mamanwa negritos from Mindanao and the neighbouring Manobo. The existence of the Denisovans was revealed just one year earlier when Reich and other colleagues (2010) published a seminal research paper in the journal *Nature* reporting the existence of a new type of hominid revealed during excavations at Denisova Cave in Siberia. In the decade since that discovery,

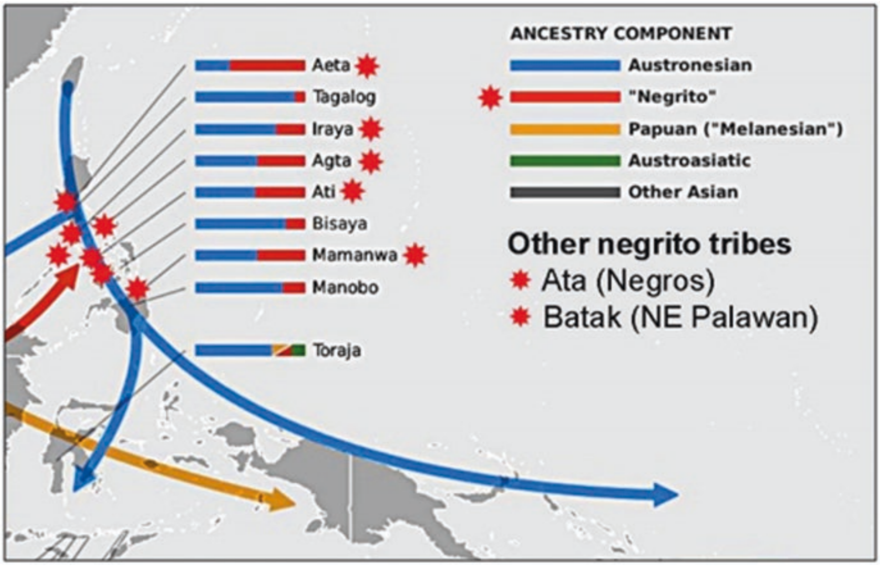

Fig. 2.34 A map showing genetic signatures of negrito and Austronesian ethnic groups in the Philippines (base map adapted for Lipson et al., 2014; map modifications: Wayne Orchiston).

many other hominids have been found to contain Denisovan genes, and the current view is that the Denisovans were Asian equivalents of Europe's Neanderthal Man and that perhaps many of the 'early modern' crania in China actually were Denisovans.

With this as background context, let us look at the Reich et al. (2011) paper. In this, they report the presence of a small but significant Denisovan genetic presence in samples derived from Melanesia, Australia, some islands in the Lesser Sunda chain and the Moluccas in Indonesia, as well as the Mamanwa negritos from Mindanao and their non-negrito neighbours, the Manobo. This is illustrated in Fig. 2.35. The fact that the Manobo also share some Denisovan genes is not surprising, given the high degree of gene-sharing between the Mamanwa and the Manobo, as displayed in Fig. 2.33 above.

What Fig. 2.35 also reveals is that Denisovan genes are absent from all mainland Asian populations sampled (including the Jehai negrito population of the Malayan Peninsula), from Borneo and Sumatra in island Southeast Asia, and from the Onge negritos of the Andaman Islands. If the negritos are indeed representative of the initial settlement of island Southeast Asia by anatomically modern man, then this would suggest that there were two or more ancestral populations of Australo-Melanesians.

Earlier in this chapter we mentioned sampling bias, and Fig. 2.35 is a case in point. While we know about the Denisovan genes in the Mamanwa, we know nothing about all of the other negrito ethnic groups in the Philippines—whether they mimic the Mamanwa, as would be expected if all derived from a single settlement population, or whether some should be grouped with the Malaysian and Andaman

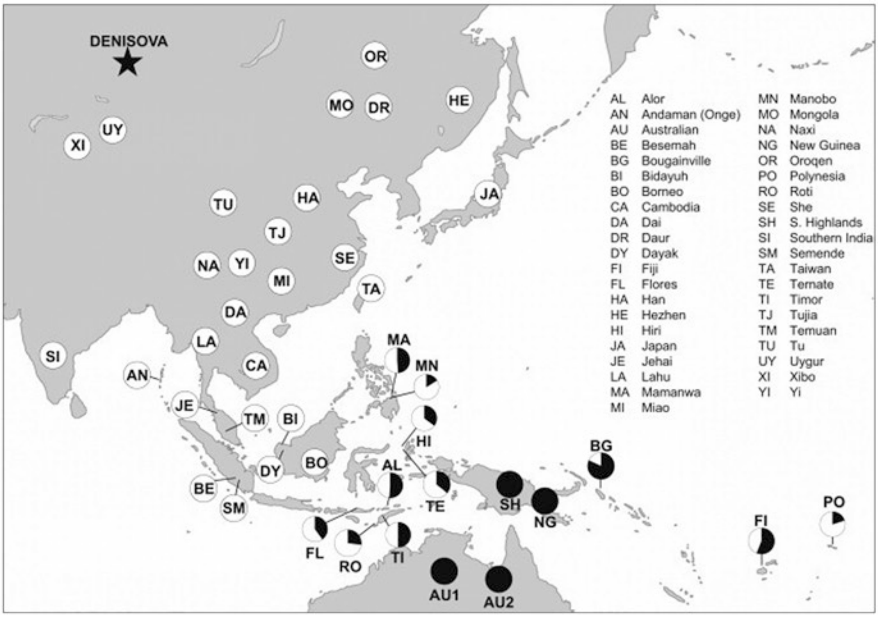

Fig 2.35 Pie charts showing Denisovan genes as a percentage of that found in New Guinea populations (after Reich et al., 2011: Figure 1).

Islands negritos, showing that two (or more) different populations originally settled the Philippines. If in fact there were two or more settlement population then this has clear astronomical implications. What does the other study show?

Jinam et al. (2017: 2013) wanted to research the Philippine negritos *vis-à-vis* other Southeast Asian negritos, so they "… generated genome-wide single nucleotide polymorphism data in the Philippine Negritos and compared them with existing data from other populations." In fact, they only included four Philippine negrito groups in their study, the Agta, Aeta, Batak and Mamanwa, along with Tagalog, Visayan and Manobo non-negrito groups. They found "… relatively high traces of Denisovan admixture in the Philippine Negritos, but not in the Malaysian and Andamanese groups …", thus confirming the early finding by Reich et al. (2011). From their analyses, they also found that the Batak and Mamanwa negritos experienced most gene-sharing with non-negrito groups, which also was documented for the Mamanwa by other researchers.

2.6.3.2 Changing Human Ecology and Changing Astronomical Systems

If we wish to document *and understand* the astronomical systems of the negrito groups it is important that we also study their human ecology and ways in which this has changed significantly in the past on the basis that among ethnic groups worldwide what is important here on the Earth is often transferred to the sky and assigned to stars, star clusters (i.e. the Pleiades), asterisms or even distinguishing features of

Table 2.1 Dates when the islands of Cebu, Masbate, Panay and Negros were formed during the post-glacial rise in sea level.

Single land mass	Separating island	Date of separation (BP)
Panay-Negros-Masbate-Cebu	Cebu	16,000
Panay-Negros-Masbate	Masbate	10,000
Panay-Negros	Negros	8000–7000

the Milky Way (e.g., for Indian, Malaysian and Aboriginal Australian examples see Clarke, 2014, 2015; Fuller et al., 2014; Gullberg et al., 2020; Halkare et al., 2019; Khairuddin and Jaafar, 2021; Leaman et al., 2016; Vahia et al., 2016).

For the negritos there were two major events that would have made them adjust or even markedly change their ecological strategies, and these were the rapid and never-ending rise in sea level between 22,000 BP and 6000 BP, and the arrival of the Austronesians.

The negritos were a coastally-oriented people, and in those parts of the Philippine archipelago where extensive areas of habitat were flooded and lost forever they had to respond to the rising seas and adjust their food-quest strategies so that there was enough to sustain localised populations. But this happened gradually on the scale of a human lifetime, so such ecological fine-tuning was hardly perceptible from generation to generation. But it had to happen. We can envisage this occurring when Greater Palawan shrank very substantially to its present size, and when the rising seas succeeded in converting Greater Panay-Negros into what are now the Visayan islands of Cebu, Masbate, Panay and Negros. Using an excellent sea level rise animation available on the web, we can identify approximately when this latter chain of events occurred, and they are listed in Table 2.1. The original island had extensive mangrove areas that were rich in resources and valuably supplemented other coastal and near-shore marine resources, but with the formation of the four main islands most of these mangrove areas were lost forever or else were relocated.

Apart from the Palawan and Panay-Negros-Masbate-Cebu areas, the only other location in the Philippines where an extensive area of land was lost during the last post-glacial sea level rise was the extensive coastal flat between Polillo and Catanduanes. Most of this was rapidly inundated between 14,000 and 12,000 BP, forcing the negritos inland, and eventually into the mountainous rain forests.

With a reduced range of coastal dietary species to hunt and gather, the negritos were forced to look more closely at non-coast resources, especially those in the rain forests, and to modify their seasonal food-quest activities in order to make optimal use of different resources found in all biotic environments that could easily be accessed in the course of a single day's return journey from their settlements.

This, then, raises the thorny issue of the dietary role that tropical rain forests were able to play in hunter-gatherer ecosystems. Back in the 1980s there was considerable debate in the literature about the ability of rain forests to sustain human populations, if they received no assistance from nearby farming communities. Mijares (2008: 101–103) nicely summarizes this debate, where people like Peter Bellwood were able to assemble archaeological and ethnographic evidence to show that rain forests were viable human habitats. But what comes through clearly from subsequent research is that late Pleistocene and early Holocene ethnic groups in the Philippines would have made use of *all* local environments in their food quest, not just the rain forests, and hunted or gathered specific flora and fauna on a seasonal basis (Barker et al., 2007, 2020; Lewis, 2007; Mijares, 2008; 2010l; Pawlik, 2017; Paz et al., 2008; Porr et al., 2012). Ethnographic evidence also supports this view. Thus, the Aeta "… hunted in the montane forest during the rainy season and in the lowland forest during the summer, deriving most of their food supply from fishing, shellfish gathering, wild yams, nuts and *Caryota* palms." (Mijares, 2008: 105).

The other event that triggered a major ecological change in the lives of most negritos was the arrival of the Austronesians in the Philippine archipelago. The Austronesians were a maritime- and coastally-oriented people, and they would have favoured settling in coastal localities, which obliged the negritos to move elsewhere, and often inland, into the mountainous rain forests. Almost total reliance on forest resources certainly would have involved a major reorientation of negrito ecological strategies, and even when they also decided to combine hunting/gathering with slash and burn agriculture—inspired, no doubt, by the horticultural successes of the Austronesians. We would expect these major ecological adjustments ultimately to be reflected in the evolving astronomical systems of the negritos.

2.6.3.3 Did the Geographical Distribution of Philippine Negritos Change Markedly in Historic Times?

We know that from around 70,000 BP until about 4000 BP what we now term the negritos were the only humans in the Philippines, and we can assume that they were living throughout the archipelago. Then the Austronesians arrived and displaced many coastally based negritos. The next group of humans to arrive in the region were the Spanish, but does Fig. 2.36 provide a realistic representation of the negrito presence at that time, or were negritos more widespread, only to die out or amalgamate with other ethnic groups in the course of the intervening 500 years? For example, given the presence today of different negrito ethnic groups on Panay and Negros, if there were negritos living elsewhere on Greater Panay-Negros, were some of these people isolated on Cebu when the seas rose around 16,000 BP and this became a separate island? Similarly, was a negrito population stranded on Masbate when it became an island around 10,000 BP?

We also can ask if there originally were negritos living on Marinduque or Catanduanes when rising seas formed these two island, separating them once and for all from Luzon, or in early Spanish times were there negritos reported on Samar, Bohol, Leyte, Dinagat, Siargao and Basilan, all of which were once part of the expansive island of 'Lusanao'. Austronesians were found in all of these areas, but were negritos? Similarly, were there originally negritos living on Busuanga Island (between Palawan and Mindoro), after it separated from Greater Palawan?

Finally, we should note the almost continuous string of Agta localities, represented in Fig. 2.36 by the yellow circles. In Spanish times were they all known as Agta, or did they go by different tribal names?

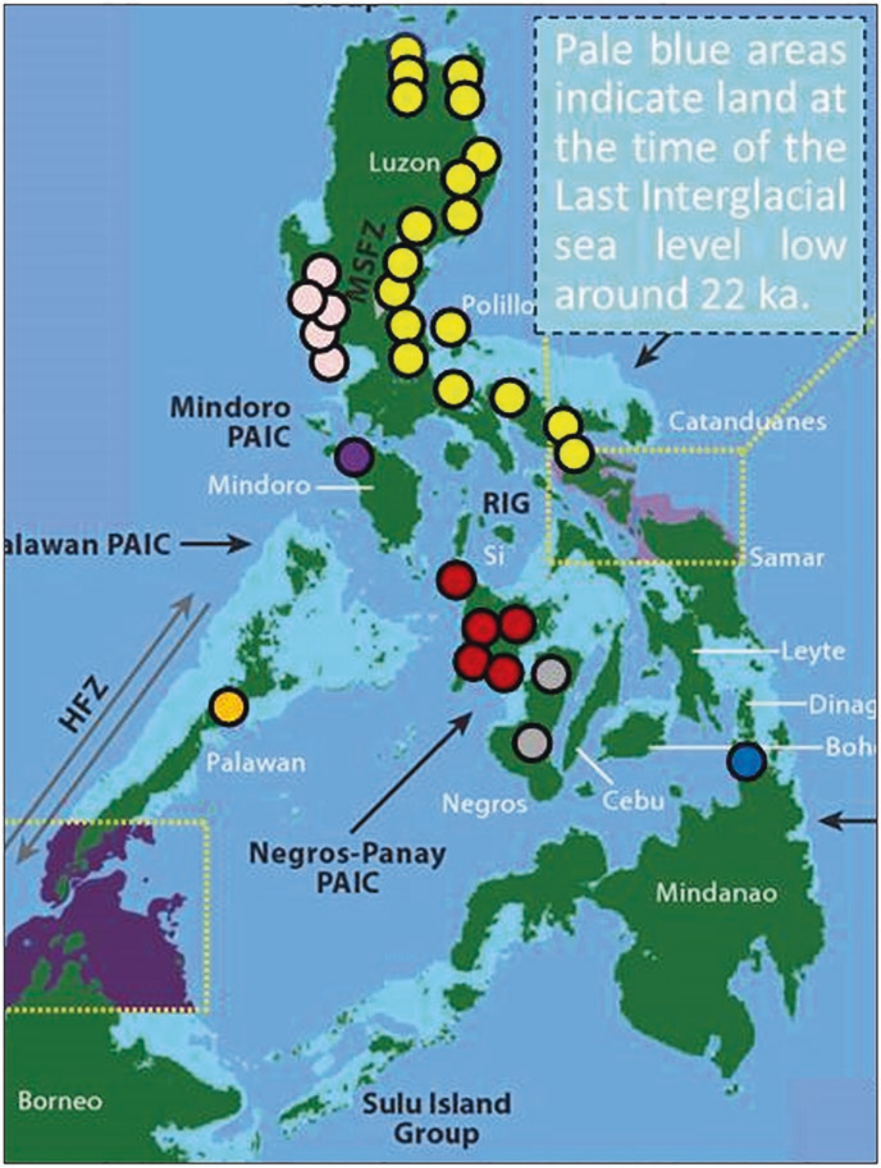

Fig. 2.36 The current location of negrito groups *vis-a-vis* land masses (green plus pale blue) as at 22,000 BP; colour coding as per Fig. 2.29 (map modifications: Wayne Orchiston).

It would be worthwhile to check missionary and other records in Blair and Robertson's 55 volumes to see if they record the presence of negritos on any of the afore-mentioned islands and locations, or on other islands in the Philippine archipelago that now have no negrito populations. Once we also add human skeletal remains that are consistent with negrito stature, and have a revised version of Fig. 2.36—which is what we suspect the records in Blair and Robertson (1903–1909) will reveal—then this will give us a starting point for any discussion on the changing distribution of negrito populations in the Philippines during colonial times. From this starting point we also can explore the likely astronomical systems of the 'missing' ethnic groups. For example, if current research shows that the astronomical systems of the Panay and Negros negritos are remarkably similar, then we can assume the same for any negrito groups that may once have been isolated on Cebu and Masbate, but if the Panay and Negros systems turn out to be dissimilar then this raises serious questions about the mooted Cebu and Masbate negrito astronomical systems. The fact that Reid (2013) found the language of the Panay negritos to be unique only adds a further complication to this proposition.

2.6.3.4 Researching Individual Negrito Astronomical Systems

We make no recommendations here about which specific negrito groups should be surveyed first, as this will require careful consideration. Clearly, a combination of factors will determine this. These will include the known numbers of surviving knowledgeable adults with astronomical knowledge in each negrito ethnic group; windows of opportunity opened by Government or other funding agencies; opportunities to participate in a multidisciplinary study of a particular negrito group in collaboration with the National Museum of the Philippines, and/or other Philippines or overseas universities; the extent to which a negrito study can be integrated into a large-scale project conducted at the same time and involving local non-negrito astronomical systems; and the chance to follow up on previous research.

These previous studies are of two types:

(1) Negrito groups discussed in Ambrosio's *Balatik*; and
(2) Studies already carried out by RTU astronomy staff and students. In this regard, we can list the following:

  - "The ethnoastronomy of Aeta in Zambales and Bataan" by C'Jacquel R. Danauto and James Bryan C. Basit
  - "A material aid of the ethnoastronomical culture of Ati in Santo Domingo, Albay" by Mika Denise C. Samson and James B. Vitin
  - *Ati. The Ethnoastronomical Culture*, a booklet Mika Denise C. Samson and Kenneth James B. Vitin (2019)
  - *Dumagat Indigenous People Astronomy Related Cultural Belief*, booklet by Mary Rose Dacula and Christian Eduard G. Demegillo (2018)
  - "The ethnoastronomical study of the Dumagat indigenous people" by Mary Rose Dacula and Christian Eduard G. Demegillo

From a review of the literature, it would appear that the negrito group least likely to still exist in a genetically pure form would be the Ata of Negros. By the 1950s only a handful could be found (see Rahmann and Maceda, 1955).

The Ata aside, the Philippines offers a veritable treasure trove of negrito ethnoastronomical projects, and it will not be enough to document, compare and contrast the astronomical beliefs and practices of each of the major ethnic groups represented in Fig. 2.29. In addition, we suspect that studies of the Aeta and the Agta will reveal regionally-discrete astronomical systems, given the geographical spread of both ethnic groups, but especially the Agta, and the fact that where different Aeta ethnic groups have been sampled genetically, their signatures are not always identical (e.g. compare Figs. 2.32 and 2.33). Moreover, as Reid (2013) notes, the languages spoken by some of the Agta differ significantly from those spoken by other Agta, even those living nearby. Will we see this reflected in their astronomical systems? Clearly, a seemingly endless succession of exciting ethnoastronomical research projects await …

2.6.4 The Philippines and Taiwan: Exploring Ancestral Austronesian Astronomical Systems

As we have outlined above, the archaeological, linguistic and genetic evidence indicates that Austronesians settled in the Philippines from around 4000 BP. Over the following millennia we can anticipate that significant changes took place in the astronomical systems of the indigenous Taiwanese, and also of those Austronesian groups that chose to remain in the Philippines, particularly as they shared genes with the original occupants (the negritos).

Given the passage of time, is there any remaining evidence of the ancestral astronomical system that was introduced to northern Luzon around 4000 BP? Thanks to genetic evidence, we now have a chance to investigate this. While several studies document the genetic links between Taiwan and the Philippines, one paper in particular stresses the special place of the Kankanaey ethnic group in northern Luzon:

> At K=9, the majority of Kankanaey ancestry is in the k6 component, which they share as the predominant ancestry component with the Ami[s] (AX-AM) and Atayal (AX-AT) from Taiwan and, hence, is putatively associated with the Austronesian expansion … the Kankanaey can be considered as a good reference population for further analyses of the ancestry component that is specific to Austronesian populations …
>
> The affinity of the Kankanaey to the Ami[s] and Atayal of Taiwan was supported by the TreeMix (Pickrell et al., 2012) analyses of 25 populations (Figures S5-S6) where the Kankanaey did not cluster with the other Filipinos but rather formed a clade with the Taiwanese aboriginal groups …
>
> In this study we have identified the Kankanaey from the northern Philippines as the population harboring the highest reported amount of the Austronesian genomic component, even higher than the ones detectable in modern aboriginal Taiwanese … (Mörseburg et al., 2016).

The locations of the two Taiwanese Aboriginal ethnic groups mentioned above are shown in Fig. 2.37.

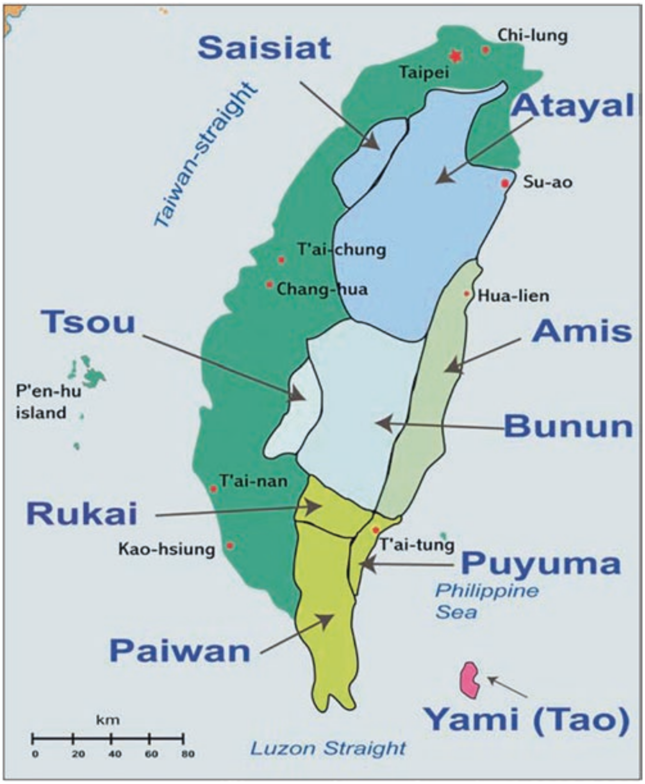

Fig. 2.37 A map of Taiwan, showing the territories of the Atayal and Amis Aboriginal tribes (after Trejaut et al., 2005: 1363).

The Kankanaey ethnic group is found in northern Luzon, and as Fig. 2.33 shows genetically is rather similar to the neighbouring Ifugao ethnic group that was not sampled by Mörseburg et al. (2016). This raises the likelihood that it, too, may also have a pristine Austronesian gene sequence. If this is the case then these two ethnic groups may provide an indication of the ancestral astronomical system that was introduced from Taiwan 4000 years ago. Princes Ilagan and Paulo de Mesa have already carried out preliminary fieldwork with the Kankanaey, and will expand this when the opportunity arises.

Meanwhile, in 2017 the distinguished Japanese astronomical historian and Southeast Asian expert Dr Yukio Ôhashi (Fig. 2.38) published a research paper titled “Astronomy of Taiwanese Austronesian people” (Ôhashi, 2017), which was based on books, papers and reports by Japanese anthropologists, mostly written between 1913 and 1935. This contained information on calendars, constellations, the Sun, the Moon, eclipses, comets and selected stars.

Upon learning of the aforementioned paper by Mörseburg et al. (2016), the first and last authors of this chapter planned to set up a collaboration with Ilagan, de Mesa and Ôhashi in order to carry out a comparison of the Taiwanese and Kankanaey astronomical systems, but unfortunately Dr Ôhashi died unexpectedly on 31 October

Fig. 2.38 Dr Yukio Ôhashi, 1955–2019, in December 2016 (after Orchiston and Nakamura, 2020: 209).

2019 before this project could be launched. We would still like to carry out this project when funding becomes available and international travel is once more possible.

As a final aside for this Sub-section we note that the University of the Philippines prehistorian Dr Alfred Pawlik (2017) has summarised the accumulated archaeological evidence for Austronesians in the Cagayan Valley in far northern Luzon. He reports that there are five archaeological sites with the distinctive red slip pottery, all dating between about 4 kyr and 3.6 kyr, and although all of these sites contain plant residue, there is no evidence of rice farming. He suggests that "Rice farming might have been viable only after 2500 BP when shorter more frequent El Nino–Southern Oscillations (ENSO) occurred" (*ibid.*; cf. Bulbeck, 2008). Pawlik (2017) also suggests that the Taiwanese Austronesians made multiple migrations to the Philippines, starting around 4 kyr, and the existence of Austronesian sites in the Batanes Islands (Bellwood and Dizon, 2005, 2008) may support this. Yang et al. (2011) found evidence of an increase in rainfall in the Taiwan region from around 4.2 kyr, indicating a strengthening of the East Asian summer monsoon, while Fig. 2.9 suggests that there also were persistent drought conditions from 4 kyr onwards. Taiwan was an island with a finite habitat, so we wonder if these continuous unpredictable climatic conditions triggered some, even most, of these Austronesian migratory episodes.

2.6.5 The Evolving Astronomical System of the Palawan Negritos During the Holocene

As Gordon and Grimes (2005) point out, currently there are more than 170 recognized ethnolinguistic groups in the Philippines, and the negritos comprise only 12% of these. We need to study the astronomical systems of many of these non-negrito

Fig. 2.39 The island of Palawan and other nearby islands, showing the traditional habitat of the Batak negritos, locations mentioned in this chapter, and the capital city, Puerto Princesa (map modification: Wayne Orchiston).

ethnic groups, but the challenge is overwhelming—even on a long-term basis—as there are simply so many of them. While individual groups can be selected for their special research potential, as with the Kankanaey and the Taiwanese Austronesians mentioned above, the best approach—in the short term—is to incorporate selected non-negrito groups in regional studies of negritos. This can be done on an island-by-island basis, selecting those non-negrito ethnic groups known to have had varying degrees of gene-sharing with their neighbouring negrito populations. The island of Palawan (Fig. 2.39) is an ideal starting point in this regard. Now, just 425 km long and 40 km maximum width, Palawan was the closest of all of the Philippine islands to Sundaland and lies between Mindoro and Borneo.

Palawan certainly was one of the access routes (if not the only one) that was used by the Australo-Melanesians to migrate from Sundaland to the Philippine region, and now is home to negrito (i.e. Batak) and non-negrito indigenous populations. Over the past century Batak culture has changed immeasurably, and most Batak who try to maintain a 'traditional' lifestyle now combine slash-and-burn agriculture with rain forest hunting and gathering. During this period, there also has been extensive intermarriage between the Batak and non-negrito ethnic groups in Palawan.

Scholes et al. (2011: 62) were very aware of these obstacles when they conducted research on Y-chromosome and mtDNA characteristics of the Batak and non-negrito groups in Palawan. They were able to show that

> … the Batak are genetically distinct from Negritos of the Andaman Islands and Malay Peninsula and instead bear most resemblance to geographically proximate Philippine Negritos and to non-Negrito populations from the Philippines and Island SEA. An extensive degree of recent admixture between the Batak and their neighbors is indicated by the high frequency of recently coalescing haplogroups in the Batak that are found throughout Island SEA. The comparison of results from these two loci further lends support to the hypothesis that male-biased admixture has, in particular, been a prominent feature of the interactions between the Batak and surrounding non-Negrito populations.

As we have already seen, this finding in respect of the Batak and the Malay and Andaman negritos is supported by other studies. Of all the Philippine negritos groups the Batak are closest to the Iraya of Mindoro, which also are their nearest negrito neighbours.

Jinam et al. (2017) included the Batak in their genetic study of Southeast Asian negrito groups (see Fig. 2.40). They found that the Batak were very similar to the Agta (from the far north of Luzon—see the Fig. 2.36 distribution of Agta groups),

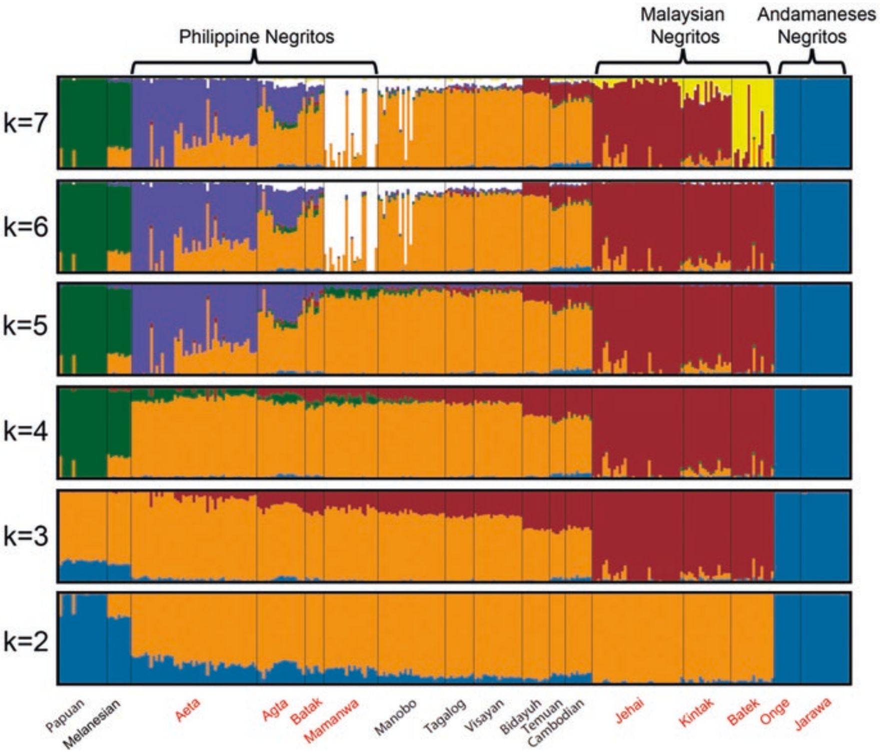

Fig. 2.40 Genetic signatures of Andaman, Malay and Philippine negrito groups (after Jinam et al., 2017: 2017).

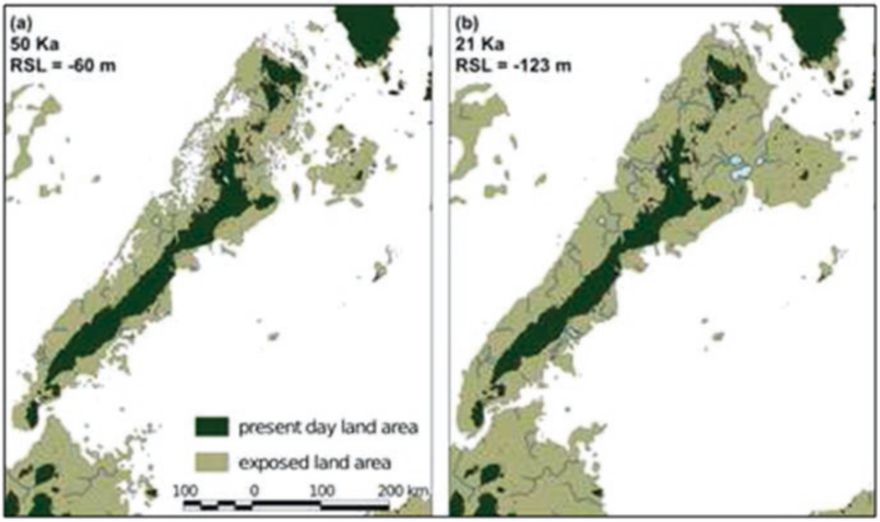

Fig. 2.41 Reconstructions of the shorelines of Greater Palawan at 50 kyr and 21 kyr (after Robles et al., 2015: 8).

similar to the Aeta, had some features in common with the Mamanwa, but differed markedly from the Malay and Andaman negritos. Jinam et al. (2017: 2018) also noted that all four Philippine negrito groups had a small Denisovan component in their genes.

The Batak have lived on Palawan for 60,000 to 70,000 years and first arrived when the sea level was lower and the island was nothing like its present-day appearance. Fig. 2.41(a) provides a reasonable approximation of the land area at this time. With seas falling Greater Palawan (Heaney, 1985) continued to expand, and by 22,000 BP, during the Last Glacial Sea Level Low, it included what are now Busuanga Island, Culion Island and Linapacan, and stretched almost to the island of Mindoro. Yet as Fig. 2.41(b) reveals, Greater Palawan did not serve as a direct land bridge from Sundaland to the Philippines as a successful water crossing of ≥13 km had to be made in order to get from Sundaland to Greater Palawan, and then from Greater Palawan a series of island-hopping episodes were required to eventually reach Mindoro. But the journey did not end there for another challenging water-crossing was required to paddle or sail by canoe, or drift by raft, from Mindoro to Luzon. Between 4000 and 3000 BP, after the present shores of Palawan were established, the Batak were joined by Austronesian settlers, and they now share the island with the descendants of these people and, as Scholes et al. (2011) have documented, have also shared their genes.

In any survey of the astronomical systems of Palawan's indigenous populations we must seek to explain differences that are found in their astronomical systems. We anticipate that the astronomical systems of the Batak will be found to differ from those of their non-negrito neighbours in a number of significant ways given the

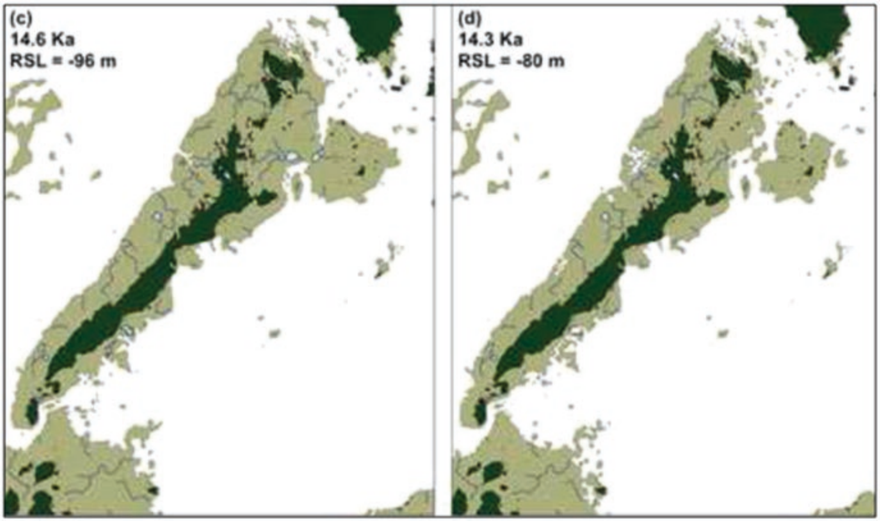

Fig. 2.42 Reconstructions showing major changes in Greater Palawan between 14.6 kyr and 14.3 kyr (after Robles et al., 2015: 8).

different histories of the two groups on the island. The Batak alone experienced the last glacial when the seas were 125 metres below their present levels, and temperatures between 23,000 and 18.000 BP were 2°–3.5° cooler than at present (Rosenthal et al., 2003). These cooler temperatures and drier conditions favoured open grassland and sparsely-wooded savannah in the Palawan region (Bird et al., 2007). At this time rain forests still existed in Greater Palawan, but mainly were restricted to mountain refugia, especially in the south of the island.

The Batak alone also experienced the rapid sea level rise from 18,000 BP, when temperatures and rainfall began to increase (Partin et al., 2007), leading to expansion of the rainforests and a concomitant rapid disappearance of Greater Palawan. Over the centuries the sea rose relentlessly, drowning former human habitants and eventually forming Busuanga Island, Culion Island, Linapacan, and—of course—present-day Palawan. Robles et al. (2015) show how the coasts of Great Palawan changed continuously over this time interval, and that *major* changes could take place in the appearance of northern Great Palawan within just a few hundred years c.f. Figs. 2.42(c) and 2.42(d)).

The seas continued to rise, further land was flooded, and by 9000 BP the west coast of Palawan was fringed by an almost continuous string of small islands, reminiscent in many ways of Australia's present-day Great Barrier Reef (see Fig. 2.43(g)). By 6000 BP, when the present coast line was established (Fig. 2.43), Greater Palawan had "… lost more than 80% of its area through Holocene sea level rise, and the vast coastal plains that once existed to the east and west of the central mountainous spine are all now submerged." (Robles et al., 2015: 17). But rain forests were widespread, and mangrove forests were established along some sections of coast

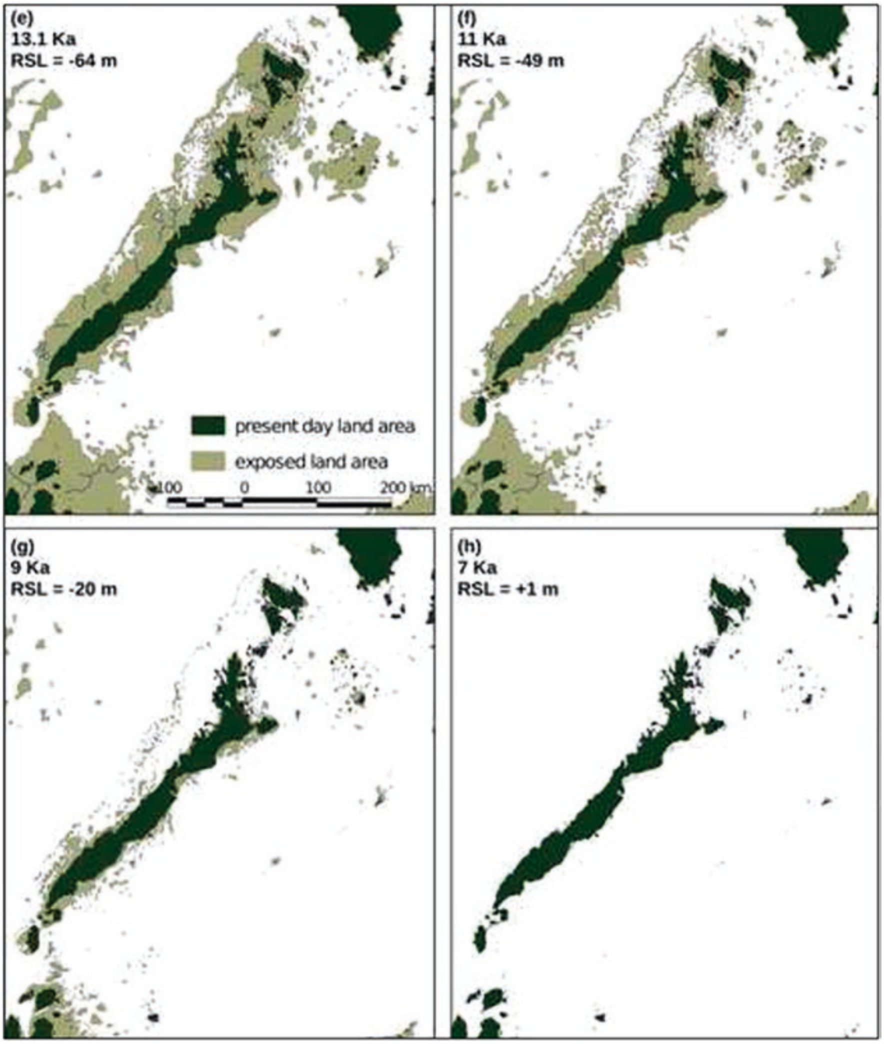

Fig. 2.43 The changing nature of Palawan between 13.1 kyr and 7 kyr (after Robles et al., 2015: 8).

(see Berdin et al., 2003), thereby providing rich environments for negrito hunter-gatherers.

It was only a couple of thousand years after the present sea level was reached that the negritos had to contend with the arrival of Austronesian newcomers to the island. They were accompanied by domesticated dogs and pigs, and grew crops, so they needed fertile land near rivers and the coast. These newcomers also brought a new language—which the Batak decided to adopt—and a new astronomical system (or systems). How much of this newly-introduced astronomical base did the Batak choose to assimilate with their own traditional beliefs, especially once they also began to combine hunter-gathering with slash-and-burn horticulture? Hopefully, fieldwork will provide an answer to this question, once the basic parameters of the Palawan non-negrito astronomical systems have been delineated.

In order to investigate possible changes to the Batak astronomical system in prehistoric times, prior to the arrival of the Austronesians, we must examine the Palawan archaeological record and see if we can identify any major ecological changes that were of such importance that the Batak may have responded by modifying their astronomical systems. Such an archaeological analysis must rest primarily on evidence from the following four sites (shown in Fig. 2.39): Giri Cave (Piper et al., 2011), Ille Cave (Lewis et al., 2008; Ochoa et al., 2014; Paz et al., 2008; Piper et al., 2011), Pasimbahan Cave (Ochoa et al., 2014) and Tabon Cave (Corny et al., 2015; Détroit et al., 2004; Dizon et al., 2002; Fox, 1970; Lewis, 2007). To this archaeological evidence can be added the detailed ethnobotanical study reported by Xhauflair et al. (2017). Although it relates specifically to Mount Mantaligahan in southern Palawan and to the Pala'wan non-negrito ethnic group, the ways in which the Pala'wan utilised the rain forests are surely a valuable guide to the Batak exploitation of this important resource in prehistoric times.

2.6.6 Negritos and the Indigenous Astronomical Systems of Mindoro

Mindoro is one of the larger Philippine islands, and is located between Luzon and Palawan, and to the west of Panay. The presence of negritos on Mindoro indicates that the Australo-Melanesians had adequate maritime technology to settle this island in Pleistocene times, as it never was connected to 'Greater Palawan', to 'Lusanao' or to 'Greater Panay-Negros' even at times of lowest seał level (see Fig. 2.44). Mindoro always remained isolated and retained its identify as a solitary island, and until historical times it only witnessed the arrival of two principal settlement populations, the negritos, between 70,000 BP and 60,000 BP and the Austronesians, around 4000 BP. Hopefully, archaeological research will provide a clearer indication of the initial negrito and Austronesian settlement dates.

Ethnographic data indicate the current presence of seven discrete ethnic groups on Mindoro, collectively referred to as the 'Mangyan Tribes', but each with its own designated territory (Fig. 2.45). Genetically, they also differ, for the northernmost of these Mangyans are the Iraya negritos, while the other six ethnic groups, although mainly of Austronesian origin, exhibit varying degrees of gene-mixing. This is very apparent from photographs that a quick web search will reveal, and the problem we had in trying to source a suitable (non-copyright) photograph to include in Fig. 2.30(b)—indeed, most of those in this picture do not appear to be typical negritos (and it is interesting that Reid (2013) discussed the Iraya but decided not to include them in his distribution map of Philippine negritos). This extensive visual evidence of gene-sharing is supported by limited genetic studies.

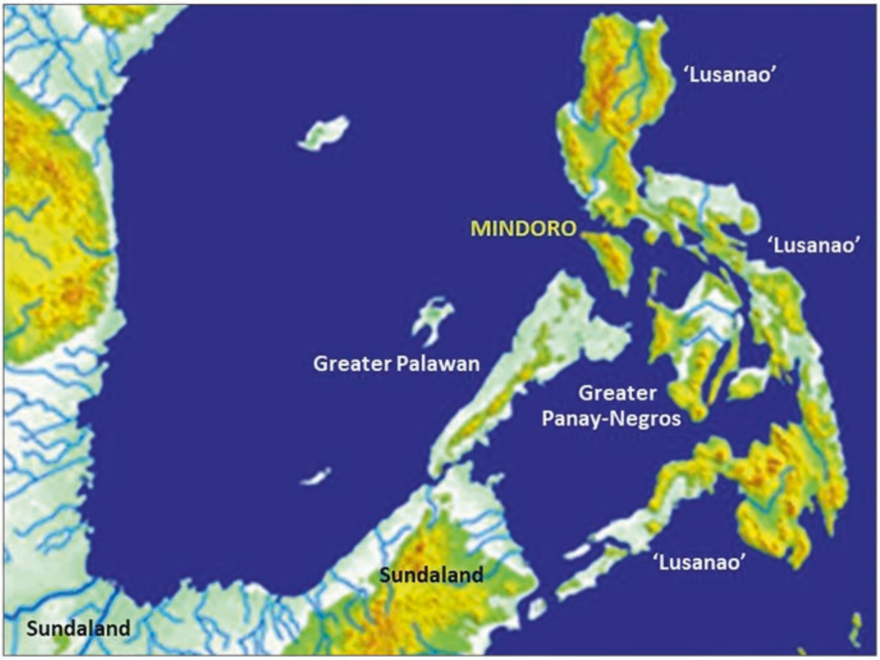

Fig. 2.44 A map showing the location of Mindoro and other land masses at 22,000 BP, the time of the Last Glacial Sea Level Low (map modifications: Wayne Orchiston).

For example, in their Y-chromosome study of Philippine ethnic groups, Delfin et al. (2011) include pie charts for the Iraya, Tadyawan, Tau-buid and the Hanunoo (see Fig. 2.32). They show that the Iraya differ significantly from the Aeta and from the Agta population that they sampled (i.e. from the second-most southerly of all the yellow circles shown in Fig. 2.36), and also from the Mamanwa. This reflects the genetic isolation of the Iraya from other negrito groups once they settled on Mindoro. The three Mindoro non-negrito groups researched by Delfin et al. (2011) exhibit marked genetic heterogeneity, as reference to Fig. 2.32 quickly reveals. The Tadyawan have a genetic make-up that is totally unlike any other recorded in the Philippines, with an extremely high incidence of the O-M100 haplogroup, while the neighbouring Tau-buid have obviously shared some of their genes but also acquired the O-M122 haplogroup from the Iraya. But of all the Mindoro ethnic groups sampled, the Hanunoo from the very south of the island have a more heterogeneous genetic make-up than any of the others, with genes deriving from all three. However, their closest Philippines correlate would appear to be the Bataan Aeta from Luzon, which also have a high incidence of the K-M9 haplotype. Perhaps the Hanunoo originally had settled in Luzon, following the Austronesian arrival in the Philippines, and they interbred with the Bataan Aeta before migrating to Mindoro, where they also inherited the distinctive O-M122 haplogroup from the Iraya. Conversely, Fig. 2.34 shows that the Iraya have a greater Austronesian gene count than any other

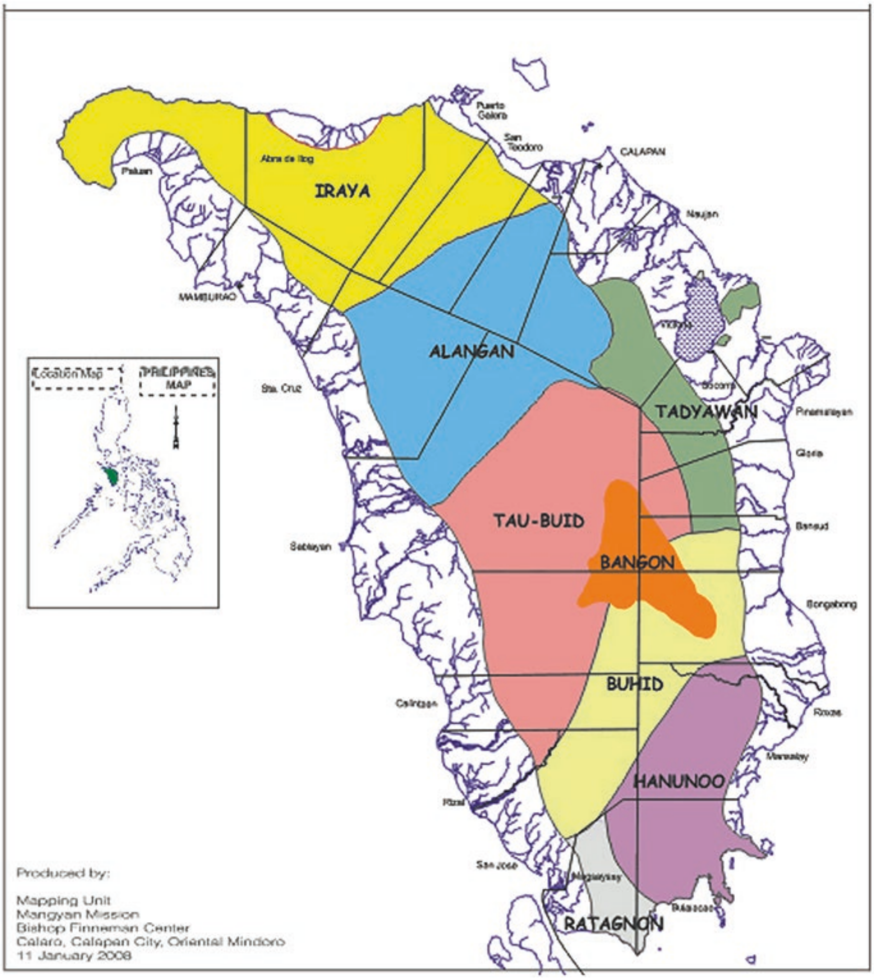

Fig. 2.45 A map showing the Mangyans (indigenous groups) of Mindoro, including the Iraya negritos (http://www.mangyan.org/book/export/html/60).

Philippine negrito group. It will be interesting to see if the astronomical systems of Mindoro's non-negrito ethnic groups reflect the inhomogeneity of their genetic histories, or merely show a simple mix of negrito and Austronesian elements.

We know that Australo-Melanesian hunter-gatherers were the sole occupants of Mindoro for much of its human history so any archaeological sites older than 4000 BP must relate to them. Currently the University of the Philippines is involved in a long-term archaeological research project on Mindoro (see Pawlik, 2017; Pawlik et al., 2014; Porr et al., 2012) that has revealed the existence of a number of archaeological sites on Mindoro itself and two small off-shore islands (Fig. 2.46). Most sites have not been dated so we do not know if they are associated with

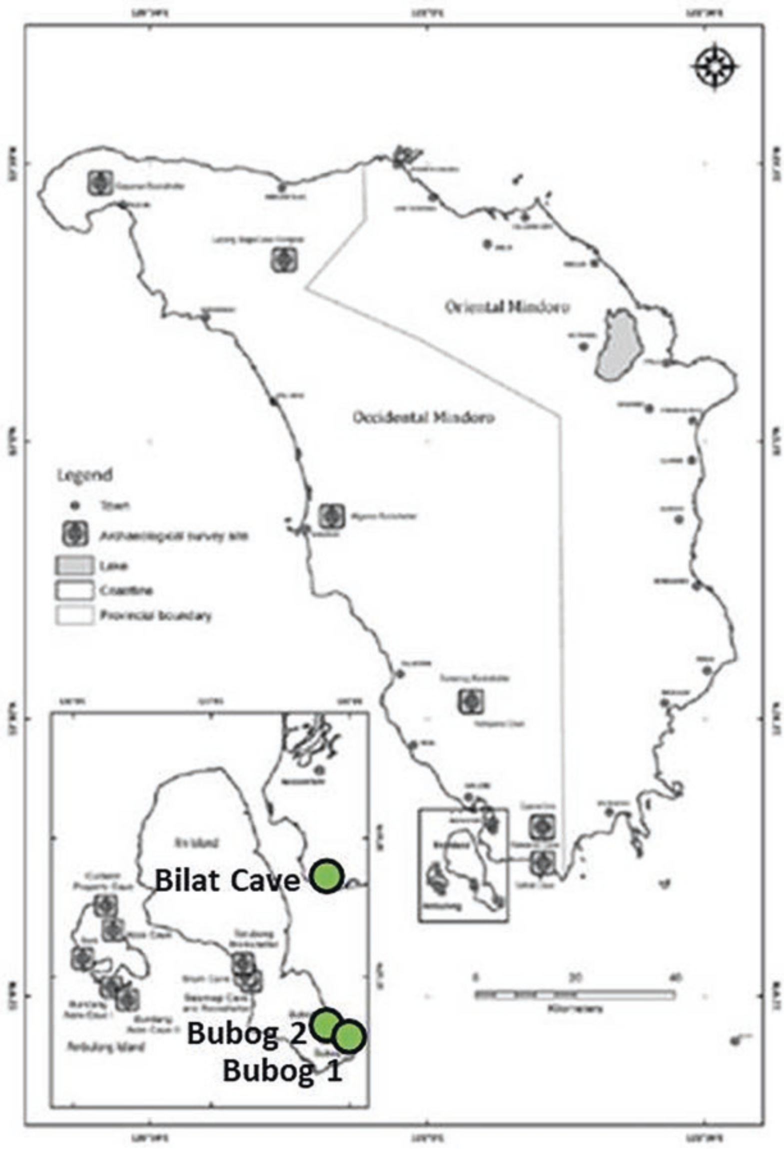

Fig. 2.46 Known archaeological sites on Mindoro and adjacent off-shore islands (after Porr et al., 2012: 111; map modification: Wayne Orchiston).

negritos or the island's more recent non-negrito populations, but Bilat Cave near the southern tip of Mindoro and Bubog 1 and Bubog 2 on nearby Ilin Island have basal occupation levels dating to around 21,500, 30,000, and 9,000 BP respectively, all proof that the negritos were resident in Mindoro at least by 30,000 years ago and that they certainly were not restricted only to the northern sector of island (as is currently the case).

Unlike the Batak, who witnessed the wholesale disappearance of Greater Palawan between 22,000 BP and 6000 BP and had to adjust their ecological strategies accordingly, because of its plunging shoreline very little additional land was exposed around the coasts of Mindoro during the Late Pleistocene when seas were 120 m below present levels so the post-glacial sea level rise caused few changes to negrito habitat. Having said that, like their Palawan cousins the Mindoro negritos would have had to respond to the climatic changes that occurred between 22,000 BP and 6000 BP. The increased rainfall caused rain forest to replace savannah, leading to changes in the relative abundance of different fauna, which in turn led to revised negrito hunting strategies. Subsequently, in a few localised coastal areas of Mindoro, the negritos also had to adjust their human ecology as sea levels closed in on current levels by substituting a marine-oriented strategy for one that focussed increasing on coastal and particularly mangrove resources.

However, we suspect that the greatest challenge for the negritos came when Austronesians decided to settle on Mindoro and some (perhaps many) negritos groups had to relocate, moving from hospitable coastal localities into the mountains, where rain forests called for new exploitation strategies. Some negrito groups also had to decide whether to develop slash-and-burn horticulture as part of their ecological strategy. If these are the types of changes that did occur, how many of them are reflected in the current astronomical systems of the Mindoro negritos? In this regard, Mindoro may prove to be a remarkable ethnoastronomical field laboratory.

2.6.7 The Indigenous Astronomical Systems of Mindanao

If Mindoro can described as a potentially "remarkable" ethnoastronomical field laboratory, then Mindanao—the most southerly of the main islands of the Philippines (see Fig. 2.47)—is nothing short of unbelievable. On this one island we have the potential to research the astronomical systems of

(1) a negrito group (the Mamanwa);
(2) an Austronesian group with substantial negrito genes (the Manobo);
(3) an Austronesian group with less evidence of negrito gene-sharing (the Surigaonon);
(4) an Austronesian group with minimal negrito gene-sharing (the Maranao), and explore the extent to which Islam altered the previously-established indigenous astronomical system;
(5) neighbouring Maranao Islamic fishing and farming communities to see if they differ significantly from one another;
(6) Islamic coastal fishermen of Mindanao to see whether they contain any elements of traditional Malaysian or Indonesian astronomical systems.

No other island in the Philippine archipelago contains the potential to conduct such wide-ranging research, and fortunately there is a relative wealth of genetic information about different ethnic groups in Mindanao, which provides us with excellent background material for most of the research projects listed above.

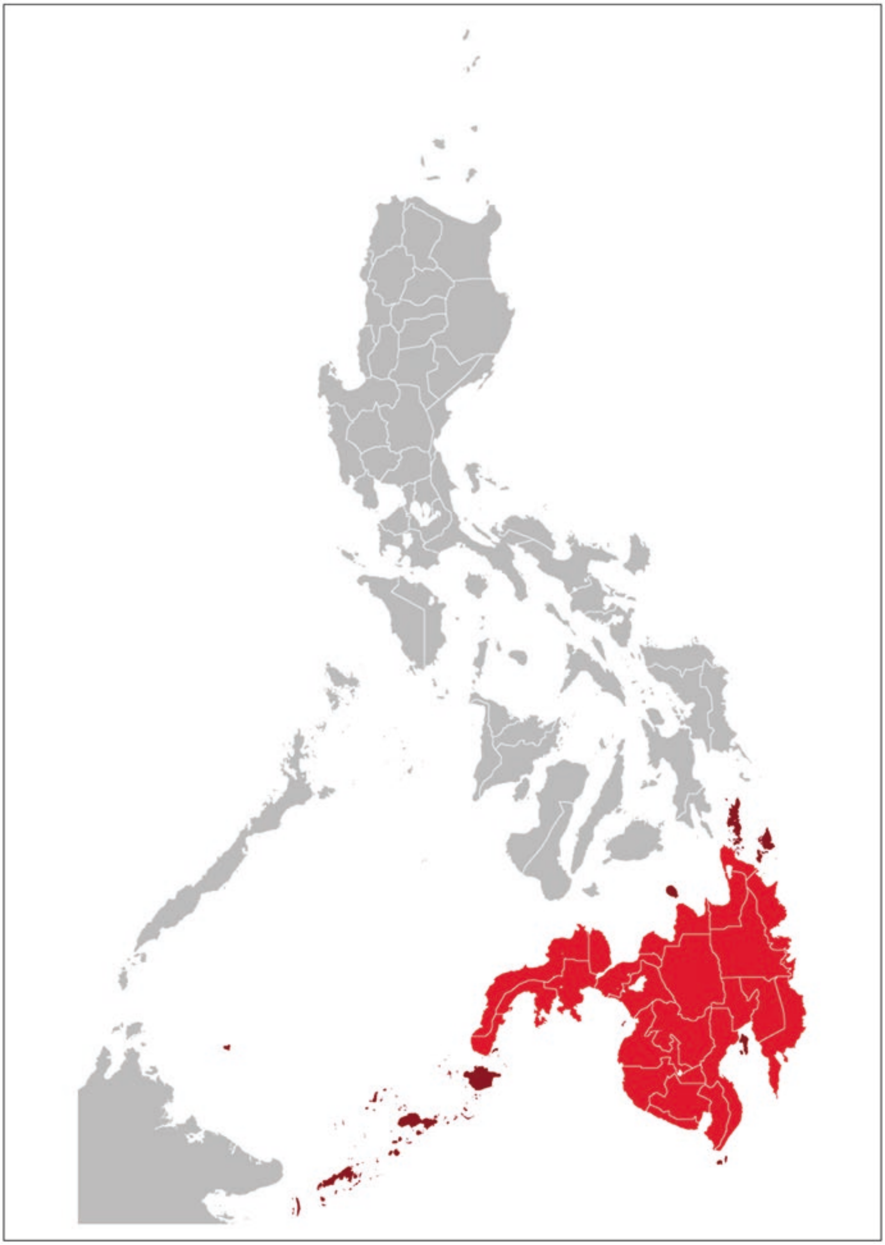

Fig. 2.47 A map of the Philippine archipelago showing Mindanao in red (https://en.wikipedia.org/wiki/Mindanao).

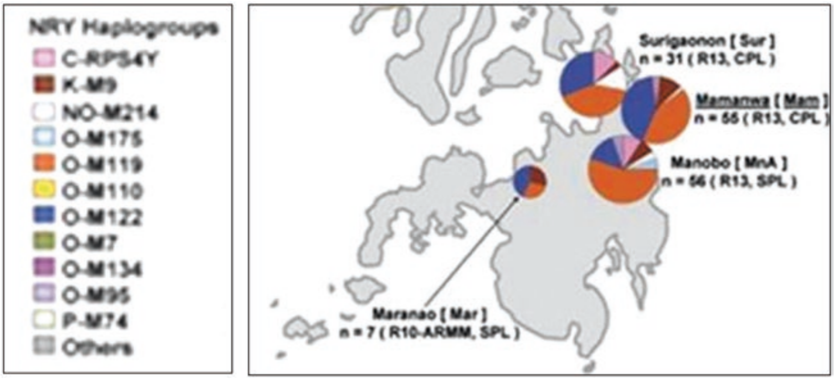

Fig. 2.48 Genetic differentiation of different Mindanao ethnic groups based on Y chromosome data (adapted from Delfin et al., 2011: 225).

For example, Delfin et al. (2011) studied the Y chromosome genetic signatures of the Mamanwa negrito group and three non-negrito Mindanao ethnic groups, and their results are shown in Fig. 2.48. The most conspicuous feature of this diagram is the high degree of gene-sharing that occurred between the Mamanwa and the Manobo. The only noticeable difference is that the NO-M214 haplogroup is not present in the Mamanwa sample, but there is a small percentage in the Manobo sample. Meanwhile, this same haplogroup is well represented in the Surigaonon ethnic group. And the prominence of the O-M119 and O-M122 haplogroups in the Mamanwa, Manobo, Surigaonon and Maranao pie charts and the presence also of the K-M9 haplogroup indicates that some gene-sharing occurred between all four groups.

Subsequently, Delfin et al. (2014) followed up with an mtDNA study of the same ethnic populations as shown in Fig. 2.48, and came up with similar findings: the heterogeneity of all four Mindanao ethnic groups. This is indicated in Fig. 2.33, above.

Gunnarsdóttir et al. (2011) also studied the mtDNA of the Mamanwa, Manobo and Surigaonon ethnic groups, and they also found that all three exhibited marked heterogeneity plus evidence of gene-sharing. If we refer to Fig. 2.49 we can see that the Mamanwa stand out because of the high incidence of the N* haplogroup (35.9%), which is also shared, but in a small percentage by the Manobo (2.3%). The Manobo, however, are characterised by a relatively high incidence of the M7c3c haplogroup (18.6%), although this is represented in smaller values in the pie charts of the other two ethnic groups (5–7%). Finally, the Surigaonon have a much higher presence of the B4b1a2 haplogroup (29.6%), although it, too, is found in the genetic signatures of the Mamanwa (15.4%) and the Manobo (4.7%). Referring to the anomalously high frequency of the N* haplogroup in the Mamanwa, Gunnarsdóttir et al. (2011: 8) note that "The estimated divergence time of this haplogroup is ~55,000–60,000 yr ago, implying that the ancestors of the Mamanwa may have become isolated from the ancestors of the other Filipino groups at about this time." Meanwhile, Soares et al. (2008: 1209) comment on the presence of E haplogroups, which "… evolved in situ [in Southeast Asia] over the last 35,000 years and expanded dramatically throughout

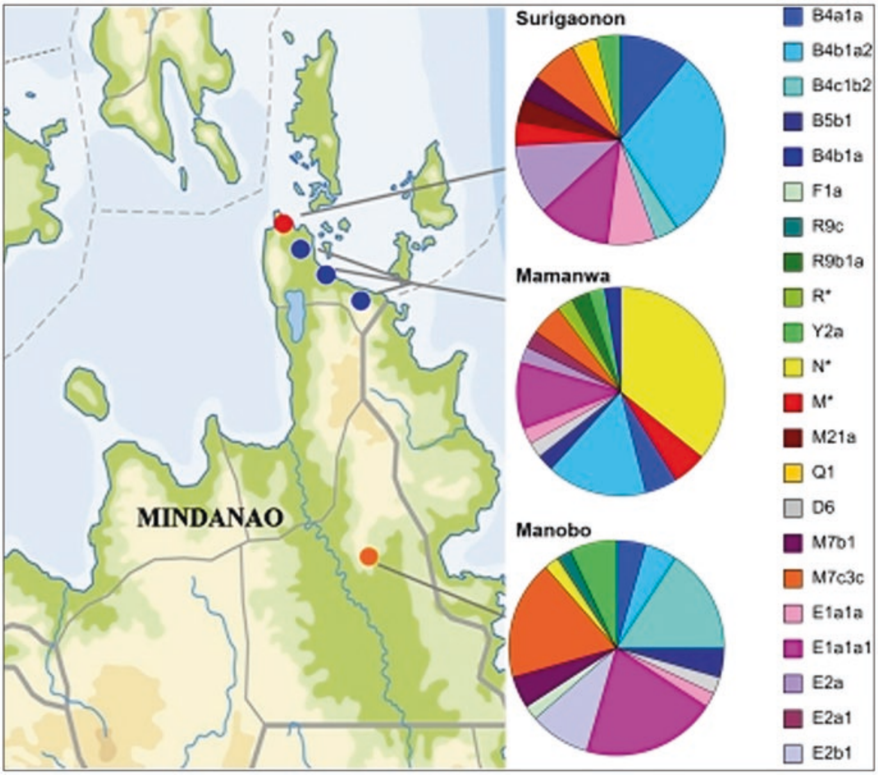

Fig. 2.49 A map of sampling locations and mtDNA haplogroup frequencies for the three North Mindanao Filipino groups in this study (adapted from Gunnarsdóttir et al., 2011: Figure 3).

ISEA around the beginning of the Holocene, at the time when the ancient continent of Sundaland was being broken up into the present-day archipelago by rising sea levels."

In Fig. 2.50 Jinam et al. (2017) provide another way for us to visually compare and contract different ethnic groups from the Philippines, including the Mamanwa, Batak, Agta and Aeta negrito groups, and the Manobo non-negrito ethnic group from Mindanao. In this diagram, we can see that among the negrito groups the Mamanwa is unique genetically, and that its closest genetic ties lie with its next door neighbours, the Manobo.

Armed with this dossier of genetic information about most of the ethnic groups of Mindanao that we wish to investigate, we can start by comparing and contrasting the astronomical systems of the Mamanwa, Manobo and the Surigaonon. As by far the longest surviving inhabitants of Mindanao, the Mamanwa should have the most authentic ancestral astronomical system, and it will be important to compare and contrast it with the astronomical systems of the Batak, and especially the Ati and Ata negrito ethnic groups of Panay and Negros (who are rarely represented in genetic studies of indigenous groups in the Philippines). It will also be interesting to compare and contrast the Mamanwa astronomical system with that revealed by the two most easterly settlements in the chain of Agta sites shown in Fig. 2.36 (note that

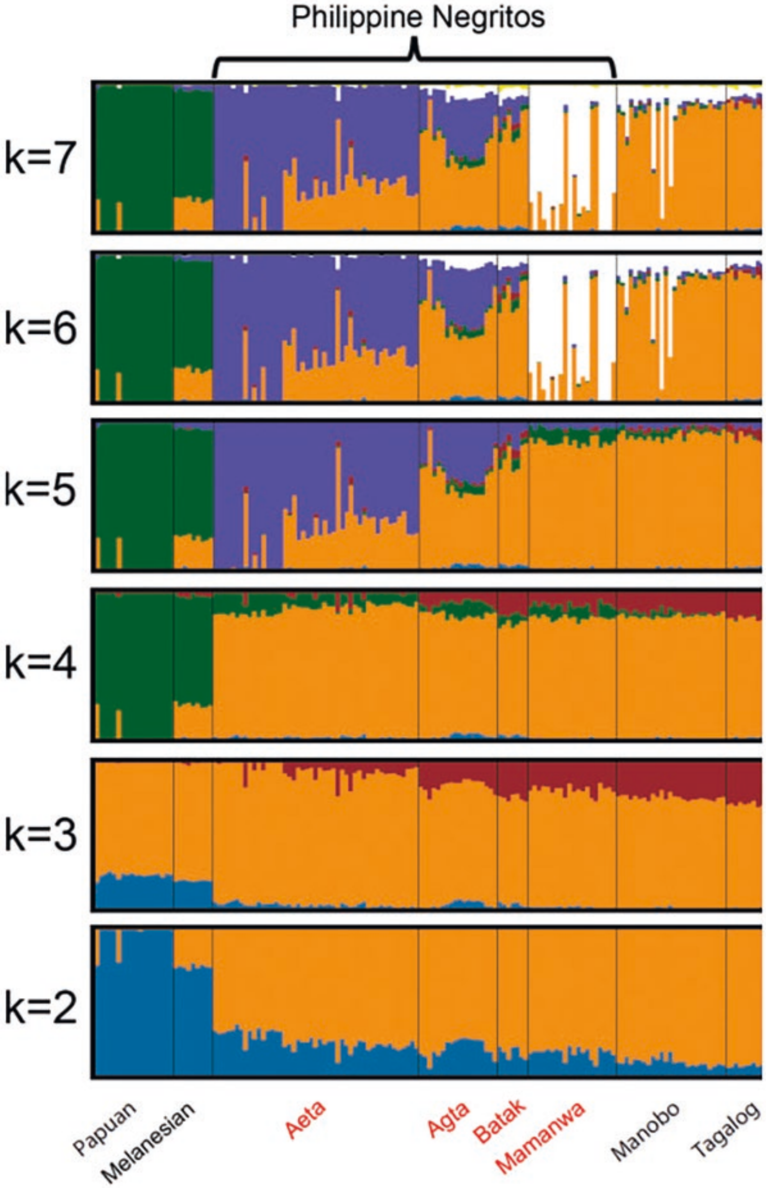

Fig. 2.50 A comparison of the genetic signatures of the Aeta, Agta, Batak and Mamanwa negrito groups and the Manobo non-negrito ethnic group from Mindanao, showing similarities between the Mamanwa and Manobo (adapted from Jinam et al., 2017: 2017).

the Agta data shown in Figure 2.501 derive from the far end of this Agta chain of sites, at the northern tip of Luzon). Given that Luzon, Samar, Leyte, Bohol, Dinagat, Siargao and Mindanao were all linked, forming one major island we have termed 'Lusanao' at the time of the 20,000 BP sea level low, and that most of these current islands also were linked at earlier times in the prehistoric past, it is reasonable to assume that Australo-Melanesians were living throughout this entire area prior to the arrival of the Austronesians, and that astronomical systems of the Mamanwa were closely aligned to some of these 'missing' people.

When conducting ethnoastronomical fieldwork in Mindanao it also will be important to anticipate that the astronomical systems of the Mamanwa, Manobo and Surigaonon will exhibit 'cultural sharing' given the extensive gene-sharing that has occurred among these three ethnic groups, so it will be important to identify a number of ethnic groups that likely contain more pristine Austronesian astronomical systems and to use them to 'calibrate' the Mindanao systems. On the basis of accumulated genetic evidence (see Fig. 2.33), it is most likely that the Kankanaey and Ifugao in northern Luzon have pristine Austronesian astronomical systems.

The role of Islam in modifying traditional astronomical systems is a field in which research has already been initiated by one of the authors of this chapter and his students (e.g. see Guido et al., n.d.), and it is important that this work is expanded in an attempt to differentiate the current astronomical systems of the different fishing and farming communities around and near Lake Lanao. On the basis of their surveys of Southeast Asia, Khairuddin and Jaafar (2021) and Jaafar and Khairuddin (2021) postulate that different astronomical systems will be found in association with these two very different ecological strategies.

Finally, Mindanao is close to the Indonesian island of Sulawesi, where the Bugis and the Mandar have been able to establish international reputations as maritime voyagers and traders (e.g., see Ammarell, 1999; Rasyid et al., 2021). If some of these voyages, or those of Malay traders and voyagers, took them to the shores of Mindanao, it will be interesting to see if any aspects of Malaysian or Indonesian maritime lore, and especially traditional astronomy, have been adopted by Mindanao fishermen and are now used by them.

2.6.8 Mine the Spanish Records for 'Astronomical Treasure'

2.6.8.1 Eclipses and Comets

A review of Espenak and Meeus' (2006) on-line *Five Millennium (–1999 to +3000) Canon of Solar Eclipses Database* shows that a great many paths of totality crossed one or more islands in the Philippine archipelago between 1999 BCE and CE 2015. However, the Philippines lie in the tropics and experience monsoonal weather, so not all of these eclipses would have been observed. What we can do though, is list those eclipses that occurred between CE 1521 and 1898 and check on how many of these were observed, or reported, by Western missionaries or others who chronicled

Table 2.2 Solar eclipses that occurred between CE 1521 and 1898 where the paths of totality crossed the Philippines (after Espenak and Meeus, 2006).

Date			
Year (CE)	Month	Day	Type of Eclipse*
1539	October	12	A
1604	April	29	A
1629	June	21	T
1637	January	26	A
1644	September	01	A
1655	August	02	T
1691	February	28	A
1698	October	04	A
1704	November	27	A
1774	September	06	A
1814	July	17	T
1817	November	09	T
1821	March	04	T
1828	October	09	A
1850	February	12	A
1861	July	08	A
1875	April	06	T

*A = Annular Eclipse; T = Total Eclipse

Philippine history and are recorded in Blair and Robertson's invaluable 55-volume work on the history of the Philippine islands, based mainly on Spanish Government and missionary records, and published between 1903 and 1909. This list of eclipses is given above in Table 2.2, along with the type of eclipse—whether total or annular (there were no hybrid eclipses in the sample). In all, 17 eclipses occurred (6 total and 11 annular), and maybe half of these would have been visible. By checking the individual paths of totality is should then be possible to identify different ethnic groups that could have seen a total or annular solar eclipse, and interview individuals in these groups to see if any have stories about these eclipses. Hamacher and Norris (2009) and Nunn and Reid (2016), among others, have shown that accounts of a significant scientific event, such as a meteorite impact or the post-glacial rise in sea level, can be passed down from generation to generation and faithfully preserved for thousands of years, so retaining oral histories of specific Philippine solar eclipses that occurred within the last 400 years should not be an issue.

2.6.8.2 Other Early Astronomical Records

While checking through the 55 volumes by Blair and Robertson (1903–1909) it would also be worthwhile looking out for reports of comets, lunar eclipses, novae, meteor showers and especially the 33-year Leonid meteor storms (Dick, 1998), and even meteorite impacts. During the sixteenth through nineteenth centuries there also

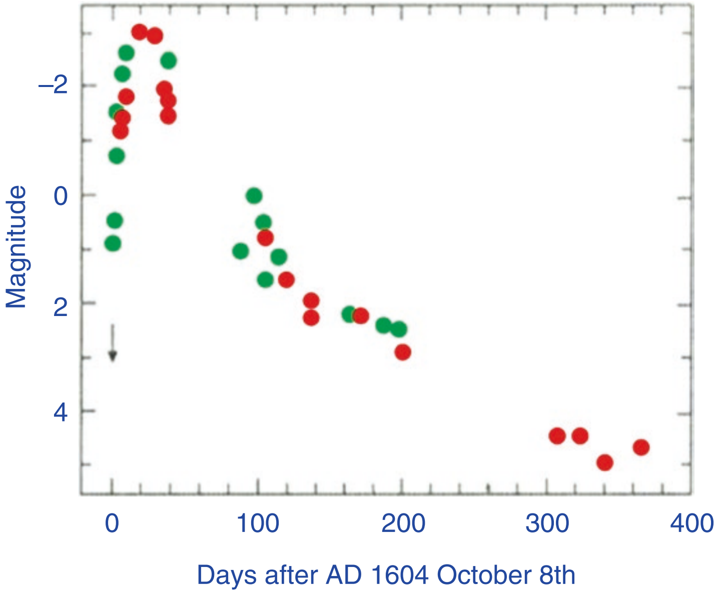

Fig. 2.51 The light curve of SN1604 based on European (red) and Korean (green) observations (adapted from Stephenson, 2004: 20; plot: Wayne Orchiston).

were Jesuit and other astronomers in India, Siam (Thailand) and Indochina, and by combining data from all available sources it may be possible to provide publishable accounts of some of these objects or events. Bright comets have particular appeal, and Kapoor (2011, 2015, 2016, 2019a, 2019b, 2019c, 2020) has already efficiently 'mined' the Indian Jesuit and Arabic records, plus twentieth century newspaper and other published records, for accounts of the Great Comets of 1577 (C/1577 V1), 1618 (C/1618 V1), 1618 (C/1618 W1), 1807 (C/1807 R1), 1811 (C/1811 F1), 1831 (C/1831 A1) and 1882 (C/1882 R1). It is to be hoped that accounts of some of these comets also will be found in Philippine records.

One other major astronomical event to look out for is any reported observations of the supernova of 1604. Located in Ophiuchus, SN1604 was visible to the naked eye for about one year from the time of its discovery in October 1604 (see Stephenson, 2004; Stephenson and Green, 2002), and it would have been clearly visible from the Philippines. The light-curve of the SN shown in Fig. 2.51 is based on a combination of European and Korean records. Note that there are two distinct gaps in this light curve with no observations, and it would be invaluable if Jesuit and other observations from the Philippines can help plug these.

2.6.8.3 First Astronomical Use of the Telescope in the Philippines

While searching for seventeenth century astronomical records in Blair and Robertson (1903–1909) it is also worth looking for the first recorded astronomical use of the telescope in the Philippine region.

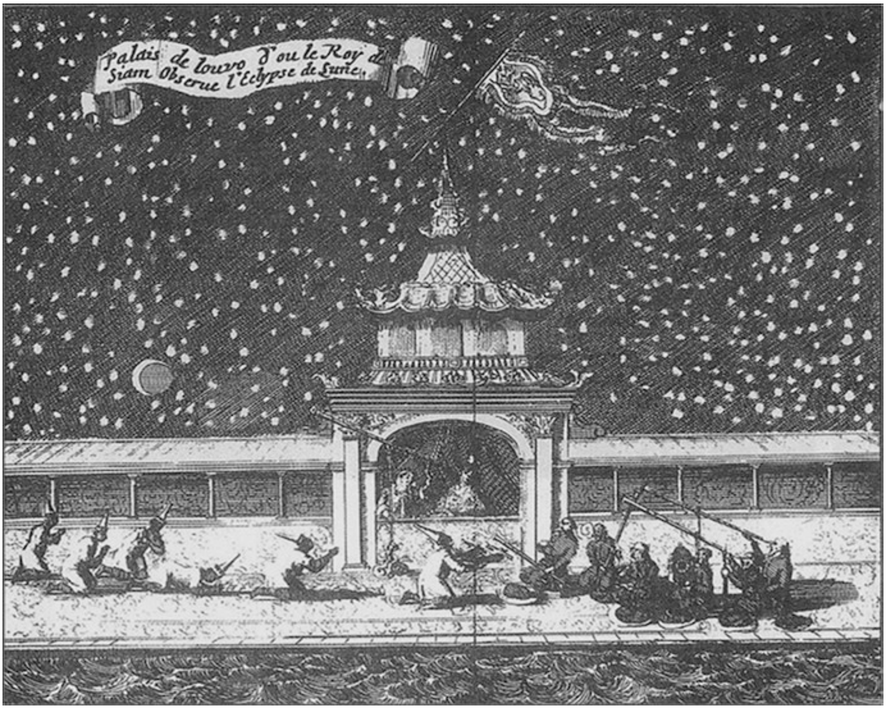

Fig. 2.52 A drawing showing King Narai (in the pavilion) and the Jesuit astronomers observing the 11 December 1685 total lunar eclipse from the King's country retreat, which was on an island in the water reservoir located to the northeast of his palace at Lop Buri, Siam (after Tachard, 1686).

During the second decade of the seventeenth century 'spyglasses' spread through the Dutch and Portuguese navies and also were acquired by the Dutch East India Company, and "The telescope or spyglass now became an essential piece of equipment for pilots, especially on long voyages …" (Sluiter, 1997). It would appear that Keplerian telescopes suitable for astronomical observations also became available at this time, and were favoured by Jesuit missionaries. The dates of their first appearance in different parts of the world varied greatly and this also appears to have been the case in Asia. Kapoor (2016, 2019a) has documented that in India the first astronomical use of a telescope (*tubo optico*) occurred in 10 November 1618 when it was used by a Jesuit missionary-astronomer to examine the head of one of the two Great Comets visible in the sky that same month, Comet C/1618 V1. On present evidence, this is the earliest use of an astronomical telescope in South or Southeast Asia, so we look forward with interest to seeing the date of its first use in the Philippines.

By comparison, the first astronomical use of a telescope in Siam occurred much later, on 11 December 1685, when French Jesuit astronomers and King Narai observed a lunar eclipse (Gislén et al., 2018; Orchiston et al., 2016). A painting purportedly showing this event, but in fact plagued with artistic license, is reproduced here in Fig. 2.52.

2.6.9 Manila Observatory

Spanish Jesuits were responsible for establishing Manila Observatory in 1865 (Fig. 2.53) as part of their nineteenth century quest to set up a world-wide network of observatories (Udias, 2003). So Manila Observatory joined the sister institutions Xujiahui and Shesan Observatories in Shanghai, China (Ning et al., 2017) and Riverview Observatory, in Sydney, Australia (Orchiston, 1985).

The primary function of Manila Observatory was to conduct research on and provide warning of cyclones. So the Observatory's initial function was meteorology, but astronomy and seismology later were added to the research portfolio. The astronomy rested on a 19-in (48.3-cm) refracting telescope (see Fig. 2.54), but Manila's cloudy skies severely limited the occasions when it could be assigned to observing, and by the time the Observatory and telescope were destroyed during World War II no enduring research of international importance had been achieved. Nonetheless, until the construction of Bosscha Observatory in the Dutch East Indies (present-day Indonesia) in the mid-1920, with its 24-in (60-cm) twin Zeiss refractor (see Hidayat et al., 2017), the Manila telescope was the largest refracting telescope in Southeast Asia. The astronomical research that was accomplished at Manila Observatory therefore deserves to be documented, as does the Observatory's substantial contributions in meteorology and seismology. It is heartening to know that this will soon happen, following the presentation of research papers at two different Southeast Asian conferences in February 2020 (Alvarez, 2020; Seitzer, 2020).

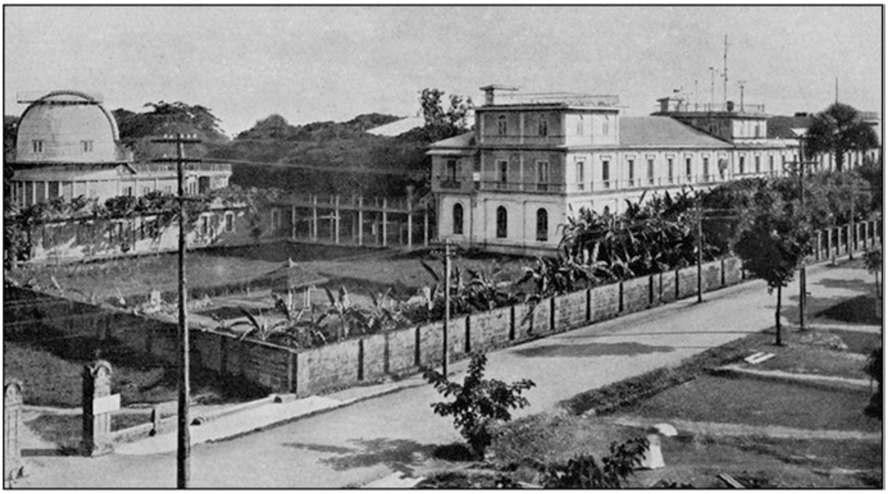

Fig. 2.53 Manila Observatory (courtesy: University of the Philippines, Diliman).

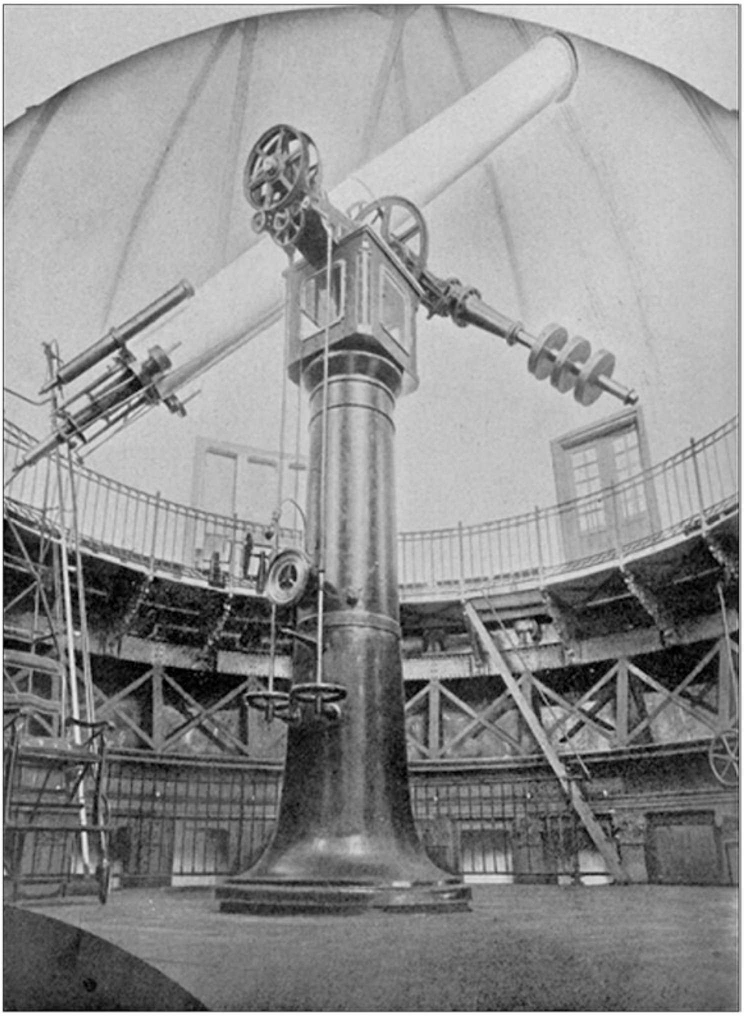

Fig. 2.54 The 19-in refracting telescope at Manila Observatory was operational from February 1899. The objective was by Merz of Germany and the mounting by Saegmuller of the USA (courtesy: University of the Philippines, Diliman).

2.7 Concluding Remarks

In this chapter we provide a framework within which to slot future studies on the history of Philippine astronomy, and we identify ethnoastronomy as an area in which the Philippines can make a major international contribution to scholarship—perhaps more so than any other country, with the notable exception of Australia.

Without doubt, after the publication of an English translation of Ambrosio's *Balatik* by one of the authors of this chapter (JT), our most urgent task is to delineate the parameters of the present-day astronomical systems found amongst the negrito ethnic groups in the Philippines while there are still surviving members of these groups who can pass on this information. In the face of acculturation and the indifference displayed by many of the younger generation to esoteric elements of their traditional culture, some of these astronomical systems are now endangered, and we must work rapidly to record them while this is still possible. In the words of the immortal Elvis Presley, "It's Now or Never"!

But documenting these disappearing astronomical systems is merely the starting point in any project. We know that many of these systems are based on an amalgam of Australo-Melanesian, Austronesian, Islamic and Western influences, and one of the challenges we face as ethnoastronomers when we analyse the data collected during our fieldwork is to try and identify the various contributing elements in this 'astronomical jigsaw puzzle'.

We can only do this if we adopt a multidisciplinary diachronic approach and combine data drawn from anthropology, archaeology, genetics, geology, linguistics, palaeoanthropology and palaeogeography, and if we can view these indigenous astronomical systems as merely an integral part of the cultures of the host groups. In this context, it is important to remember that cultures generally are not static but evolve and change with time. Astronomical systems will do likewise.

Ethnoastronomical studies in various parts of the world have demonstrated that there is often a close relationship between human ecology and astronomical systems, so what is valued here in the Earth is often projected into the sky. Therefore, major changes in human ecology can lead to changes in the associated astronomical systems.

In this chapter we have identified a number of ways in which an ethnic group may have to drastically re-orientate its human ecological strategies. For example, through

(1) major habitat changes caused by naturally-occurring environmental changes (e.g. the rapid sea level rise from 22 kyr to 6 kyr following the last glacial);
(2) major cultural change as when the Austronesians first settled the Philippines and decided to adopt a hunter-gatherer lifestyle *in lieu* of relying on rice cultivation; and later when they abandoned hunting-gathering and reverted to rice-growing; or
(3) major habitat changes caused by relocation of an ethnic group (as when the Austronesians drove the negritos from their comfortable coastal habitats into the inhospitable rainforest in the mountains); or
(4) a conscious decision by a negrito group to begin combining hunting-gathering with slash-and-burn horticulture; or the most extreme case of all
(5) catastrophic acculturation, as is happening now with some negrito groups where 'lowlanders' and forestry companies have taken over their fertile river valleys and logged their rain forests, so the negritos have had to abandon their traditional lifestyles entirely and rely on work and aid from the 'lowlanders' and

> others in order to to survive. Nowadays, their ecology is solely about day-to-day survival, their cultures are destroyed, and so too are their astronomical systems.

On a somewhat different catastrophic scale, we can also consider major ecological changes demanded of a group following major volcanic eruptions, or a succession of devastating cyclones that forced coastal groups to permanently relocate inland away from constant flooding and tidal surges. An interesting case is the Aeta who were relocated following the June 1991 eruption of Mt Pinatubo, the second most violent volcanic eruption of the twentieth century. Some were encouraged to abandon their hunter-gather lifestyles and become horticulturalists. If they persist with this ecological strategy, how long will it take before we see changes in their astronomical systems?

Although our focus has rightly been on the negritos, there are also many non-negrito ethnic groups that deserve to be studied, whether they are the Kankanaey and what they may be able to tell us about the ancestral astronomical system that the incoming Austronesians brought with them to the Philippines 4000 years ago, or the interplay between negrito and non-negrito astronomical systems on Palawan, Mindoro and Mindanao in light of the extensive gene-sharing that occurred on all three islands. In this respect, we look forward to forthcoming publications by the authors of this chapter.

Ethnoastronomy aside, there are other research projects we have identified that will build on the foundations laid in Philippine history of astronomy. For example, there is a wealth of astronomical information buried within the pages of Blair and Robertson's (1903–1909) 55-volume masterpiece, *The Philippine Islands, 1493–1898*, and it is heartening to see that one of the authors of this chapter (R-AD) is intent on excavating this information. We also await the forthcoming publications about the astronomical and meteorological achievements of the original Manila Observatory.

Finally, we believe that the multidisciplinary approach used in this chapter of placing cultures and their astronomical systems within a chronologically-evolving time frame can be used effectively when researching the astronomical histories of other ASEAN nations, but especially those that provide opportunities in ethnoastronomy and/or archaeoastronomy. This Philippines chapter is merely a starting point, a new approach to history of astronomy for all of us. We certainly enjoyed the challenge of researching and writing this chapter. We hope that you enjoyed reading it.

Acknowledgements This is primarily a literature-based review, and we made extensive use of the web. We are particularly grateful therefore to Dr Alfred Pawlik (University of the Philippines) for making his 2017 Powerpoint presentation "Connecting Islands – Archaeological Research in the Philippines" available on the web. This provided a wealth of useful yet-to-be-published and up-to-date information on Philippines archaeology and palaeogeography.

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Part II

Southeast Asian Studies: Eclipses, Calendars, Time-Keeping and Tropical Astronomy

Chapter 3
A Brief History of Vietnamese Astronomy and Calendars During the Reign of the Royal Dynasties

Phạm Vũ Lộc and Lê Thành Lân

3.1 Introduction

Under French colonial rule (i.e. before 1945), some calendars were published to convert Vietnamese lunisolar dates in history into Gregorian dates (Cordier and Lê Đức Hoạt, 1935; Deloustal, 1908). However, all mistakenly assumed that the Vietnamese calendar was identical to the Chinese calendar (both countries were indeed using the same method of calculation during that time). After the 1945 Revolution, Chinese characters were abandoned in the education system, and this misunderstanding persisted. However, Chang (1940) and Hoàng Xuân Hãn (1944) started a new line of research with the discovery of perpetual calendars called *Bách Trúng Kinh*,[1] which has been then pursued by several researchers. Particularly important has been the contributions of Hoàng Xuân Hãn (1982) and Lê Thành Lân (2010).

The history of the Vietnamese calendar cannot be separated from the history of Vietnamese astronomy through the whole feudal period, meaning the history of the Royal Office of Astronomy. In Sinosphere culture, the calendar is related to the seasons, which was thought to be ruled by Heaven. The Emperor, as the Son of Heaven (天子), was the only human who could receive the Order from Heaven

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[1] Chang Yung used a manuscript *Bách Trúng Kinh* coded A.2517 in EFEO archives, having a calendar from 1759 to 1886, and Hoàng Xuân Hãn used another manuscript with the same name but having a calendar from1624 to 1799, suggested to be coded A.2872 in the EFEO archives.

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(天命) and had the authority of defining the seasons (essential for agriculture) through calculating the calendar, of predicting eclipses, of identifying propitious locations and days (hemerology and astrology), etc. In practice, it was the Office of Astronomy that had the responsibility to accomplish these tasks on behalf of the Emperor.

In Vietnam, knowledge of astronomy was mainly imported from China and only a few scholars could master this difficult field, while society was paying much attention to it, but only as a matter of superstition. The scholar Lê Quý Đôn (1726–1784) discussed astronomy in his book *Vân đài loại ngữ* 芸臺類語 in 1773, with many critical comments relating to ideas taken from several books of both Chinese and Western cultures. For instance, he argued that it is the agglomerated gas (*qi* 氣), rather than rock, that causes the brightness of stars. When a star fell to Earth, the cold wind condensed it into rock, i.e. into a meteorite (Lê Quý Đôn, 1773: 85). He also introduced the Western geographical coordinate system and the astronomical geocentric system with nine layers of the sky, as brought to Asia by the Western missionaries (Lê Quý Đôn, 1773: 86–87, 95–97).

This system was maintained until the late nineteenth century, in a book called *Sử học bị khảo* 史學備考 (*Appendix of History*), compiled by Đặng Xuân Bảng (1828–1910). Its first part, "Study on Astronomy", is the most detailed document available in this domain, summarizing the near totality of what was known at that time, including the following topics:

- Nine levels of the Sky
- Degrees around the sky
- Dimension of the 28 Mansions
- Twelve zodiacs
- Stars (and constellations)
- Ecliptic pole and Celestial pole
- Equator, Ecliptic, Moon's orbit
- Motion of the sky and planets
- Polar altitude
- Gnomon shadow
- Sun motion speed
- Reference stars at culmination
- Sunrise and sunset azimuths
- Sunrise and sunset time
- Sun motion interval
- Tropical year
- Solar terms
- Moon movement speed
- Moonrise and moonset time
- Lunation
- Intercalary month setting method
- Eclipses
- Five planets
- Nine virtual stars
- Correspondence of stars with geographical regions

Another book discussing astronomy was written by Phạm Đình Hổ (1768–1839) in about 1777, and titled *Tham khảo tạp kí* 參考雜記. In 1853, a textbook with the title *Khải đồng thuyết*, ước 啟童說約 was compiled to teach scientific knowledge through illustrations (along with common textbooks that only contained literature required to pass the Royal examination), and its first chapter was on astronomy.

Astronomy and science in general were not part of the topics covered in Royal examinations, so they were rarely taught, studied or summarized in books. Moreover, humidity and wars destroyed many documents. We did not find many early books on astronomy preserved in libraries, but those we did find are listed in the References section at the end of this paper.

Traditional Vietnamese science was dominated by medicine, and the history of astronomy did not attract many researchers; yet one may mention, besides Hoàng Xuân Hãn and Lê Thành Lân for calendar studies, Ho Peng Yoke and Akira Okazaki for astronomical phenomena in historical texts, and Alexei Volkov and Yukio Ohashi for the history of Vietnamese science. The purpose of the present paper is to provide a brief chronological summary of the history of Vietnamese astronomy and Vietnamese calendars.

3.2 Before Independence (Before the Tenth Century CE)

Very few records from antiquity suggest the existence of a calendar used for agriculture in Vietnam before the tenth century. The *Tong Zhi* 通志—a Chinese encyclopedia—mentions a tribute paid by the Việt Thường clan (now Central Vietnam) to the legendary Emperor Yao 堯 (ca. 2356–2255 BCE), which included a tortoise-shell with tadpole scripts recording history from the Creation. Yao ordered that a record of it be kept, and he named it the ‘turtle calendar’ (Zheng, 1161(II): 9a).

We know of local calendars that may have existed already at such early times. One such calendar is mentioned in the following account:

> Aborigines in Bất Bạt and Mỹ Lương districts (now West of Hanoi) takes the 11th month as beginning of the year, the 2nd day as beginning of the month, and the 1st day as end of the month. [This rule is] called ‘backward month’ and ‘forward day’. And this [calendar] is called ‘internal date’ for local use, while the official calendar is called ‘external date’, only used for administrative matters. (Đại Nam nhất thống chí, 1883(IV): 236).

The terms ‘backward month’ and ‘forward day’ actually appear in a folkloric proverb of today’s Mường people—the closest ethnic group to modern Vietnamese (Kinh people). The Mường are thought to have separated from the Kinh between 1000 and 2000 years ago, when the Kinh became progressively Sinicised from the invasion of China in the second century BC. Therefore, Mường Culture is thought to be close to ancient Việt-Mường culture before its Sinicization, in the period when the calendar was used for agriculture.

The Mường Calendar is still known today as ‘Khách Đoi’ (The book of the Đoi star), because they use the Đoi star (the Pleiades) as the milestone of the Moon’s motion in the sky to define the intercalary month. The Vietnamese now have many folk verses that also mention the Pleiades with the name ‘Tua Rua’ or Sao Mạ (rice star), as it played a role in defining the seasons. The descriptions of lunar phases that appear in a Mường folk song also have a Kinh version.

The Mường Calendar is represented by a set of 12 bamboo sticks (each representing one month). Each stick has 30 carved slots along one side, representing 30 days. The sticks are grouped into three strings of 10 days (named Kâl, Lồông and Cối). The day begins when the rooster crows (around 5am), and is divided into 16 hours (8 hours of day and 8 hours of night). There are also carved signs next to the day slot to note about natural conditions on this day (see Fig. 3.1).

The method of calendar calculation is now lost because it is only used by the priests (thầy mo) in the villages to define the propitious days for the villagers. Each priest individually acquired and explained his set of bamboo sticks without exchanging knowledge with others.

The length of the month must be 29 or 30 to follow the lunation, while the slots are always 30 for every stick. Chu Văn Khánh (2001: 57–58) guessed that the priests observed the crescent Moon to define the first day of the new month. It is the first day of the waxing crescent, one day after the New Moon (which is the first day of the month in the Kinh lunisolar calendar).

The calendar uses the Đoi star (the Pleiades) as the key to set the intercalary month, in order to follow the sidereal year: the day when the Moon trespasses the Đoi star (known as Đoi day) is marked by five dots beside the day slot on the bamboo stick (see Fig. 3.2). The first month of a new year is defined as the month having the Full Moon trespassing the Đoi star (the Lồông 4 day). In such a Đoi day, if the Full Moon does not trespass the Pleiades yet, this month is set as an intercalary month of the previous year (and becomes the thirteenth month of it), while the next month will

Fig. 3.1 The Mường bamboo stick calendar (source: kienthuc.net.vn).

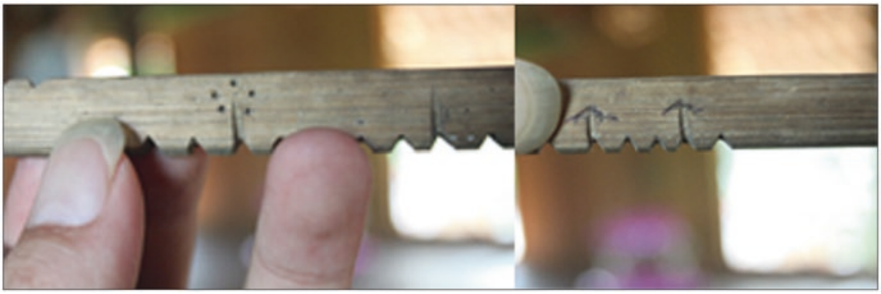

Fig. 3.2 Close up of two Mường bamboo calendar sticks, showing (left) the Đoi day sign (5 dots), and draining day's sign (line), and (right) the rainy day's sign (up arrows) (source: kienthuc.net.vn).

Table 3.1 The name of the months in the Mường and Kinh (Vietnamese) calendars.

Mường month	1	(11)	(12)	2	3	4	5	6	7	8	9	10
Mường name	Môch	Hap	Chiêng	Hal	Pa	Pươn	Đăm	Khẩu	Páy	Thảm	Chỉn	Mươl
Kinh name	Một	Chạp	Giêng	Hai	Ba	Bốn	Năm	Sáu	Bảy	Tám	Chín	Mười
Lunisolar month	11	12	1	2	3	4	5	6	7	8	9	10

be the first month of the new year (Chu Văn Khánh, 2001: 60–61). The use of the Pleiades suggests that this calendar is based on actual observations, instead of calculations, and originates from antiquity, before the lunisolar calendar based on a more complicated method of calculation was importing from China (Chu Văn Khánh, 2003).

The month is named by the cardinal numbers from one to ten, plus two extra months (see Table 3.1). This suggested that the calendar primarily had only 10 months, before the introduction of the l unisolar 12-month system from China. It is explained that after 10 months, the remaining time interval of the year corresponds to the winter which is meaningless for agriculture. Mường people celebrate the New Rice Ceremony (Lễ cơm mới) upon the harvest in the tenth month (around November). Then the next month is the first month (tháng Một), which contains the Winter solstice. Later, two months were added after the first month and before the second month. These two kept their Chinese names (臘 → Hap/Chạp and 正→ Chiêng/Giêng) when they were introduced. This explains why the eleventh month in the present the lunisolar calendar is called 'Một' (one), instead of 'Mười Một' (eleven). This naming of months also appears in other ethnic groups in Vietnam, but further research is required in order to determine whether this practice originated locally or was borrowed from elsewhere in Vietnam.

Today, the bamboo stick calendars are mostly preserved and used by priests. In some regions the Mường people no longer use the bamboo stick calendar and do not understand the observations required to define the month and intercalary months, so they follow their traditional calendar by referring to the lunisolar calendar of the Kinh people. They subtract 1 day and add 1, 2 or 3 months from the date of the Kinh

Calendar. The intercalary month also follows the Kinh Calendar and its days are presented in the sticks of the preceding months (Chu Văn Khánh, 2001: 62). The special Đoi day of the 1st month in the Mường Calendar (as presented above) corresponds to the Full Moon day of the 10th or 11th month in the Kinh lunisolar Calendar. Therefore, Mường people in some regions take the 11th month of the Kinh Calendar as their 1st month, while other regions take the 10th month (Chu Văn Khánh, 2001: 63).

Beside the Pleiades, the ‘Sao Cày’ (Plough star–Orion’s Belt) and the ‘Sao Thần Nông’ (The deity of agriculture–Scorpius) appear in Vietnamese culture just like in other Southeast Asian countries, with obvious connections to agriculture.

Before it became an independent state in the tenth century, North Vietnam was under Chinese rule from the second century BC and certainly used Chinese lunisolar calendars, which will be described below.

During this period, Chinese astronomers came to Vietnam to make astronomical observations. *Jiu Tang Shu* 舊唐書 (*The History of Tang*) mentioned a gnomon measurement, made around the year CE 350 (at the time of the conquest of Lâm Ấp 林邑—now Central Vietnam—by the Qin Dynasty) by General Guan Sui 灌邃 on the 5th day of the 5th month in lunisolar calendar (near the summer solstice). The measured length of the shadow was 9 cun 寸 1 fen 分 (*Jiu Tang Shu*, Vol. 41: 103a).[2] This meant the latitude of 17–19° N, namely today’s Central Vietnam.

Jiu Tang Shu quoted a text from *Nan Yue Zhi* 南越志 (*Record of the Nan Yue Kingdom*), which is now lost, mentioning a gnomon shadow length of 3 cun in Giao Châu (now Hanoi) and 9 cun 1 fen in Lâm Ấp, in agreement with the above measurement. The gnomon height is usually 8 chi 尺 (*Jiu Tang Shu*, Vol. 35). *Zhoubi Suanjing* 周髀算經 (one of the oldest Chinese books about mathematics) gives detailed information about the measurement of this shadow length: it was performed in CE 442 by an agent sent to Giao Châu, whose center is today’s Hanoi, at a latitude of 21° N. The shadow length was 3 cun 2 fen to the South, corresponding to a latitude of 21° N (*Zhoubi Suanjing*, Vol. 2A: 14a).

Jiu Tang Shu (Vol. 35: 12b–13a) also recorded a measurement made in CE 724 under Royal order, performed by an official expert (太史) at Giao Châu. The shadow length is 3 cun 3 fen, similar to the 442 result quoted above. It also reported the polar altitude at Giao Châu 交州 was above 20° (in agreement with Hanoi’s latitude of 21° N) and the surprisingly-high altitude above sea level of the Old-man Star 老人星 (Canopus) in the South direction in August, as well as other bright stars below it. These stars cannot be observed from China or recorded in star charts because of their small distances from the South Celestial Pole. The book *Jiu Tang Shu* (Vol. 35: 15a–15b, 18a–b) also listed data on gnomon shadow length, zenith distance, and polar altitude at An Nam (An Nam đô hộ phủ—now Hanoi) and at Lâm Ấp, as listed in Table 3.2 (Jiu Tang Shu, pp. 15a–b,18a–b vol.35). These data display some deviations from reality, possibly due to errors in the measurements or in copying the text.

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[2] 1 chi = 10 cun = 100 fen = 1/10 zhang ≈ 0.242 m during the Six Dynasties 六朝 period (CE 220–589) in South China.

3.3 The Lý, Trần, and Hồ Dynasties and Ming Invasion (CE 1009–1427)

After having gained independence and establishing a new regime, Vietnamese historians started to mention precise dates of historical events, using the lunisolar calendar inherited from China. The lunisolar calendar followed both the lunation and tropical year cycles by inserting intercalary days at the end of the months and intercalary months somewhere in the year. It is to make the month and the lunation, as well as the year and the tropical year approximately match. A month may have 29 or 30 days (including the intercalary day), and a year may have 12 or 13 months (including the intercalary month). The intercalary day causes the first days (New Moon days) of consecutive months to appear 29 days or 30 days apart (which can be evidenced by the sexagenary term shown in the calendar).

As no calendar has survived from this period, Hoàng Xuân Hãn used an indirect method by comparing the intercalary months of the lunisolar calendar appearing in Vietnamese historical texts with the Chinese calendar. He noted that small differences in the method of calculations or in the adopted parameters could cause shortly thereafter differences in the intercalary months and days (Hoàng Xuân Hãn, 1982: 55). However, the effect of such differences does not persist with time but is compensated for later on by another difference of opposite effect: differences between calendars are limited to a short time interval (no more than a month for intercalary days and no more than a year for intercalary months). Therefore, the differences provide direct evidence of a continuous independence between the two calendars, while similarities are just associated with the gaps between the differences.

Historical texts provide examples of the presence of an intercalary month when an historical event had been recorded, but the presence of an intercalary day, meaning a difference in the New Moon day, is rarely detected. They are presented in Table 3.3 as ‘slices’ through the Vietnamese historical calendar.

In comparing with the Chinese calendar, Hoàng Xuân Hãn detected three intercalary months in 969, 1042 and 1078 from the *Bản Kỉ* (BK) section in *Đại Việt sử ký toàn thư* 大越史記全書 (*Complete Annals History of Đại Việt*, or *Toàn Thư* (TT) for short)—one of the most important Vietnamese history books—and *Việt sử lược* (VSL) 越史略 (*Brief History of [Đại] Việt*). These intercalary months are the same for both documents (see Table 3.3). He first noted a difference between the two calendars for year 1080, suggesting that Vietnam was using a calendar obtained from China before the reign of Emperor Lý Thánh Tông (1054–1072). Vietnamese Emperors had been sending diplomatic envoys to China with a mission to secretly

Table 3.2 Astronomical data in present-day Vietnam from *Jiu Tang Shu.*

Gnomon: 0.8 zhang	Gnomon shadow length (zhang)				
Location	S. solstice	W. solstice	Equinoxes	Zenith distance	Polar altitude
Giao Châu —An Nam (Hanoi)	0.033	0.794	0.293	2.4°	20.4° 26.6°
Lâm Ấp (Central)	0.057	0.69	0.285	6.6°	17.4°

Table 3.3 Historical events containing information about the calendar before CE 1428, revised from Hoàng Xuân Hãn (1982: 56–57). Chinese dates are based on Chen (1962), and differences are in bold print. The Gregorian year in this and the following tables is simply the corresponding year of the lunisolar year, which may differ by 1 to 2 months.

Year		Vietnamese intercalary month	Chinese intercalary month	Vietnamese source
969	Kỷ Tị	5	5	(TT, p. 3a BK vol.1)
1042	Nhâm Ngọ	9	9	(TT, p. 30b BK vol.2)
1078	Mậu Ngọ	1	1	(VSL, p. 16b vol.2)
1080	**Canh Thân**	**8**	**9**	(VSL, p. 17a vol.2)
1124	**Giáp Thìn**	**1**	**3**	(TT, p. 22b BK vol.3)
1126	Bính Ngọ	11	11	(TT, p. 24b BK vol.3)
1129	Kỷ Dậu	8	8	(TT, p. 34a BK vol.3)
1132	**Nhâm Tý**	**5**	**4**	(TT, p. 37a BK vol.3)
1146	**Bính Dần**	**6**	**No**	(TT, p. 5b BK vol.4)
1151	Tân Mùi	4	4	(Thiền Uyển Tập Anh, p. 70a)
1176	Bính Thân	Distribution of the calendar (Wenxian tongkao, 1317, p. 34a vol.330)		
1188	**(day Giáp Tý)**	**(1st day of 7th month)**	**(1st day of 8th month)**	(Okazaki, 2021: #1-35)
1206	Ất Sửu	Distribution of the calendar (An Nam Chí Lược, p. 16b vol.2)		
1210	**Canh Ngọ**	**(Short 9)**	**(Long 9)**	(TT, p. 26b BK vol.4)
1211	Tân Mùi	2	2	(VSL, p. 22a vol.3)
1256	**Bính Thân**	**3**	**No**	(TT, p. 21b BK vol.5)
1265	Ất Tị	Distribution of the calendar (Yuan Shi, p. 4a vol.209)		
1285	**Ất Dậu**	**(Long 2)**	**(Short 2)**	(TT, p. 47b BK vol.5)
1287	**Đinh Hợi**	**(Long 12)**	**(Short 12)**	(TT, p. 52b BK vol.5)
1300	**Canh Tý**	**3**	**8**	(TT, p. 8b BK vol.6)
1301	Tân Sửu	Đặng Nhữ Lâm read ‘forbidden books’ (Yuan Shi, p. 24a vol.209)		
1306	Bính Ngọ	1	1	(Thiền đạo yếu học, p. 36a)
1311	Tân Hợi	Distribution of the calendar (An Nam Chí Lược, p. 9b vol.2)		
1321	Tân Dậu	Distribution of the calendar (An Nam Chí Lược, pp. 11a vol.2, 10a vol.3, 4a vol.17)		
1324	Giáp Tý	Distribution of the Shou Shi calendar (An Nam Chí Lược, p. 12a vol.2) (TT, p. 42a BK vol.6)		
1335	Ất Hợi	Distribution of the Shou Shi calendar (An Nam Chí Lược, pp. 12b vol.2, 6a vol.17)		
		12	12	(Ma nhai kỷ công bi văn)
1339	Kỷ Mão	Trần Dynasty changed the calendar name from Thụ Thì to Hiệp Kỷ (TT, pp. 9b–10a BK vol.7)		
1367	Đinh Mùi	Ming Dynasty changed the calendar name from Shou Shi to Da Tong (Ming Shi, p. 2b vol.31)		
1369	Kỷ Dậu	Distribution of the Da Tong calendar (Ming Shi Lu, pp. 3a-b 太祖 vol.43)		
1371	Tân Hợi	3	3	(TT, p. 37a BK vol.7)
1401	Tân Tị	Hồ Dynasty changed the calendar name from Hiệp Kỷ to Thuận Thiên (TT, p. 39a BK vol.8)		

learn the method used to calculate the calendar, at least before the war against the Song Dynasty (1075–1077), at a time when they could not obtain calendars from their enemy. And because of secrecy, there exists no record of this in history. Later on, the Chinese calendar was modified on several occasions but the Vietnamese calendar was not updated accordingly, causing the observed differences (Hoàng Xuân Hãn, 1982: 58).

The Royal Court needed an Office of Astronomy to calculate the calendar. *Toàn Thư* (TT: 20a) mentions the first observatory being constructed in CE 1029 during the Lý Dynasty: "In front [of the Thiên An palace] founded Phụng Thiên palace. Above it, established Chính Dương floor as the place for timekeeping." (cf. BK, Vol. 2).

Hoàng Xuân Hãn states that the change from the Lý Dynasty to the Trần Dynasty (1225–1400) did not cause any change in the administrative system nor in the calendar being used.

Circa 1107, a Vietnamese envoy asked the Song Dynasty for permission to buy books and was accepted, but it was forbidden to buy books relating to calendar calculations (Song Shi, 1346). However, *Yuan Shi* (Vol. 209: 24a; our bold lettering) mentions an interesting event:

> The 2nd month of the 5th year of Da De (1301), the Taifu 太傅 (title of an official) E Lei Zhe 諤勒哲 stated: 'Annamese (Vietnamese) envoy Đặng Nhữ Lâm secretly drew a map of the royal palace, bought maps and **forbidden books**, copied documents related to Giao Chỉ (Vietnam) campaign, and took note about military situation on the northern border and about the royal mausoleum. Please send blame to show righteousness'.

It was not clear which were the forbidden books that had been bought by Đặng Nhữ Lâm, but a few lines in *Toàn Thư* about his son Đặng Lộ (Lê and Trần, 2011) may shed some light on it:

> Kỷ Mão year (1339) … in the spring, Thụ Thì calendar was changed into Hiệp Kỷ 協紀[3] calendar. That time, the Timekeeper and Head of Thái Sử Cục [named] Đặng Lộ stated that calendars before are all named Thụ Thì[4] and asked to rename it as Hiệp Kỷ. The Emperor agreed. (TT: 9b–10a; BK, Vol. 7).

Đặng Lộ had probably learnt calendar-making from his father (who had learnt it from the 'forbidden books') and had applied it after having succeeded his father with its original name (Thụ Thì) until this event. The differences between Vietnamese and Chinese dates before 1300 and their agreement from at least 1306 to the end of Yuan Dynasty in 1368 (see Table 3.3) suggests that the Vietnamese calendar used the same method as the Chinese Shou Shi Calendar (after Đặng Nhữ Lâm's journey (Hoàng Xuân Hãn, 1982: 59).

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[3] The name協紀 has its origin in a phrase of Shu Jing 書經 (Classic of History–one of the Five Classics of Confucianism): "協用五紀" ("… arrange harmoniously five elements: the year, the month, the day, the stars and planets, and the calendar calculation.").

[4] The Shou Shi 授時Calendar in Chinese is very accurate compared to earlier Chinese calendars, and was invented by Guo Shou Jing (1231–316) in 1281. Also see Footnote 5.

The Chinese Dynasty offered Vietnam calendars on several occasions, in order to show their domination, as partly documented. Among these, were distributions of the Shou Shi Calendar of the Yuan Dynasty in the years 1311, 1321, 1324 and 1335, made at times when both calendars were calculated simultaneously and gave the same results. But calendar distributions made in 1176, 1206 and 1265 before the introduction of the Shou Shi Calendar (1301) might not have been annual, in particular when occurring during times of war between the two countries (1258, 1285–1288), causing a lack of synchronization between the two calendars (see Table 3.3).

Đặng Lộ is also known for having constructed what was probably a celestial globe (Ho 1964: 129) or an armillary sphere (Needham, 1959(III): 369), which was called Linh Lung Nghi (TT: 10a; BK, Vol. 7)—literally meaning 'splendid instrument'—possibly copied from a similar Chinese instrument with the same name (玲瓏儀), created by Guo Shou Jing. The latter text also mentions the name given to the Office of Astronomy during the Trần Dynasty: Thái Sử Cục 太史局 (similar to that used by the Tang and Song Dynasties in China, the administrative system which Vietnam imitated). The office is under the Bí thư sảnh, or Royal Secretariat (Sử học bị khảo: 515).

In 1367, the Ming Dynasty changed the name of the calendar from Shou Shi to Da Tong, and in 1401, the newly-founded Hồ Dynasty (1400–1407) changed the name Hiệp Kỷ to Thuận Thiên (TT: 39a; BK, Vol. 8) without changing the method of calculation. In 1407, the Ming invaded the Hồ and colonized Vietnam (which remained under their rule until 1427): the Da Tong Calendar was the official Vietnamese calendar until 1426.

When made prisoner by the Ming, Prince Hồ Nguyên Trừng (ca. 1374–1446) wrote memoirs called *Nam Ông Mộng Lục* 南翁夢錄 (*Record of Dreams of the Old Man from the South*) that report on a Vietnamese Emperor's advisor named Trần Nguyên Đán (ca. 1325–1390):

> He mastered the method of calendar calculation and compiled Bách Thế Thông Kỷ Thư 百世通紀書 (*Book of the comprehensive chronicles for hundred generations*) which covered, from the year Giáp Thìn of Emperor Yao to the Song and Yuan Dynasties, solar & lunar eclipses and coordinates of planets and stars, in agreement with earlier [calculations]. (Nam Ông Mộng Lục: 123).

Unfortunately, this book was lost during the Ming invasion, but it reveals a certain degree of astronomical knowledge in Vietnam during these times.

3.4 The Lê, Mạc and Tây Sơn Dynasties (1427–1788)

3.4.1 The Tonkin Regime (North Vietnam)

The victory of Lê Lợi (ca. 1384–1433) against Ming's army had brought to an end the use of the Da Tong Calendar in Vietnam from the 10th month of 1426 onwards (TT: 23a; BK, Vol. 10). Lê Lợi established the Lê Dynasty with Tonkin (now Hanoi) as the capital. The Lê Dynasty was interrupted by the Mạc Dynasty (1527–1592), and was divided into two periods: The Early Lê period (1428–1527) and the Restored Lê period (1592–1788), with the Trịnh Lords actually retaining power during the latter.

The staff of the Office of Astronomy usually held ‘part-time jobs’: a military officer had been appointed as Calendar Manager (Chưởng Lịch掌曆), and a member of the Board of Revenue 戸部as Timekeeper (Linh Đài Lang 靈臺郎) in 1435 (TT: 21a; BK, Vol. 11). These ‘part-time’ positions were in fact meant to serve as stepping-stones to higher positions. In this context, *Toàn Thư* mentions a story about a member of the Thái Sử Viện 太史院 (the former Thái Sử Cục) named Bùi Thì Hanh. He had been appointed as Deputy Head of Thái Sử Viện (Thái Sử Thừa太史丞) in 1434 (TT: 4a; BK, Vol. 11). He then took advantage of his new position to mislead the Emperor: he suggested that the Emperor sacrifice monkeys because the monstrous monkey would otherwise eat the Sun on the occasion of the next solar eclipse, which would provoke a disaster in the country (TT:8b-9a; BK, Vol, 11). He kept having a strong influence on the rituals and ceremonies at the Court and was rewarded by the Emperor (TT, pp. 30a, 59a BK vol.11). After he was exposed by the Royal Inspector for a mistaken eclipse prediction, he was dismissed but later was promoted to a higher position (Head of Thái Sử Viện—Thái Sử Lệnh 太史令) for his unique talent as an astronomer (TT, pp. 71a–72b & 82a–82b BK vol.11).

Some positions in the Thái Sử Viện are described in *Quan Chức Chí* 官職誌 (Record of Officials)—1 of 10 parts of the nineteenth century encyclopedia *Lịch Triều hiến chương loại chí* 歷朝憲章類誌 (*The Categories Book of Rules of Dynasties*)—including: the Thái Sử Lệnh (Head), the Thái Sử Thừa (Deputy Head), the Linh Đài Lang (Timekeeper), the Thái Chúc (Ritual Official) and the Chưởng Lịch (Calendar Manager) (LTHCLC, p. 11a vol.13).

Later, Emperor Lê Thánh Tông (r. 1460–1497) reformed the regime and established a new Office of Astronomy called Tư Thiên Giám 司天監, as first mentioned in *Toàn Thư* in 1470 (TT, p. 59b BK vol.12). The name was taken from the Chinese Office of Astronomy during the Yuan Dynasty and introduced in 1314. The Emperor has also been praised by historians for his knowledge of the calendar and of mathematics (TT, pp. 78a,79b BK vol.13).

The oldest known map of Vietnam (a seventeeth century copy of the *Hồng Đức bản đồ* dating from 1490) displays a map of the Central Capital 中都 (Tonkin) locating Tư Thiên Giám (A) south of the citadel (see Fig. 3.3). The exact place of the observatory is still unknown, but there exists today a street in Hanoi with the name of ‘Khâm Thiên’ in this area. This name comes from Khâm Thiên Giám 欽天監[5]—mentioned in *Quan Chức Chí* in 1787, near the end of the Lê Dynasty (1788) (LTHCLC, pp. 6b,17b vol.16)—suggesting that the Office of Astronomy in Hanoi changed its name from Tư Thiên Giám to Khâm Thiên Giám between 1751 and 1787, before the capital was moved to Huế in 1789. The name was still used in Huế during the Nguyễn Dynasty as we shall see later.

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[5] The names Thụ Thì 授時 and Khâm Thiên 欽天 came from phrases of *Shu Jing*: “乃命羲和, 欽若昊天, 歷象日月星辰, 敬授人時” ([Emperor Yao] thus orders Xi and He, to follow the Heaven, observe the Sun, the Moon, and stars, respectfully give the Time (weather or calendar) to people).

Our current fieldwork has revealed the existence of a village with the same name, Khâm Thiên Giám, which was later renamed Khâm Đức after the capital had moved to Huế (Long Biên bách nhị vịnh, p. 11a). The French later moved the village to its present location (further South) to make room for the construction of the Hanoi train station (ca. 1902). The village became a small hamlet inside a crowded quarter where the name of Khâm Đức is only remembered as the names of an alley and of a small temple.

Volkov (2013: 119) has noted the identity of names between the Phụng Thiên Palace, built during the Lý Dynasty as mentioned above, and Phụng Thiên Phủ 奉天府 (B in the Fig. 3.3 map), an administrative division (phủ) established at least from 1469 during the Lê Dynasty (TT, p. 51a BK vol.12). But actually, it is rather just a random coincidence: the name often given to the administrative division surrounding the capital during the Ming and Qing Dynasties in China usually had Thiên 天 (Heaven) as the second character (Ying Tian fu 應天府—now Nanjing, Shun Tian fu 順天府—now Beijing, Feng Tian fu 奉天府—now Shenyang); such divisions were under direct rule of the Court, instead of a province like others. The Lê Dynasty copied this naming convention and adopted the name Phụng Thiên phủ for their capital.

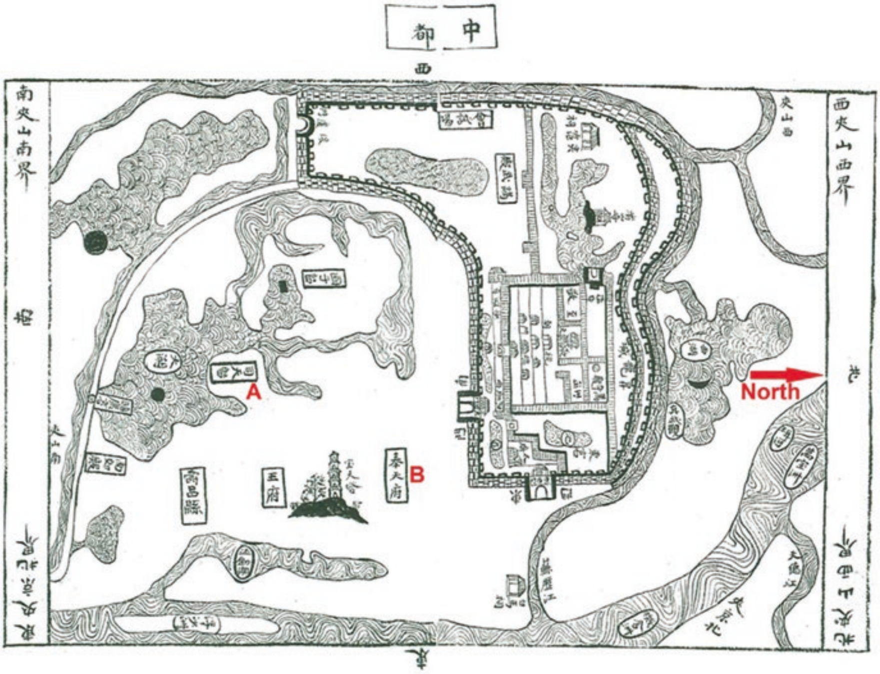

Fig. 3.3 The Hồng Đức bản đồ map of the capital (now Hanoi) (Hồng Đức bản đồ, 1490).

The grades[6] of the staff of the Tư Thiên Giám were recorded in 1721, with the comment that they had been kept unchanged since the Hồng Đức era (under the reign of Emperor Lê Thánh Tông, r. 1460–1497) as follows (LTHCLC, pp. 19b–21b vol.13): Tư thiên lệnh 司天令 (Head of office): upper 6th grade, Giám phó 監副 (Deputy Head): upper 7th grade, Giám thừa 監丞 (Assistant): upper 8th grade, Ngũ quan chính 五官正 (five Observers—four named after the seasons and the fifth one called 'Center Observer'): lower 8th grade, Tư thần lang 司辰郎 (Timekeeper): upper 9th grade.

This suggests that the structure of the Tư Thiên Giám remained rather stable throughout the Lê Dynasty, including during the interruption by the Mạc Dynasty (1527–1592). In 1751, the function of the Tư Thiên Giám was described as to "…measure and calculate the coordinates of celestial [objects], calculate calendar, forecast the weather, etc.; predict and report on good or bad omens." (LTHCLC, p. 23b vol.14). Its other important mission was hemerology, which was playing a major role in nearly all royal rituals and ceremonies.

Hoàng Xuân Hãn (1944) states that the Da Tong method for calendar calculation was used in Vietnam under a different name until 1812, on the basis of a perpetual calendar manuscript in his possession, the *Bách Trúng Kinh* (which is now lost). The name of the calendar used during the Early Lê and Mạc Dynasties (1427–1527 & 1527–1592) is unknown, but the calendar of the year 1758 in *Bách Trúng Kinh* as well as the record of ritual processes in *Lễ Nghi Chí* (another part of *Lịch triều hiến chương loại chí*) mention the name of Khâm Thụ[7] (LTHCLC, 1821, p. 89a vol.22). Hoàng Xuân Hãn (1982: 60) suggests that this name was already used from the beginning of the Lê Dynasty (c.1427) and was changed during the Mạc Dynasty (1527–1592), before being again in use during the Restored Lê Dynasty (from 1592).

Hoàng Xuân Hãn continued to compare both calendars and found that they are identical. We also added some more events from historical documents and revised some differences in his table (see Table 3.4). The massive distribution of calendars made by China in 1542 is suggested to be a diplomatic gesture of the Mạc to gain political support from the Ming against the raising strength of the Restored Lê force during the civil war, rather than for a practical use. Even if the Mạc Dynasty used Chinese calendars and even if they were called Da Tong, it still remains that the Office of Astronomy kept operating during these times, because after having defeated the Mạc, the Restored Lê Dynasty could use the Office to calculate their own calendar (Hoàng Xuân Hãn, 1982: 61).

Okazaki (2010: 42) compared the sexagenary dates in *Toàn Thư* with Chinese dates and divided the period running from 1306 (date of the first known similarity after Đặng Nhữ Lâm's journey) to 1543 (the last year before the introduction of the *Khâm định vạn niên thư* which is described below) in three intervals:

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[6] The grades of officials are usually divided into 9 levels with upper and lower grades for each, giving 18 grades in total.

[7] *Bách Trúng Kinh* (A.2873) printed this name only in the 1644 calendar, which suggested that it was used from this year, maybe due to the fall of the Ming Dynasty (and the Da Tong calendar). This name (欽授) also comes from the phrase in Shu Jing, see Footnote 5.

- From 1306 to 1434: covering 129 years, with 18 sexagenary dates, all similar.
- From 1435 to 1475: covering 41 years, with 21 sexagenary dates showing 2 differences.
- From 1475 to 1543: covering 68 years, with 29 sexagenary dates showing 15 differences.

He suggested that the increasing number of differences is due to the use of different parameters, causing an accumulation over time and eventually showing up later.

Hoàng Xuân Hãn (1982: 62–63) took a further step: he restored the Da Tong Calendar using its algorithm. He found agreement between his calculated calendar with Vietnamese recorded historical dates, and with the version of the *Bách Trúng Kinh* that he had (see Table 3.6). He then concluded that

> The Vietnamese used the Da Tong method until 1812 throughout the Lê Dynasty, possibly the Tây Sơn Dynasty and the early period of the Nguyễn Dynasty, as was done in China by the Ming Dynasty. When the Qing Dynasty came in power in 1644 and changed to another method of calculation, the Vietnamese and Chinese calendars became very different.

After Hoàng Xuân Hãn's work, three old Vietnamese calendar books were discovered and studied:[8]

(1) *Bách trúng kinh* (BTK) 百中經 (Accurate calendar) (nineteenth century) Woodblock-printed and handwritten A.2873. Library of the Institute of Sino-Nom Studies: 1624–1785 calendar (Lê Thành Lân, 1997).[9]
(2) *Khâm định vạn niên thư* (KĐVNT) 欽定萬年書 (Royal calendar of ten-thousand years) (c.1850) Woodblock-printed R.2200. National Library of Vietnam: 1544–1903 calendar (Lê Thành Lân, 1996).
(3) *Lịch đại niên kỷ bách trúng kinh* (LĐNKBTK) 曆代年紀百中經 (Accurate calendar for successive generations) (nineteenth century) Handwritten A.1237. Library of the Institute of Sino-Nom Studies: 1740–1883 calendar (Lê Thành Lân, 2008).

These three calendars are shown in Fig. 3.4 and cover 360 years of Vietnamese history. They were used as the main sources for calendar studies from that period.

From 1544 to 1644 the calendars of the Lê and Ming Dynasties displayed small differences, contrary to the statement of Hoàng Xuân Hãn (1982: 60) that they were identical until 1618. Note that every difference of intercalary days or month is compensated shortly after, making them appear in couple. They include minor differences of intercalary days and a single major difference of intercalary months that occurred in 1621, but are only one month apart (see Table 3.5). The major differences are less frequent than for the Lý and Trần Dynasties, but their occurrence demonstrates that during this period the Vietnamese were calculating calendars

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[8] These publications are mainly in Vietnamese, but for the most recent English-language paper see Lê Thành Lân & Nguyễn Thị Trường (2017b).

[9] This is a woodblock-printed book, not to be confused with one with same name that Hoàng Xuân Hãn or Chang Yung used but is now lost—see Footnote 1.

Table 3.4 Historical events containing information about the calendar between 1428 and 1623, revised from (Hoàng Xuân Hãn, 1982: 56–57). Chinese dates is based on (Chen, 1962). Differences are in bold print.

Year		Vietnamese intercalary month	Chinese intercalary month	Vietnamese source
1428	Mậu Thân	4	4	(TT, p. 59a BK vol.10)
1433	Quý Sửu	8	8	(TT, p. 74b BK vol.10)
1466	Bính Tuất	3	3	(TT, p. 23a BK vol.12)
1469	Kỷ Sửu	2	2	(TT, p. 50a BK vol.12)
1471	Tân Mão	9	9	(TT, p. 70a BK vol.12)
1474	Giáp Ngọ	6	6	(TT, p. 4a BK vol.13)
1477	Đinh Dậu	2	2	(TT, p. 10b BK vol.13)
1485	Ất Tị	4	4	(TT, p. 45a BK vol.13)
1488	Mậu Thân	1	1	(TT, p. 57a BK vol.13)
1496	**Bính Thìn**	**2**[a]	**3**	(TT, p. 72b BK vol.13)
1507	Đinh Mão	1	1	(TT, p. 43a BK vol.14)
1517	Đinh Sửu	12	12	(TT, p. 38a BK vol.15)
1520	Canh Thìn	8	8	(TT, p. 50b BK vol.15)
1540	Canh Tý	Mạc begged for the Da Tong calendar (TT, pp. 3b,4a BK vol.16)		
1542	Nhâm Dần	Mạc received 1000 copies of the Da Tong calendar (TT, p. 6a BK vol.16)		
1557 **1558**	**Đinh Tị** **Mậu Ngọ**	**7**[b]	**7**	(TT, p. 14b BK vol.16)
1591	Tân Mão	3	3	(TT, p. 22b BK vol.17)
1593	Quý Tị	11	11	(TT, p. 45a BK vol.17)
1596	Bính Thân	8	8	(TT, p. 57b BK vol.17)
1602	Nhâm Dần	2	2	(TT, p. 6a BK vol.18)
1615	Ất Mão	8	8	(TT, p. 10b BK vol.18)
1618	Mậu Ngọ	4	4	(TT, p. 13b BK vol.18)
1623	Quý Hợi	10	10	(TT, p. 6b BK vol.21)

[a] Hoàng Xuân Hãn noted this difference is just a mistake by copying the documents several times. The right intercalary month is the 3rd month (Hoàng Xuân Hãn, 1944: 48).

[b] Maybe another mistake due to copying: 1557 is the 1st year of Thiên Hựu (reign name) and has no intercalary month while the next year 1558 is also the 1st year of Chính Trị and has an intercalary 7th month.

independently, but using the same Da Tong method as used in China and making similar calendars with only small differences.

In 1644, the Ming Dynasty revised the Da Tong method that had become inaccurate after the accumulation of small deviations over several centuries from the time of its invention. Emperor Chong Zhen 崇禎 (1611–1644) asked Johann Schreck (1576–1630) and Johann Adam Schall von Bell (1591–1666) to devise a new method of calculation, called the Western method. The work was completed in

Table 3.5 Differences between the Vietnamese and Chinese calendars during 1544–1644. The Vietnamese calendar is from (KĐVNT, c.1850), and the Chinese calendar is from (Chen, 1962).

Year		Vietnamese month	Chinese month	Vietnamese source
1558	Mậu Ngọ	Long 11 Short 12	Short 11 Long 12	(KĐVNT, c.1850, p. 8b)
1559	Kỷ Mùi	Long 9 Short 10	Short 9 Long 10	(KĐVNT, c.1850, p. 8b)
1569	Kỷ Tị	Long 11 Short 12	Short 11 Long 12	(KĐVNT, c.1850, p. 9a)
1581	Tân Tị	Short 9 Long 10	Long 9 Short 10	(KĐVNT, c.1850, p. 9b)
1588	Mậu Tý	Long 2 Short 3 Short 11 Long 12	Short 2 Long 3 Long 11 Short 12	(KĐVNT, c.1850, p. 10a)
1599 1600	Kỷ Hợi Canh Tý	Long 12 Short 1	Short 12 Long 1	(KĐVNT, c.1850, p. 10b)
1608 1609	Mậu Thân Kỷ Dậu	Long 12 Short 1	Short 12 Long 1	(KĐVNT, c.1850, p. 11a)
1616	Bính Thìn	Long 6 Short 7	Short 6 Long 7	(KĐVNT, c.1850, p. 11b)
1621	Tân Dậu	Short 3 **Long intercalary 3**	**Long intercalary 2** Short 3	(KĐVNT, c.1850, p. 11b)
1641 1642	Tân Tị Nhâm Ngọ	Long 12 Short 1	Short 12 Long 1	(KĐVNT, c.1850, p. 12b)

1644, the year of the fall of the Ming Dynasty. The new calendar was then adopted by the Qing Dynasty from year 1645 under the name of the Shi Xian Calendar. The fallen Ming Dynasty fled to the South and maintained diplomatic relations with Vietnam under the name of Southern Ming. Both Vietnamese and Southern Ming calendars remained similar, while the Qing Calendar displayed strong differences (see Table 3.5). The Southern Ming Dynasty fell in 1662 and Vietnam then turned to the Qing Dynasty.

In 1664 the Manchu military commander Oboi (ca. 1610–1669), who had amassed enormous power in the Qing court, abolished the Western method and restored the Da Tong method from 1665 to 1668. But experiments initiated by Emperor Kang Xi (r. 1661–1722) in 1669 demonstrated that the Western method was better, and the intercalary 12th month of this year, which had been already announced, was moved to the 2nd month of the next year (1670) (cf. Table 3.6). From then, the Western method was used to calculate the Shi Xian Calendar until the end of the Qing Dynasty (1912), while the Da Tong method was still in use in Vietnam until 1812, causing major differences between the two calendars for nearly 150 years (see Tables 3.6 and 3.7).

Table 3.6 Intercalary months in South Vietnam (KĐVNT), North Vietnam (BTK), Chinese (Chen, 1962) and Hoàng Xuân Hãn's calendars (calculated using the Da Tong-method – HXH) between 1623 and 1788, developed from Hoàng Xuân Hãn (1982: 64–65). Only differences between North and South Vietnamese calendars are bolded. See Sub-section 3.4.2.

Year		Vietnamese					Event dates from Vietnamese sources	
		Sou.	Nor.	HXH	Chinese			
1623	Quý Hợi	10	10	-	10		10	(TT, p. 6b BK vol.21)
1626	Bính Dần	6	6	-	6			
1629	Kỷ Tị	4	4	-	4			
1631	Tân Mùi	**12**	**11**	-	11			
1634	Giáp Tuất	8	8	-	8			
1637	Đinh Sửu	4	4	-	4			
1640	Canh Thìn	1	1	-	1		1	(TT, p. 35b BK vol.18)
1642	Nhâm Ngọ	11	11	-	11			
1644					Ming	Qing		
1645	Ất Dậu	6	6	6	6	6		
1648	Mậu Tý	3	3	3	3	4		
1650 1651	Canh Dần Tân Mão	11	11	11	11	2		
1653	Quý Tị	**8**	**7**	7	7	6		
1656	Bính Thân	5	5	5	5	5	5	(TT, p. 49a BK vol.18)
1659	Kỷ Hợi	1	1	1	1	3	1	(TT, p. 54b BK vol.18)
1661	Tân Sửu	10	10	10	10	7	10	(TT, p. 63b BK vol.18)
1662					Qing ↓			
1664	Giáp Thìn	6	6	6	6		6	(TT, p. 8b BK vol.19)
1667	Đinh Mùi	4	4	4	4			
1669 1670	Kỷ Dậu Canh Tuất	12	12	12	(12) →2		12	(TT, p. 25a BK vol.19)
1672	Nhâm Tý	8	8	8	7		8	(TT, p. 31b BK vol.19) (ĐNTL, p. 92 vol.1)
1675	Ất Mão	**6**	**5**	5	5			
1678	Mậu Ngọ	2	2	2	3			
1680	Canh Thân	10	10	10	8			
1683	Quý Hợi	6	6	6	6		6	"Cung phụng sắc lệnh tôn phong chuẩn cấp" stele

(continued)

Table 3.6 (continued)

Year		Vietnamese		HXH	Chinese	Event dates from Vietnamese sources	
		Sou.	Nor.				
1686	Bính Dần	**4**	**3**	3	4	3	(Lịch triều tạp kỷ, p. 98)
1689	Kỷ Tị	**3**	**1**	1	3	1	(ĐNTL, p. 107 vol.1)
1691	Tân Mùi	**7**	**8**	8	7	8	(ĐNTL, p. 114 vol.1)
1694	Giáp Tuất	5	5	5	5		
1697	Đinh Sửu	**3**	**2**	2	3		
1699	Kỷ Mão	**7**	**9**	9	7		
1702	Nhâm Ngọ	7	7	7	6	7	(ĐVSKTB, 2011, p. 54)
1705	Ất Dậu	3	3	3	4	3	(ĐVSKTB, 2011, p. 57)
1708	Mậu Tý	1	1	1	3		
1710	Canh Dần	8	8	8	7		
1713	Quý Tị	5	5	5	5		
1716	Bính Thân	**3**	**2**	2	3	2	(Lịch triều tạp kỷ, p. 204)
1718	Mậu Tuất	**8**	**10**	10	8	10	(ĐVSKTB, 2011, p. 74)
1721	Tân Sửu	**6**	**7**	7	6	7	(ĐVSKTB, 2011, p. 82)
1724	Giáp Thìn	4	4	4	4	4	(ĐVSKTB, 2011, p. 95)
1726 1727	Bính Ngọ Đinh Mùi	12	12	12	3		
1729	Kỷ Dậu	8	8	8	7	7[a]	(ĐVSKTB, 2011, p. 111)
1732	Nhâm Tý	4	4	4	5	4	(ĐVSKTB, 2011, p. 136)
1735	Ất Mão	3	3	3	4	*[b]	(ĐVSKTB, 2011, p. 146)
1737	Đinh Tị	11	11	11	9		
1740	Canh Thân	7	7	7	6	7	(ĐVSKTB, 2011, p. 172)
1743	Quý Hợi	4	4	4	4		
1745 1746	Ất Sửu Bính Dần	12	12	12	3		
1748	Mậu Thìn	9	9	9	7	9	(ĐVSKTB, 2011, p. 213)
1751	Tân Mùi	5	5	5	5		
1754	Giáp Tuất	2	2	2	4		

(continued)

Table 3.6 (continued)

Year		Vietnamese				Event dates from Vietnamese sources	
		Sou.	Nor.	HXH	Chinese		
1756	Bính Tý	11	11	11	9	12	(ĐVSKTB, 2011, p. 255)
1759	Kỷ Mão	6	6	6	6	6	(ĐVSKTB, 2011, p. 261) (ĐNTL, p. 178 vol.1)
1762	Nhâm Ngọ	4	4	4	5	4	(ĐVSKTB, 2011, p. 271)
1764 1765	Giáp Thân Ất Dậu	12	12	12	2	*[c]	(ĐVSKTB, 2011, p. 284)
1767	Đinh Hợi	9	9	9	7	9	(ĐVSKTB, 2011, p. 311)
1770	Canh Dần	5	5	5	5	5[d]	(ĐVSKTB, 2011, p. 338)
1773	Quý Tị	2	2	2	3		
1775	Ất Mùi	11	*11*[e]	11	10	11	(ĐVSKTB, 2011, p. 402)
1778	Mậu Tuất	6	6	6	6	6	(ĐNTL, p. 222 vol.1)
1781	Tân Sửu	5	5	5	5	5	(ĐNTL, p. 225 vol.1)
1784	Giáp Thìn	1	1	1	3	1	(ĐVSKTB, 2011, p. 461) (ĐNTL, p. 236 vol.1)
1786	Bính Ngọ	9	*9*	9	7	9	(ĐNTL, p. 243 vol.1)
1788	Lê Dynasty → Tây Sơn Dynasty						

[a] The book was misprinted from the 8th month to the 7th month (Lê Thành Lân, 1988: 79).

[b] In the 4th month, Venus occulted Mars (ĐVSKTB, 2011, p. 146) on 26 May (Okazaki and Tanokura, 2011: 78) which is in the intercalary 4th month of the Chinese calendar (Chen, 1962: 195), thus the Vietnamese calendar must have an intercalary month before the 4th month.

[c] A lunar eclipse occurred on the 1st month of year Ất Dậu (1765), which is on 7 March 1765 and is also recorded in a Chinese source as having occurred in the 2nd month (Okazaki, 2021a: 10, no.49). Thus, there must be an intercalary month before this date (and the two New Year dates were one month apart).

[d] The text says an intercalary 4th month after a record of a solar eclipse on the 1st day of the 5th month, which is reliable (Okazaki, 2021b: #1-92). Thus it should be an error: from intercalary 5th month to intercalary 4th month.

[e] Bách Trúng Kinh (A.2873) and Bách Trúng Kinh of Hoàng Xuân Hãn (A.2872?) have the same calendars from 1624 to 1785, but the former has lost the 1775-1776 pages and ends in 1785, while the latter contains these missing calendars (in italics) until 1799.

3.4.2 The Regime of the Nguyễn Lords (Cochinchina – South Vietnam) (1558–1802)

From the late sixteenth century, the Nguyễn Lords progressively seceded the Southern half of Vietnam (later called Cochinchina) from the Lê Dynasty (controlled by Trịnh Lords in the North). This lasted until 1802, when the country was unified under the Nguyễn Dynasty.

Fig. 3.4 From left to right: Covers of the Bách trúng kinh, the Khâm định vạn niên thư, and the Lịch đại niên kỷ bách trúng kinh.

The *Đại Nam thực lục* 大南寔錄 (ĐNTL – Chronicles of Đại Nam), compiled under the Nguyễn Dynasty, is the most important document covering the history of the Nguyễn Lords. It records events in relation with astronomical activities in Cochinchina. The scholar Đào Duy Từ (1572–634) is thought to be the author of the Southern calendar that came in use in 1631 or even earlier (see below). He had fled from the North and served Nguyễn Lords between 1625 and 1634; he is described as having "… thorough knowledge of the literature and history, as well as of astronomy and astrology." (ĐNTL, p. 46 vol.1). Other Northern officials who had surrendered to the Southern army in 1659 were members of the Tư Thiên Giám: Chu Hữu Tài and Observer Cổn Lương (ĐNTL, p. 79 vol.1). Another person named Nguyễn Quang Tiến is mentioned as being "… very knowledgeable about astronomy and calendar …" and had been promoted to the Royal Bureau (ĐNTL, p. 164 vol.1). Zhu Zhi Yu 朱之瑜—a refugee of the Ming Dynasty in Cochinchina—recorded in his memoirs 安南供役紀事 (Records of the service in Annam), in 1657, a brief conversation with a member of the calendar office (治曆局) (Zhu, 1936, p. 307).

The Nguyễn Lords used their own calendar (here called Southern Calendar, as opposed to the Northern Calendar of the Lê Dynasty) in their territory. It was called Vạn Tuyền from 1781, when Nguyễn Ánh (the last Nguyễn Lord and later first Nguyễn Emperor) declared himself as Vương (King) in 1780 (ĐNTL, p. 224 vol.1). The earlier name of this calendar is still unknown. KĐVNT, covering calendars from 1544 (when Nguyễn Kim, the ancestor of the Nguyễn Lords, had been promoted as Marshal) to 1903, contains the only evidence of this calendar. It shows differences from the Northern Calendar of the same period.

Table 3.7 Intercalary months of different calendars during the Tây Sơn Dynasty (1788–1802) in (LĐNKBTK) and early period of the Nguyễn Dynasty (1802–1812) in (KĐVNT). The Chinese calendar is based on Chen (1962). The Hoàng Xuân Hãn's calendar (HXH) was calculated using the Da Tong method (Hoàng Xuân Hãn, 1982).

Year		Vietnamese		HXH	Qing (Shi Xian)	Event dates from Vietnamese sources	
		Nguyễn (KĐVNT)	Tây Sơn (LĐNKBTK)				
1789	Kỷ Dậu	5	5	5	5	5	(ĐNTL, p. 265 vol.1)
1792	Nhâm Tý	2	4	2	4	2	(ĐNTL, p. 306 vol.1)
1794 1795	Giáp Dần Ất Mão	11	2	11	2	11	(ĐNTL, p. 337 vol.1)
1797	Đinh Tị	7	6	7	6	7	(ĐNTL, p. 382 vol.1)
1800	Canh Thân	4	4	3	4	4	(ĐNTL, p. 439 vol.1)
1802	Nguyễn defeated Tây Sơn						
1803	Quý Hợi	1		1	2	1	(ĐNTL, p. 580 vol.1)
1805	Ất Sửu	8		8	6	8	(ĐNTL, p. 680 vol.1)
1808	Mậu Thìn	6		6	5	6	(ĐNTL, p. 776 vol.1)
1811	Tân Mùi	2		2	3	2	(ĐNTL, p. 860 vol.1)
1812	Vạn Tuyền cal. (Da Tong) → Hiệp Kỷ cal. (Shi Xian)						(ĐNTL, p. 903 vol.1)

The first difference between Southern Calendar (retrieved from KĐVNT) and the Northern Calendar (retrieved from BTK) occurred in 1631, suggesting that the Southern Calendar was written no later than this date. Then, the two calendars displayed rare occasional differences in intercalary months (see Table 3.6) and day (not shown here) between 1631 and 1675. More differences occurred later, until 1725. But from 1725 to the end of BTK (1785), there exists only a single difference of an intercalary day in 1745.

Okazaki (2021b: Subsection 4.5.4) compared the Northern and Southern Calendars with the Chinese Da Tong Calendar in the period between 1631 and 1644 and found 10 new-moon-day differences in addition to an intercalary-month difference occurring in 1631 between the Southern and Chinese Calendars, compared with a single new-moon-day difference between the Northern and Chinese Calendars. He also reviewed erroneous records of solar eclipses between 1660 and 1720, a period with a high concentration of intercalary-month differences. He suggested that the Southern Calendar was using the same method of calculation as the Chinese Calendar but contained calculation errors and that solar eclipse records were based on predictions, not on observations.

Hoàng Xuân Hãn reported that from 1780 onwards, the dates of historical events were calculated using the Northern Calendar; at that time, Nguyễn Ánh (1762–1820) had been defeated and had fled from Gia Định (now Saigon or Ho Chi Minh city) before returning there in 1788, where he established his home base (Hoàng Xuân Hãn, 1982: 62). In 1796, a record of Nguyễn Ánh's words reveals that during the war of restoration, Nguyễn Ánh had his own astronomers (Lê Đức Lộc and Nguyễn Ngọc Lân) and was receiving calendars from the Qing Dynasty (ĐNTL, p. 362 vol.1). But our comparison of the Southern and Qing Calendars suggests that Nguyễn Ánh was probably not using the Qing Calendar, but the calendar that his astronomers were calculating, resulting in the differences that we have noted in this period (see Table 3.7).

3.4.3 Memoirs of the Missionaries

In the seventeenth century, the Jesuit missionaries came to Vietnam at a time when the country was divided. With their knowledge of science and their language proficiency, they soon gained confidence from the Lords and the people.

In his memoirs about Cochinchina, in 1621, Christoforo Borri (1583–1632) mentions the existence of schools where astronomy was taught to a large number of students. He also reported that when eclipses had been announced by the astronomers, at the predicted date, the Lords would wear a funeral dress and the court would gather together in the Palace, while people would gather in their villages and, when the eclipse started, they would kneel and pray in order to prevent "… the dragon from swallowing the Sun or the Moon."

Borri had predicted a lunar eclipse to occur on 9 December 1620 while the local astronomers had not. He made a bet with the local administrator and won. In these days, the Lord (who resided in the capital, now Quảng Trị) and his heir (in Quảng Nam) employed their own astronomers. The heir's astronomer had predicted this eclipse but one day too early while the Lord's astronomer had not. The missionary François de Pina (ca. 1585–1625) had told the heir's astronomer that his prediction was one day too early, but the astronomer did not trust him until the eclipse occurred. Borri explained the flaw in the method that had caused the wrong prediction. The Chinese astronomers had made the same mistake (Ming Shi Lu, pp. 15b-16a 熹宗 vol.3), suggesting that Vietnamese and Chinese astronomers were using the same method, or that the prediction of the Chinese astronomers had been communicated in advance to the Vietnamese astronomers (through Quảng Nam).

Another interesting story concerns a solar eclipse of 21 May 1621.[10] The local astronomers had predicted it would last two hours after having checked with Borri's book, but they had not noticed that it could not be observed from Cochinchina, a mistake for which they were punished (Borri, 1631: 124–134).

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[10] Borri erroneously recorded the date as 22 May 1621.

Volkov comments further on these two eclipses from another document: the letter of Gaspar Luiz. He then concluded that the Jesuits used Western science, especially astronomy, as a means for their missionary work. For more details, see Volkov (2008: 172–179).

The Trịnh Lords, who ruled Tonkin, were also paying attention to astronomy. Lord Trịnh Tráng (r. 1623–1657) invited Giuliano Baldinotti (1591–1631)—the first European to come to Tonkin—on the occasion of his visit in 1626 to teach him about "… the things of the sky." (Baldinotti, 1903: 72).

The most famous Jesuit missionary (for his contribution to the invention of the modern Vietnamese writing system), Alexandre de Rhodes (1591–1660), went to Tonkin in July 1627. His memoirs, *History of the Kingdom of Tonkin,* reported on a lunar eclipse that occurred after one Christmas and one Easter, namely the total lunar eclipse of 16 July 1628. The accuracy of his prediction made him regain confidence from the Trịnh Lord after having been suspected of being disloyal (de Rhodes, 1651: 195–196). The book also mentions the total solar eclipse of 21 June 1629 (de Rhodes, 1651: 237).

Giovanni Filippo de Marini (1608–1682) in his book dated 1663 (translated into French in 1666) gives a detailed description of the conception that the Vietnamese people had of eclipses. They thought that "… a dragon was devouring the Sun and the Moon …", and they used all kinds of instruments to fill the air with a din of noise and sounds meant to terrify and chase it away. He also describes the royal ceremony associated with solar eclipses: the King (the Emperor or the Trịnh Lord?) and the mandarins would gather together near a large pond and make demonstrations of sorrow during the time when the Sun was hidden. When it would shine anew, the King would recover his good mood and wash his face with water from the pond (de Marini, 1666: 181b–183a).

De Marini also relates how astronomy was being studied in Tonkin: They used to study astrology and the trajectories of the planets to know the date of "… the birth of the Moon …" (the new Moon), and to predict eclipses. But they could only predict the date of an eclipse, not its time. Moreover, they often made calculation errors. He mentions the case of an astronomer who had made a mistake of one day; he had to confess his error and learn more in order to keep his position as teacher of younger astrologers (de Marini, 1666: 182a–183a).

In commenting on Marini's text, Volkov (2008: 179–183) concludes that astronomy was practiced in both parts of Vietnam during the seventeenth century, but with no interaction with other astronomical systems, contrary to what was happening in China with interactions between the Chinese and Islamic systems.

Astronomy played an important role in social life in both North and South, but the authorities did not seriously consider reforming it when Western science appeared, in spite of the frequent errors made by the local astronomers. Volkov (2008: 183) explained this by the absence of a proficient, pro-Western progressive astronomer: the astronomers of the Lord and of his heir were instead busy competing with one another in order to gain political influence.

3.5 The Tây Sơn Dynasty (1788–1802)

The Tây Sơn Dynasty covers a short period dominated by the thirty-years civil war (1771–1802). After 1788, the Tây Sơn occupied the North and the Nguyễn Ánh the South. Hoàng Xuân Hãn (1982: 70) suggested that during this period the Tây Sơn used the Qing Calendar, and the Nguyễn Ánh the Southern Calendar, as mentioned above.

The handwritten calendar *Lịch đại niên kỷ bách trúng kinh* (LĐNKBTK) is the only known calendar surviving from this period (the Nguyễn Dynasty burnt nearly all documents related to the Tây Sơn). The BTK ended in 1786 and the KĐVNT covers only the Southern Calendar (Lê Thành Lân, 1987).

As shown in Table 3.7, the calendar in LĐNKBTK, during the period between 1788 and 1801, is very similar to the Chinese Shi Xian Calendar of the Qing Dynasty. We only found three differences of New Moon days in 1795, 1796 and 1800, and no difference of intercalary months. This suggested that the Tây Sơn Dynasty used to calculate their own calendar but using the same Shi Xian method as the Qing Dynasty. The Đại Nam thực lục is the official document (compiled by the Nguyễn Dynasty) covering this period, and it uses the Southern Calendar, which therefore kept using the Da Tong method during the war against the Tây Sơn Dynasty and after the reunification of the country in 1802 until the adoption in 1812 of the Shi Xian method used by the Qing Dynasty.

3.6 The Nguyễn Dynasty (1802–1945)

After having unified the country, Nguyễn Ánh (r. 1802–1820) became Emperor with the name of Gia Long and progressively brought the nation to a state that is seen today as one of the most glorious periods of the Vietnamese history. Many documents available today bear witness of these times.

3.6.1 The Calendar

In 1810, the diplomatic envoy Nguyễn Hữu Thận (1754–1831), upon returning from China, brought back the book *Lịch tượng khảo thành* 曆象考成 (*Study on the Observation of the Phenomena*) to Emperor Gia Long and proposed:

> Our Vạn Tuyền calendar, as the Shi Xian calendar of the Qing dynasty, has been using the Da Tong method introduced by the Ming more than 300 years[11] ago without any change.

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[11] The number 300 is not accurate, maybe due to the lack of information about the history of the calendar in Vietnam. And actually the Shi Xian calendar was using the Western method before the reign of Kangxi. It changed to the Da Tong method for the short period (1665–1668) under Oboi's order, but then changed back to the Western method, as mentioned above.

> The longer time, the bigger mistake. Under the reign of Kangxi (1662–1722), the Qing have adopted the Western method to calculate the calendar. It is very accurate, much more than the Da Tong method, and the trigonometry is very efficient. Please order the students of Khâm Thiên Giám (Royal observatory) to study this method, in order to regulate the celestial coordinates and fix the weather.

The Emperor agreed (ĐNTL, p. 834 vol.1) (Đại Nam liệt truyện, p. 6b vol.26).

It took then a couple of years for the new method of calculation to be used. In 1812, the Emperor promoted Nguyễn Hữu Thận as Deputy Supervisor of the Khâm Thiên Giám, in appreciation of his knowledge of astronomy (ĐNTL, p. 882 vol.1). The same year, on the occasion of the calendar distribution ceremony, the name of the calendar was changed from Vạn Tuyền to Hiệp Kỷ[12] (ĐNTL, p. 903 vol.1) became the official calendar from year 1813 onwards. Before this date, the Da Tong method had been used in Vietnam for over five centuries, from ca. 1301 to 1812.

In the foreword of his book on mathematics *Ý trai toán pháp nhất đắc lục*, Nguyễn Hữu Thận states that:

> Becoming an adult, [I] thoroughly studied the Da Tong calendar.[13] After having checked it for a long time, [I] started to realize [that it contained] many errors. Learning about the history of the calendar under the Ming dynasty, I found out that toward its end, and at the beginning of the Qing dynasty, [the method of calculation] was changed to the new Western method. People who got this book, only taught internally within their families. I often asked the friend who copied it, but was not accepted because of secrecy. In the year Kỷ Tị of the reign of Gia Long (1809), [I] was appointed head of the diplomatic mission and, by the way, kept in mind looking for it with no hesitation of expenditures, [finally] acquired the book *Lịch tượng khảo thành*. In my free time beside the duty, [I] immediately returned to the hotel, or stayed on the boat on the returning journey, to calculate tirelessly, started to realize the depth of calendar study. This whole book is complete and extraordinary without any more question. Back home, [I] immediately reported to the Court. In the year Quý Dậu of the reign of Gia Long (1813), [I] took part in the supervision of the work of the Khâm Thiên Giám and proposed to use the Hiệp Kỷ calendar. The method of calculation has been defined since then. (Ý trai toán pháp, pp. 1b,2a).

In 1820, the *Khâm định vạn niên th*ư was printed for the first time. Copies of his first version may still exist today; as reported in (Nguyễn Mậu Tùng, 1983: 17). However, the version in our possession is a later one, printed circa 1850 (Lê Thành Lân and Nguyễn Thị Trường, 2017b: 36). It was reprinted at least one more time in 1861 (ĐNTL, p. 569 vol.7). The first version possibly contains the 1544–1843 calendar. It was then extended 20 more years (until 1863) in 1831, and 40 more years (until 1903) in 1835 (Hội điển chính biên, p. 536 vol.8).

In 1822, it was proposed to calculate a "Seven objects[14] calendar" (ĐNTL, p. 191 vol.2) but this was only achieved in 1841, by Phạm Văn Lân and his team at the Khâm Thiên Giám and printed in the next year (Hội điển chính biên, p. 538 vol.8).

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[12] Like the calendar name in the Trần Dynasty, see Footnote 3.

[13] The calendar method that was used in Vietnam at that time.

[14] Thất chính 七政 (Seven objects): The Sun, the Moon, Mercury, Venus, Mars, Jupiter and Saturn.

This calendar was lost during the Battle of the Capital in 1885 and the Khâm Thiên Giám produced a new version in the next year (Hội điển tục biên, pp. 121,122 vol.10).

Chang Yung has compared the Qing pre-calculated calendar in *Wan Nian Shu* 萬年書 (1624–2020) printed in the reign of Dao Guang (1821–1850) with his version of *Bách trúng kinh* (A.2517). He found five differences in New Moon days in 1841, 1848, 1856, 1866 and 1869. He stated that from 1841 (from the reign of Emperor Thiệu Trị), Vietnamese used another calendar (Chang, 1940: 32). But as we continue the comparison after this year, KĐVNT has only three New-Moon-day differences with Chinese calendar in 1887, 1890 and 1896 (see Table 3.8) before its end in 1903. These rare and small differences suggested that Shi Xian method was still used in Vietnam, like in China. The small differences from 1841 in Table 3.8 are possibly due to the correction of the longitude of the Capital, which is used as the prime meridian for calendar calculation in 1837, as mention below in Subsection 3.6.5.

From 1883 onwards, the French colonized Vietnam, the Khâm Thiên Giám and the calendar were then given less attention. Beside the three perpetual calendars mentioned, the official distributed calendars also remain for some years: 1913, 1923, 1920, 1922, 1944 (in France), 1933, 1943, 1944 (in National Library of Vietnam), 1901, 1904, 1918, 1933 (in the library of the Institute of Sino-Nom Studies in Hanoi). The latter library also keeps a copy of the *Thành Thái bách niên lịch* 成泰百年歷 (100-year calendar from Thành Thái era) that includes a calendar covering the period from 1889 to 1989. However, this copy is considered unreliable; it is only the hand-written version of a low-level official.

In 1904, the Gregorian-lunisolar calendar was printed (ĐNTL VIb, p. 463 no.1282) in order to comply with French rule, but the traditional calendar kept being distributed throughout the dynasty, until 1945 (see Fig. 3.5).

3.6.2 Calendar Distribution

Right after regaining power in 1802, Emperor Gia Long ordered to produce the silver seal *Trị lịch minh* ***thì*** *chi bảo* 治曆明時之寶[15] (The Seal of regulating calendar and clarifying seasons) to be stamped on calendars distributed by the Court (ĐNTL, p. 553 vol.1). The silver seal was later replaced by a gold seal in 1827. In 1847, it was then replaced by another gold seal *Đại Nam Hiệp Kỷ lịch chi bảo* 大南協紀曆之寶 (Seal of the Hiệp Kỷ calendar of Đại Nam) (Hội điển chính biên, p. 545 vol.8) due to the naming taboo of the new Emperor Tự Đức whose first name Thì was forbidden to figure in the name of the former seal. These three seals are shown in Fig. 3.6.

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[15] 治曆明時 came from Yi Jing 易經 (Classic of Changes — one of the Five Classics of Confucianism): “君子以治歷明時” (The superior man, regulates the calendars and clarifies the seasons).

Table 3.8 Differences between the Vietnamese and Chinese calendars in documents during 1813–1903, developed from 表四 (Table 4) of Chang (1940: 32).

Year		Vietnamese			Chinese	
		(LĐNKBTK)	*BTK (A.2517)*	(KĐVNT)	(Wan Nian Shu)	(Chen, 1962)
1841	Tân Sửu	*Short 11* *Long 12*	*Short 11* *Long 12*	*Short 11* *Long 12*	Long 11 Short 12	*Short 11* *Long 12*
1848	Mậu Thân	*Long 11* *Short 12*	*Long 11* *Short 12*	*Long 11* *Short 12*	Short 11 Long 12	*Long 11* *Short 12*
1849	Kỷ Dậu	*Short 7* *Long 8*	*Short 7* *Long 8*	Long 7 Short 8	*Short 7* *Long 8*	Long 7 Short 8
1856	Bính Thìn	*Long 10* *Short 11*	*Long 10* *Short 11*	Short 10 Long 11	Short 10 Long 11	*Long 10* *Short 11*
1866	Bính Dần	*Short 3* *Long 4*	*Short 3* *Long 4*	Long 3 Short 4	Long 3 Short 4	*Short 3* *Long 4*
1869	Kỷ Tị	*Long 3* *Short 4*	*Long 3* *Short 4*	Short 3 Long 4	Short 3 Long 4	*Long 3* *Short 4*
1887	Đinh Hợi	(ended)	(unknown)	Short 2 Long 3	Short 2 Long 3	*Long 2* *Short 3*
1890	Canh Dần		(ended)	Short 6 Long 7	Short 6 Long 7	*Long 6* *Short 7*
1896	Bính Thân			(Long 12) Short 1	(Long 12) Short 1	*(Short 12)* *Long 1*

Emperor Gia Long started to celebrate the *Calendar distribution ceremony* (Lễ ban sóc) in 1790 in Gia Định (ĐNTL, pp. 289-290 vol.1). In 1802, he held the first official ceremony in the capital Phú Xuân (now Huế) on the occasion of the reunification of the country (ĐNTL, p. 575 vol.1). The *Quốc sử di biên—Nineteenth Century Private History Book*—recorded this event and described the contents of the distributed calendar. It listed propitious and unfavourable days, including what had to be avoided and was sealed with *Trị lịch minh thì chi bảo*. The ceremonial days were printed in red (Quốc sử di biên, p. 49).

From 1806 onwards, the calendar distribution ceremony was scheduled on the 1st day of 12th month of the preceding year (ĐNTL, p. 726 vol.1). And from 1809 onwards, in the 4th month, advanced copies of the calendar for the following year were sent to Gia Định (now Ho Chi Minh city, the sub-capital of the South), and Bắc Thành (now Hanoi, the sub-capital of the North), to be printed. In the 10th month, the covers were sent to the capital to be sealed by the Khâm Thiên Giám. The Central Provinces were given their copies directly from the Khâm Thiên Giám in advance in order to distribute the calendars on the same day as the distribution ceremony in the capital (1st day of 12th month) (ĐNTL, p. 797 vol.1).

The calendars used high-quality paper for the printing and also were well-decorated. There were two types of official calendars: *Bảo lịch* (calendars marked with the royal gold seal), and *giám lịch* (calendars marked with the seal of Khâm Thiên Giám). The numbers of calendar of each type being distributed depended on the receiver. There were also some special editions that were reserved solely for

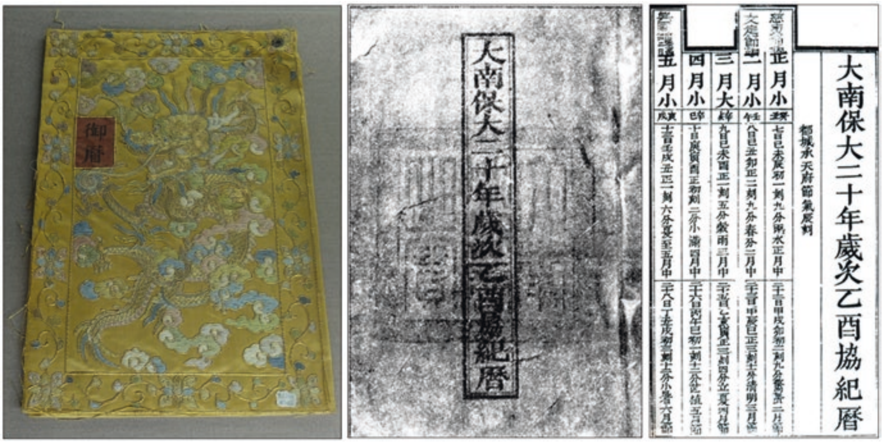

Fig. 3.5 Left: Cover of the ngự lịch (calendar reserved for the Emperor). Center: Cover with name and impression of the seal Đại Nam hiệp kỷ lịch chi bảo. Right: the first page of the last Royal Hiệp Kỷ calendar of 1945 (after Hồ Vĩnh, 1998: 16).

members of the Royal Family and for temples. The Emperor also had a unique edition called *ngự lịch* (The Calendar only reserved for the Emperor). Its cover was made of gold silk fabric and decorated with dragons in clouds (see the leftphand image in Fig. 3.5). Vassal states also receive calendars as a sign of domination of the Vietnamese empire (Hội điển chính biên, p. 528 vol.8). Starting in 1845, the distributed calendars included 24 poems of Emperor Thiệu Trị (Hội điển chính biên, pp. 539-544 vol.8).

3.6.3 The Staff of the Khâm Thiên Giám

Nguyễn Hữu Thận was not promoted as Supervisor of the Khâm Thiên Giám in 1812, possibly because this position was usually given to a Minister upwards, while Nguyễn Hữu Thận was of a lower grade at that time. He was later appointed to Bắc Thành (now Hanoi) in 1816 (ĐNTL, p. 915 vol.1). But the next year, having correctly predicted the solar eclipses of May and November 1817, he could return to the capital where he served as Minister (ĐNTL, p. 1020 vol.1). He was appointed as Supervisor of the Khâm Thiên Giám from 1822. He is recalled as having been "… knowledgeable of calendar, proficient in calculation, invincible in astronomy." (Đại Nam liệt truyện, pp. 8a-9a). He is also a leading mathematician in Vietnamese history through his work *Ý Trai toán pháp nhất đắc lục* 意齋算法一得錄 (*Record of Mathematic Notes of Ý Trai*—his pen name).

Another skillful astronomer of the Nguyễn Dynasty was Trương Quốc Dụng (1797–1864). He served in the Khâm Thiên Giám between 1857 and 1862, and has been quoted as having restored the method of calendar calculation after it had been

Fig. 3.6 Left: Trị lịch minh thời chi bảo silver seal made in 1802; Center: its golden version made in 1827, Right: Đại Nam Hiệp Kỷ lịch chi bảo golden seal made in 1847 (Nguyễn Đình Chiến, Phạm Quốc Quân, & Nguyễn Công Việt, 2009).

lost (possibly after Nguyễn Hữu Thận, at a time when the country was missing talented astronomers).

Also in 1812, on the occasion of the new calendar Hiệp Kỷ, new Khâm Thiên Giám staff were appointed. Besides Nguyễn Hữu Thận as Deputy Supervisor, Hoàng Công Dương was appointed as Deputy Head and 11 other staff members as astronomers (Quốc sử di biên, p. 133). Hoàng Công Dương was then promoted to Head of the Khâm Thiên Giám for nearly 30 years (ca. 1819–1845). By 1943, there were only three officials left: the Head named Hoàng Thiện and two clerks (Nguyễn Văn Hà and Lê Văn Thái). Hoàng Thiện may have been a descendant of Hoàng Công Dương and was the last Head of the Khâm Thiên Giám (until 1945). In 1954, after retaking the throne as the Chief of the State of Vietnam, Emperor Bảo Đại (the last Nguyễn Emperor) invited him to continue the calculation of calendar. The lunisolar calendar of year 1954 was also called Hiệp Kỷ as a mark of continuity from the Nguyễn Dynasty (Hoàng Thiện, 1954). The staff of the Khâm Thiên Giám during the nineteenth century are listed below in Table 3.9.

From 1824 onwards, there were branches of the Khâm Thiên Giám in each province, called "Chiêm hậu ty" and led by a lower 7th grade Linh đài lang (Timekeeper) from 1824 (ĐNTL, p. 276 vol.2).

The staff of the Khâm Thiên Giám was mostly recruited on recommendation of local officials. The candidates were summoned to the capital to take an examination, before being promoted (Hội điển chính biên, p. 530 vol.8).

3.6.4 The Observatory (Quan Tượng Đài)

The Royal Observatory, officially called *Quan Tượng Đài* 觀象臺 (Base for Observing Phenomena), and being located at the southernmost (southwestern) corner of the capital citadel, was commonly called *Nam Đài* 南臺 (South base). It had been built in 1827 topped by the richly decorated *Bát Phong Đình* 八風亭 (Eight-direction wind pavilion) (ĐNTL, p. 451 vol.2). Two years after construction, it had to be repaired (Hội điển chính biên, p. 78 vol.7). The ground floor was 5.9 m high, the front face measures 18.65 m wide at the base and 16.8 m wide at the top. The base was made of bricks with an 8.2 m wide entrance porch accessed by gently sloped stairs ((Phan Thuận An, 1999: 233). Such wide stairs, in comparison with the top floor, suggest that the Observatory was meant to host large and heavy instruments (see Fig. 3.7).

The maps of Huế, most of which have been shown in the *Bulletin of Friends of the Old Hue No.1–2 January-June 1933* (BAVH 1-2, 1933, p. 66) usually mention the Quan Tượng Đài as a featured building in the Southwest corner of the citadel (see Fig. 3.8).

3.6.5 Office of the Khâm Thiên Giám

The office of the Khâm Thiên Giám was first built in 1822, close to the Quan Tượng Đài in Nam An commune (Hội điển chính biên, p. 102 vol.7) located south-west of the citadel (Phan Thuận An, 1999: 232). It was later moved to another place in the same commune in 1832 (ĐNTL, p. 293 vol.3). This location is indicated on most of the maps listed in Table 3.10. In 1856, the office was enlarged to host the astronomy school and the calendar printing house (Hội điển tục biên, p. 120 vol.10).

After the French established an observatory in Vietnam, the Quan Tượng Đài was no longer important, and the office of the Khâm Thiên Giám did not need to be close to the observatory anymore. The office was later moved to its present location in 1918 (ĐNTL VII, p. 217 no.0413) (Nguyễn Bá Trác, 1963: 364)—No.231bis in Planche XXX[16] (BAVH 1-2, 1933, p. 130). Hoàng Xuân Hãn reported his visit to the office in 1943, two years before the end of the Nguyễn Dynasty. There were not many things left in the office at that time, just a few old books and a large abacus (Hoàng Xuân Hãn, 1982: 69). It is used today to provide accommodation for a

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[16] This place formerly belonged to the palace of Emperor Đồng Khánh before his coronation (1885). In 1892, the temple of Medicine and the Royal Medicine Department moved to this place, and remained there until 1903 (ĐNTL VIb, p. 153 no.0300).

Fig. 3.7 (a): Photograph of Quan Tượng Đài ca.1916; (b): Picture of the Southwest corner of the citadel drawn by Tôn Thất Sa c.1924; (c) Ruins of Bát Phong Đình in 2012; The rest: Quan Tượng Đài and Bát Phong Đình after the restoration in 2013, source: kienthuc.vn.

family. The main hall has become a humid and dirty storage place. On the wall, a star chart can still be recognized. Two other charts related to solar and lunar eclipses, on opposite sides of the room, are nearly wiped away. Right above the main entrance, the wooden name plate is still hanging but half of it has fallen off (see Fig. 3.9).

Table 3.9 Staff of the Khâm Thiên Giám during the Nguyễn Dynasty, with titles, grades and numbers of positions (u. = upper, l. = lower).

	Secretary	Manager	Observer	Timekeeper	Clerk*		Staff	Source
Title	Câu kê ↓	Cai hợp ↓	Chiêm hậu ↓				Chiêm hậu sinh ↓	(Hội điển chính biên, p. 529 vol.8)
1802	1	1	3				50	
1805	Giám chính ↓ (Head)			Thủ hợp ↓			Vị nhập lưu ↓	
	l.5th 1		l.5th 3	u.7th 1				
1824		Giám phó ↓ (Deputy Head)		Linh đài lang ↓	Thư lại ↓			(ĐNTL, p. 276 vol.2)
	u.5th 1	l.5th 1	l.5th 1	l.7th → u.7th 2	8th 4	9th 4		
1827	u.5th	l.5th	Ngũ Quan Chính↓ u.6th	u.7th	u. 8th 4	u. 9th 4		(ĐNTL, pp. 508-509 vol.2)
1837							30	(Hội điển chính biên, p. 529 vol.8)
1842							20	(ĐNTL, p. 305 vol.6)
1850	1	2	4	2	4	4	20	(ĐNTL, p. 143 vol.7)
1868		2	3	3	4	4	15	(ĐNTL, p. 886 vol.7)
1884			3		3	3	8	(Hội điển tục biên, p. 110 vol.10)
1886	1	2	2	2	3	3	8	(ĐNTL, p. 180 vol.9)
							15	(Hội điển tục biên, p. 110 vol.10)
1887	1	2	2	2	2	2	10	(ĐNTL, p. 257 vol.9)
1891							10	(Hội điển tục biên, p. 110 vol.10)

*The clerk board was first called "Chiêm hậu ty", then "Kính cẩn ty" in 1829 and "Khác cẩn ty" in 1834. It kept this name until the end of the Nguyễn dynasty (1945) (Hội điển chính biên, p. 529 vol.8).

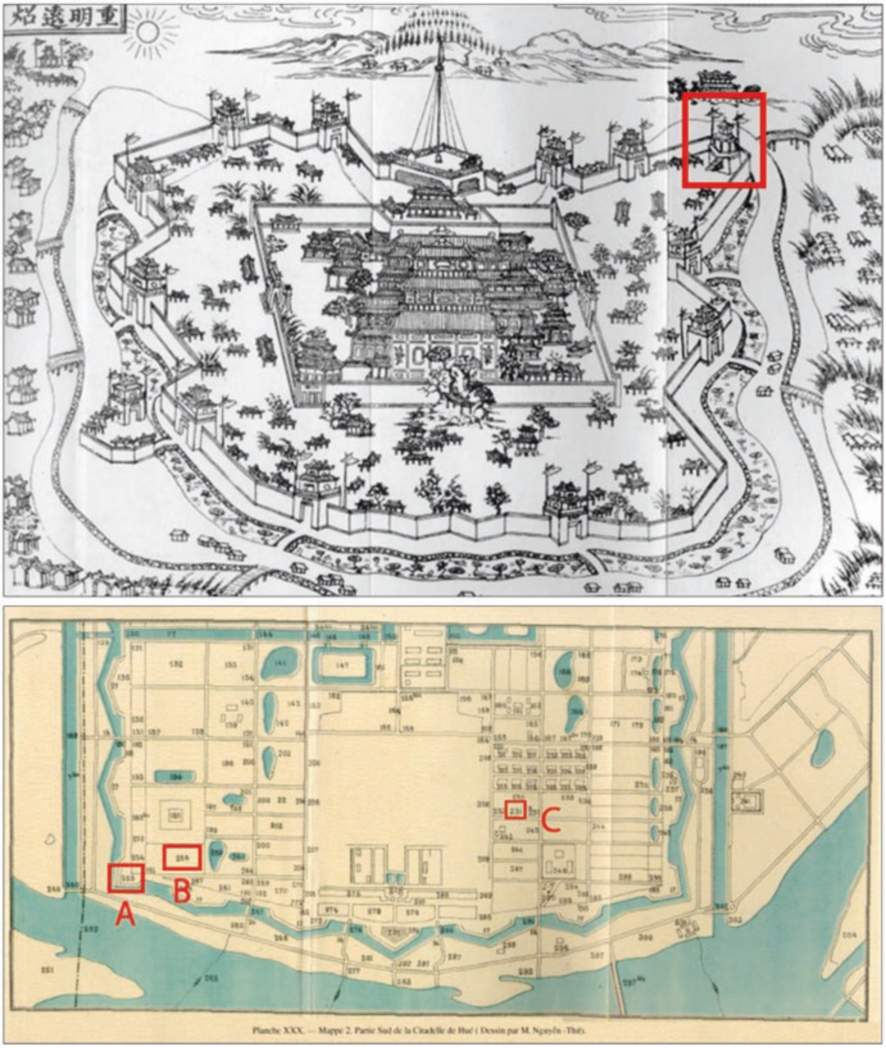

Fig. 3.8 Top: The earliest illustration of the Quan tượng Đài (in the red rectangle) appeared in Planche XXVII. It is originally a bronze plate presenting 1 of 20 most beautiful features of the Capital, selected and given poems by Emperor Thiệu Trị (Thần kinh nhị thập cảnh, 1997). Bottom: The location of Quan tượng đài (A) and Khâm Thiên Giám (B–before 1918, C–after 1918) within the capital citadel of Huế in Planche XXX (BAVH 1-2, 1933, p. 130).

The *Đại Nam thực lục* lists the instruments that were at the Khâm Thiên Giám:

- Sand clock (1822): 10 (ĐNTL, p. 192 vol.2)
- Solar scope (1825): 3 (ĐNTL, p. 345 vol.2)
- Telescope (1825) 1 big, 1 normal (ĐNTL, p. 345 vol.2)
- Thermometer (1826): 1 (ĐNTL, p. 412 vol.2)
- Barometer (1826): 1 (ĐNTL, p. 412 vol.2)
- Monocular (1827): 1 (ĐNTL, p. 487 vol.2)

The *Đại Nam hội điển* gives a more detailed list (Hội điển chính biên, pp. 531, 532 vol.8):

- In the left-hand-side lobby of the Cần Chánh Palace: sand clock, timekeeping bell, clock bell, sundial, ruler, gnomon, gnomon shadow ruler with compass, western baro-thermometer, microscope, mercury, black crystal cup, western compass, hanging sundial, celestial ruler, thermometer and timekeeping ivory tag.
- In the office: sand clock, round and square shape basins, gnomon, gnomon shadow ruler, western baro-thermometer, soil basin, microscope, celestial map, thermometer and monocular.
- In the observatory: timekeeping flag, anemometer, sundial and gnomon.

3.6.6 Astronomical Observations and Calculations

In 1803, a gnomon was erected in the yard of the Royal Palace (ĐNTL, p. 553 vol.1). In 1830, the Khâm Thiên Giám measured the gnomon shadow length in the capital and reported to the Emperor (ĐNTL, p. 47 vol.3), but the report was not properly archived. In the middle of the nineteenth century, Trương Quốc Dụng measured the gnomon shadow length in the capital, Huế, on the day of the summer solstice: a Sun zenith distance of 7° and a shadow length of 9 cun 4 fen (Sử học bị khảo, p. 96), in agreement with Huế's latitude of 16° 22′. The *Sử học bị khảo* mentions also the calculated sunrise and sunset times in Huế for a full year (Sử học bị khảo, pp. 106-107).

In 1820, the sunset and sunrise times were calculated by applying the longitude and latitude for each province. From 1826 onwards they were printed in the calendar. In 1828, Emperor Minh Mạng (1791–1841) himself measured the altitude of Polaris from the capital and found that the previously-accepted figure of 18° 3′ was inaccurate due to a wrong calibration of the instrument; the correct value was 16° 22′ 30″. He then ordered astronomers to use the Huế meridian as the origin for longitude determinations throughout the country, knowing that Huế was 105° east of the Greenwich meridian (Hội điển chính biên, p. 527 vol.8). The new coordinate system was adopted for the first time in the 1839 calendar (the 1829–1838 calendars had already been printed when Minh Mạng gave the order to adopt the new system) (Hội điển chính biên, pp. 533, 534 vol.8). The measured latitudes and longitudes of provincial branches of the Khâm Thiên Giám's are listed in Table 3.11. The method used to measure longitudes was by comparing the occurrence times of lunar eclipses (Sử học bị khảo, p. 91).

Table 3.10 Maps collected in BAVH No.1–2 of 1933 with signs marking the location of Quan Tượng Đài and Khâm Thiên Giám.

Year	Quan Tượng Đài	Khâm Thiên Giám	Map in (BAVH 1-2, 1933, p. 66)
1845	x		Planche XXVII (Ngự đề đồ hội thi tập)
1867	x		Planche III (Chaigneau, 1867, p. 179)
1875	x	x	Planche VII (J.Sambet)
1884	x	x	Planche VIII (L. du Génie Jullien)
c.1884	x	x	Planche IX (L. du Génie Jullien)
c.1885		x	Planche X (L. du Génie Jullien)
1885	x	x	Planche XI (Perrier)
1909	x		Planche XVII (Association des Amis du Vieux Hué)
1910	x		Planche XVIII (Trương Sĩ Tế)
1910	x	x	Planche XIX (Đại Nam nhất thống chí, 1909, p. 19 vol.1)
1914	x	x	Planche XX (Eberhardt, 1914)
1919	x	x	Planche XXI (École Professionnelle de Hué)
1920	x	x	Planche XXII (Hộ Thành)
1930	x	x	Planche XXV (Bureau officiel du Tourisme de Hué)

Fig. 3.9 Relics of the last office of the Khâm Thiên Giám. From upper left clockwise: The gate with the script "Gate of the Khâm Thiên Giám"; view of the main hall; a star chart on the left wall of the hall; the wooden name plate saying "Khâm Thiên Giám".

The Khâm Thiên Giám sometimes failed to predict an eclipse that had been announced by the Qing Dynasty (ĐNTL, p. 741 vol.1), and the astronomers were punished in such cases, as for the solar eclipse of December 1852 (ĐNTL, p. 119 vol.7). The *Sử học bị khảo* states the calculated dates of the occurrence of eclipses in 1881, obtained from the motion of La Hầu (*Rahu*) and Kế Đô (*Ketu*), the two nodes of the lunar orbit (Sử học bị khảo, pp. 132-134).

Emperor Minh Mạng paid much attention to astronomy, with which he was familiar. He often oversaw the work of the Khâm Thiên Giám and discussed it with the supervisors. In 1838, he spent a full night checking the drums announcing each hour, and noted many errors. He punished the responsible staff and ordered them to produce a timetable of sunset and sunrise times for a whole year (Hội điển chính biên, pp. 554-555 vol.8). In 1839, after having seen a Western star chart, he complained that the Milky Way was shown as a real river, which was "silly", he said. He explained that it actually is the accumulation of many faint stars forming what looked as a river (ĐNTL, p. 416 vol.5). When the Khâm Thiên Giám predicted the solar eclipse of 4 March 1840, he also complained that the Chinese ritual of 'saving the Sun and the Moon' by making noise with drums and showing repentance during eclipses was unreasonable (ĐNTL, p. 446 vol.5). At the time of this eclipse, it was raining and the Sun could not be observed. The astronomers wanted to honour the Emperor by claiming that the eclipse had not occurred because he had shown his repentance (actually it was only a partial eclipse and the cloudy sky did not get much darker), but Minh Mạng refused the compliment and said that if the eclipse had occurred, it must have been observed from other places and that if it had not, the astronomers must have made an error in their calculations. Later, some regions reported the eclipse, while others did not, because of the rain (ĐNTL, p. 499 vol.5). In 1840, the Emperor claimed that the astronomers were unable to use their telescopes properly and ordered them to practice (ĐNTL, p. 572 vol.5).

Emperor Tự Đức (1829–1883) also was interested in astronomy and in 1860 he had a long discussion with the astronomers about the appearance of Venus during the daytime, but their answers did not satisfy him (ĐNTL, pp. 506-508 vol.7). Indeed, he found the level of their knowledge quite low.

The teaching program of the Khâm Thiên Giám was established in 1856 (Hội điển tục biên, p. 119 vol.10) as shown below:

- Calendar calculation:

  1st year: Hiệp Kỷ calendar calculation
  2nd year: Seven objects calendar calculation
  3rd year: Eclipses calculation and hemerology

- Astronomy:

  1st year: Twenty-eight mansions and other stars

Table 3.11 Latitude and longitude values for provincial centres, measured by Khâm Thiên Giám in 1837 (Sử học bị khảo, pp. 91-93), with adjustment (Hội điển chính biên, pp. 533,534 vol.8). With longitude, a positive value is to the east and a negative value to the west of the capital.

Province	Latitude		Longitude (from the Capital)	
	°	′	°	′
Capital (Huế)	16	22	--	--
Quảng Trị	16	17	–0	21
Quảng Bình	17	17	–0	53
Hà Tĩnh	18	5	–1	30
Nghệ An	18	31	–1	42
Thanh Hóa	19	26	–1	40
Ninh Bình	19	46	–1	29
Nam Định	19	56	–1	20
Hưng Yên	20	26	–1	26
Hải Dương	20	26	–1	12
Quảng Yên	20	29	–0	49
Hà Nội	20	32	–1	28
Sơn Tây	20	36	–1	55
Bắc Ninh	20	40	–1	26
Hưng Hóa	20	41	–2	7
Thái Nguyên	21	2	–2	30
Tuyên Quang	21	10	–2	25
Lạng Sơn	21	17	–0	50
Cao Bằng	22	0	–1	18
Quảng Nam	15	49	+0	43
Quảng Ngãi	15	3	+1	14
Bình Định	14	15	+1	35
Phú Yên	13	24	+1	41
Khánh Hòa	12	20	+1	29
Bình Thuận	11	19	+1	2
Biên Hòa	10	51	–0	26
Gia Định	10	43	–0	31
Định Tường	10	18	–0	49
Vĩnh Long	10	7	–1	9
An Giang	10	31	–1	56
Hà Tiên	10	17	–2	33
Trấn Tây (Cambodia)	11	25	–2	8

2nd year: Three Enclosures 三垣

3rd year: Five planets position and Chinese and Western constellations' "territories"

3.7 Twentieth Century French Astronomy in Vietnam

During the French occupation, an observatory was built in 1902 on top of Phù Liễn Hill in Hải Phòng, on the northern coast of the Gulf of Tonkin with the name of Central Indochina Observatory (see Fig. 3.10). Astronomer Georges le Cadet (1864–1933) was Director for nearly 20 years (1907–1925), the Observatory being simply equipped with a modest 12-cm telescope (Lagrula, 1935: 388). Le Cadet was succeeded as Director by Paul Carton (1927–1936).

The French also sent an expedition to observe the 1929 solar eclipse from Poulo Condor (now Côn Sơn island) in the South of Vietnam (Fig. 3.11). The team was led by André-Louis Danjon (1890–1967), with participation of André Lallemand (1904–1978) and Gilbert Rougier (1886–1947).

The 1945 Revolution marked the end of the Nguyễn Dynasty and also the feudal era in Vietnamese, as well as the historical function of the Khâm Thiên Giám.

3.8 Astronomical Calendars of Ethnic Minorities

Beside the Mường calendar presented in Section 3.1, there are some other ethnic minorities in Vietnam that have their own calendars. Many minorities in the Central Highlands, e.g. Jarai, Stieng, Ta-oi, Sedang, Cor, etc., use the 10-month calendar like the old Mường calendar. The interval of more than two months to complete a full year is for resting after the agricultural crops have been harvested.

Thai people in the northwest of the country use calendars that have 12 months, but differ from the Vietnamese calendar by six months. They also inherited the Chinese sexagenary system (10 stems and 12 branches) to name the year.

The Cham people, an Austronesian ethnic group that in the past established a splendid kingdom in Central Vietnam, also have their own calendar that is still used today. The Cham calendar first used the Saka calendar from India until the fiftenth century (and the fall of the Vijaya Kingdom in 1471), and evidence of this is found on inscriptions (Sakaya, 2016: 30–31). Later, with the spread of Islam, the Sakawi calendar was used, which was derived from the Saka (Indian) and Jawi (Muslim) calendars.

One day is divided into 8 hours, and there is a week with 7 days (inherited from the Indian calendar). One month has 29 and 30 days alternatively, and the days are counted from the New Moon day (from 1 to 15) then from the Full Moon day (from 1 to 14 or 15). The Cham calendar also imported the twelve branches (地支）from China to name the year. Later, they combined these twelve with eight terms from the Javanese calendar (Alip, Ehe, Jimawal, Je, Dal, Be, Wawu, Jimakhir) for counting years (Sakaya, 2016: 56–58).

The Cham community is divided into two main groups according to religion: Ahier (Hindus) and Awal (Moslems). Their calendars also differ. The Awal calendar is a lunar calendar, and is used to set the three intercalary days in one 8-year cycle

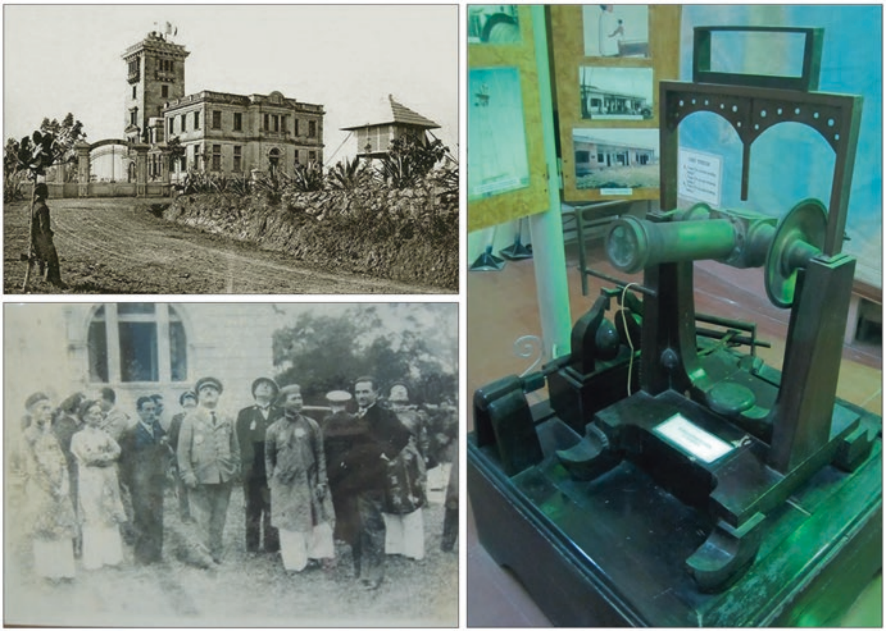

Fig. 3.10 Upper left: Central Indochina Observatory on top of Phù Liễn Hill, now the meteorology station of the North Eastern region. Lower left: Emperor Bảo Đại visits the observatory. Lower right: the Observatory's transit telescope is now on display.

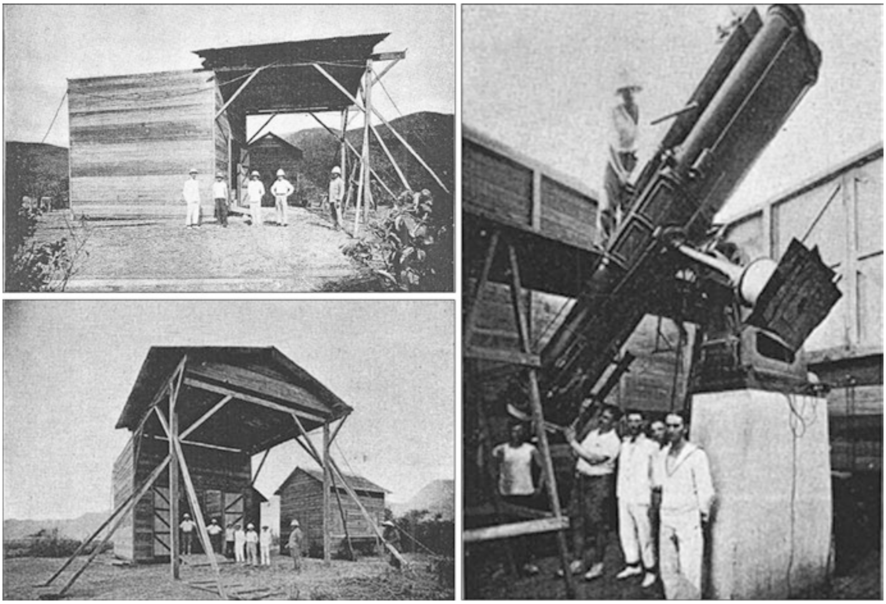

Fig. 3.11 The French observing station at Poulo Condor for the 9 May, 1929 total solar eclipse (castel.oca.eu).

to follow the lunation. Because it does not follow the tropical year, it cannot be used for agriculture, only for religious ceremonies. The names of the months are also derived from Muslim names (Sakaya, 2016: 61–76).

The Ahier calendar has 12 months each year with the first 10 months named by cardinal numbers and last two months derived from the Indian month (Sakaya, 2016: 48–52). This scenario is quite similar to the above-mentioned Mường calendar. The Ahier calendar is calculated based on the Awal calendar. But because it is a lunisolar calendar, it also has to follow the year. It uses 'bituk bingu rung' (the Pleiades), 'bituk caow' (Scorpius) and 'bituk lingal' (Orion's belt) as the milestones to follow the sidereal year, by setting three intercalary months of 29 days in one 8-year cycle (Sakaya, 2016: 87–96).

The calendar of the Khmer people in the Mekong delta has many similarities with the Cham calendar. It counts the days in the waxing and waning phases of the Moon separately. The number of day in a month is alternatively 29 and 30 days.

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Appendix: Old Vietnamese Astronomy Books Preserved in the Library of the Institute of Sino-Nom Studies (ISNS) and the National Library of Vietnam (NLV).

Book	Author	Year	Code	Library
Reference Book				
Vân đài loại ngữ	Lê Quý Đôn	1773	R.118	NLV
Tham khảo tạp kí	Phạm Đình Hổ	1777(?)	A.939	ISNS
Sử học bị khảo	Đặng Xuân Bảng	late 19th c.	A.1490	
Thiên nam tiện lãm	Đoàn Cao Đệ	1907	A.78	
Quốc triều thiên văn chí (Thiên văn chí lược biên)		late 19th c.	VHv.370	
Thiên văn loại lược biên			A.1664	
Thiên văn thể			A.1366	
Thiên văn lịch			VHv.1012	
Textbook				
Khải đồng thuyết ước	Phạm Vọng	1853	R.562	NLV
Ấu học phổ thông thuyết ước	Phạm Quang Xán	1903	VHv.64	ISNS
Perpetual Calendar				
Bách trúng kinh (tích niên thư)		mid 18th c.	A.2873	ISNS
Lịch đại niên kỷ bách trúng kinh		copied c.1904	A.1237	
Khâm định vạn niên thư		c.1850	R.2200	NLV

Besides, not listed here are the Chinese-Vietnamese dictionaries by categories, that take astronomy as its first category, and the remained Royal Calendars that are mentioned earlier in this chapter.

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Chapter 4
Solar and Lunar Eclipse Records in Vietnam from Ancient Times Through to the Nineteenth Century

Akira Okazaki

4.1 Introduction

Some Vietnamese historical sources contain a moderate number of astronomical records. For example, Ho (1964) and Okazaki and Yokoo (1983) found astronomical records in such Vietnamese sources. However, very few studies have been published so far of the examination of these records by comparing them with the results obtained using modern astronomical computations. In these circumstances, Okazaki and Tanokura (2011) examined lunar occultation and planetary phenomena records in Vietnamese sources. We focus here on solar and lunar eclipse records contained in the following three Vietnamese historical sources: *Việt Sử Lược* (*VSL*), *Đại Việt Sử Ký Toan Thư* supplemented by *Đại Việt Sử Ký Tục Biên* (*TT&TB*) and *Đại Nam Thực Lục* (*ĐNTL*).

Ho (1964) surveyed natural phenomena records in the *TT* (the *TT&TB* without the *TB*), and found 69 solar and 34 lunar eclipse records. Okazaki and Yokoo (1983) searched astronomical records in the *VSL*, and found six solar and no lunar eclipse records. The above two studies listed their collected eclipse records, giving individual brief remarks to them. However, neither of these works made a detailed discussion of those eclipse records. Moreover, as far as we know, no systematic survey has been reported so far of astronomical records in the *ĐNTL*, which is another important historical source covering a period after the time described by the *TT&TB*.

In this chapter, we present the results of our survey for solar and lunar eclipse records in the *VSL*, *TT&TB* and *ĐNTL* and make an extensive discussion of these eclipse records, based on our recent studies (Tanokura and Okazaki, 2011; Okazaki and Tanokura, 2012; Okazaki, 2013, 2017, 2021) and our further investigations.

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In Section 4.2, we briefly mention the Vietnamese historical sources that we survey for solar and lunar eclipse records. In Section 4.3, we provide a brief overview of the luni-solar calendar used in Vietnam until the mid-nineteenth century. In Section 4.4, we present the results of our survey. In Section 4.5, we discuss the eclipse records collected in our survey from several points of view: the reliability of these eclipse records; their relation to luni-solar calendar-making methods; whether they were based on observations or predictions; the low reliability of solar eclipse records in the *ĐNTL-TB*; and the beginning of the day as inferred from lunar eclipse records. A summary is given in Section 4.6. We list all the solar and lunar eclipse records, including their original texts in classical Chinese, collected in our survey in the Appendices of this chapter.

4.2 Three Vietnamese Historical Sources

In this section, we briefly mention the three Vietnamese historical sources that we surveyed for solar and lunar eclipse records. These sources were written in classical Chinese, as were those in some East Asian countries in the same period.

Việt Sử Lược (越史略, *Abridged Chronicles of Viet*, *VSL*) is a historical text that is believed to have been compiled finally in the fourteenth century. Although the original edition of the *VSL* perished in Vietnam, its reprints are preserved in a few Chinese library series, such as the *Siku quanshu* (四庫全書) and *Shoushange congshu* (守山閣叢書). It covers the period from the late third century BCE to 1225 CE. In our survey, we used the *VSL* contained in the *Shoushange congshu* in the collection of the Institute of Oriental Culture, at the University of Tokyo.

Đại Việt Sử Ký Toan Thư (大越史記全書, *Complete Annals of Great Viet*, *TT*) is the official history of the Later Lê dynasty and other earlier dynasties. The *TT* had been compiled by court historians of the Later Lê Dynasty intermittently from the fifteenth century through to the seventeenth century. It covers the period from ancient times to 1675. The period is extended to 1789 (the end of the Later Lê dynasty) by the text entitled *Đại Việt Sử Ký Tục Biên* (大越史記續編, *Sequel of Annals of Great Viet*, *TB*), which had been compiled also by court historians, though it was not officially published by the Dynasty. Considering this situation, we will often deal with both the texts as a single one (*TT&TB*) in this chapter. Chen (1984–1986), who conflated several existing versions of the *TT* and *TB* and published a comprehensive unified edition of the *TT&TB*, which we used in our survey.

Đại Nam Thực Lục (大南寔録, *the Veritable Record of the Great South*, *ĐNTL*) is the official history of the Nguyễn Dynasty, which ruled Vietnam from the early nineteenth to the early twentieth century. The early part, called *Tiền Biên* (前編, *the Prequel Records* [or *the Early Volumes*]), of the *ĐNTL* (*ĐNTL-TB*) is the annals of the Nguyễn Lords, who governed the southern part of Vietnam from the mid-sixteenth through to the late eighteenth century, having a hostile relationship with the Later Lê Dynasty. Their descendants established the Nguyễn Dynasty later on. The main part, called *Chính Biên* (正編, *the Principal Records* [or *the Main Volumes*]), of the *ĐNTL* (*ĐNTL-CB*) is the annals of the Nguyễn Dynasty from 1778, before the Dynasty started ruling Vietnam in 1802, through to 1925. Although Vietnam became a protectorate of France in 1885, the Nguyễn Dynasty continued their own activity including solar and lunar eclipse recording and luni-solar calendar calculation. Keio University (1961–1981) published a facsimile edition of an original block print of the *ĐNTL* up to 1888 (up to Annals No.6). We used this facsimile edition in our survey. Thus, eclipse records after 1888 are not covered in this chapter. As will be discussed in Subsection 4.5.4, there is much difference in the reliability of the solar eclipse records between the *ĐNTL-TB* and *ĐNTL-CB*. Then, we will often refer to each of them separately.

Fig. 4.1 shows the chronological coverage of the *VSL*, *TT&TB* and *ĐNTL* that we used in our survey.

4.3 The Vietnamese Luni-solar Calendar

In this Section, we provide a brief overview of the Vietnamese luni-solar calendar, which is used in historical eclipse records.

It is important to have exact knowledge of the Vietnamese calendar for the following two reasons. Firstly, we have to convert the dates given in eclipse records into those of the Julian/Gregorian calendar in order to compare the eclipses described in the records with those obtained with modern eclipse computations. Secondarily, we are going to examine eclipse records in relation to luni-solar calendar-making methods because some previous studies (e.g., Saito and Ozawa, 1992) suspected that many of brief eclipse records in East Asian historical sources were based on predictions deduced by calendar-making calculations rather than observations really made (See Subsection 4.5.3).

The Vietnamese luni-solar calendar has often been regarded to be practically the same as the Chinese one in the same period, although Chang (1940) pointed out that

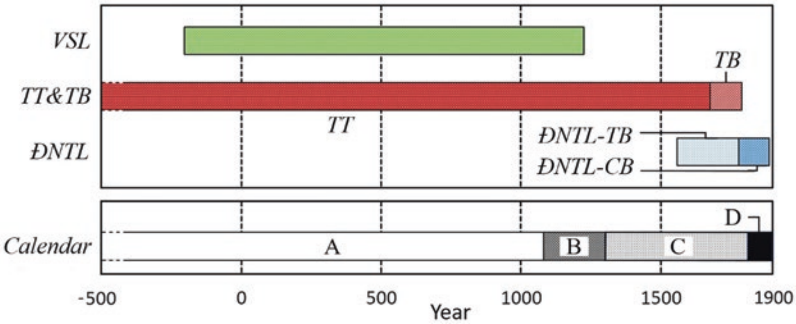

Fig. 4.1 Top panel: the period coverage of the three Vietnamese historical sources that we used in our survey. See Section 4.2. Bottom panel: Four periods (A, B, C and D) divided according to what luni-solar calendar-making method was used in Vietnam. See Section 4.3.

there exist some differences between the two calendars. In fact, some previous works (e.g., Ho, 1964; Okazaki and Yokoo, 1983) on Vietnamese astronomical records adopted the Chinese calendar to convert described dates to the Julian/Gregorian one. It was only a few decades ago that Hoàng (1982) and Lê (2007) restored the Vietnamese luni-solar calendar in the pre- and early modern era.

From his comparative investigation of Vietnamese and Chinese historical sources, Hoàng (1982) demonstrated that some definite differences exist between both calendars since as early as the late eleventh century. He also suggested that Vietnamese court astronomers calculated their own country's official calendar by themselves using a Chinese calendar-making method since the late eleventh century. Subsequently, Lê (2007) restored the Vietnamese luni-solar calendar up to 1544 based on old calendar materials and published conversion tables between the Julian/Gregorian and the Vietnamese luni-solar calendars. For recent reviews on the history of the Vietnamese luni-solar calendar, see Lê and Nguyễn (2017), Okazaki (2017) and Phạm and Lê (2021).

For later discussion, we divide here the time covered by the historical sources used in our survey into four periods (Periods A, B, C and D) by the calendar-making methods used in Vietnam, as given in Table 4.1. These four periods are also displayed in Fig. 4.1. As shown in Table 4.1, besides Period A when the Chinese calendar was directly used, Vietnam and China had used the same calendar-making method during a part (1301–1644) of Period C and the whole of Period D. This does not necessarily mean, however, that the calendars of the two countries were *exactly* the same during the time mentioned above because they were calculated independently in each country (see Hoàng, 1982).

In this chapter, we used Lê's (2007) table to convert the dates described in eclipse records since 1544. For the period before 1544, we had no choice but to adopt a conversion table for the Chinese luni-solar calendar because we had no available table for the Vietnamese luni-solar calendar; then, we utilized Chen's (1962) conversion table for the Chinese luni-solar calendar.

4.4 Eclipse Records in the *VSL*, *TT&TB* and *ĐNTL*

4.4.1 Solar Eclipse Records

We collected 6, 89 and 31 solar eclipse records from the *VSL*, *TT&TB* and *ĐNTL-CB*, respectively, in our survey. Among them, two records in the *TT&TB* turned out to be the same as those in the *VSL*. This means that the *VSL*, *TT&TB* and *ĐNTL-CB* contain records of 124 solar eclipses in total. We list all of them in Appendix 4.1, where the original texts, their English translations and the remarks of the individual records are provided.

Many of these eclipse records are so brief that each of them tells us nothing more than the occurrence of a solar eclipse and the date. Thus, we can hardly determine

Table 4.1 The four periods divided by the calendar-making method used in Vietnam. See Subsection 4.3 and Fig. 4.1.

Period	Years	Explanation
A	Before 1080*	The Chinese calendar was directly used during the Chinese domination and before. After the domination, early Vietnamese dynasties seem to have kept using the Chinese calendar in the same period. Very few calendar materials in this Period have survived.
B	1081* – 1300*	The Vietnamese calendar was not the same as the Chinese one in the same period. Vietnamese court astronomers calculated the official calendar by themselves, although the calendar-making method adopted by them is unknown. Hoàng (1982) suggested that it may have been one of the short-lifetime calendar-making methods used in China around the same time.
C	1301* – 1812	Vietnamese court astronomers calculated the official calendar by themselves using the same method as the Chinese *Shoushi* (授時) or *Datong* (大統) method (These two methods were almost the same). The methods used in both the countries were the same until 1644, when the Qing Dynasty in China introduced a new calendar-making method (*Shixian* 時憲). However, even before 1644, the calendars of the two countries had some differences in intercalary months and long/short months. Besides the official calendar, another calendar was used by the Nguyễn Lords, who governed the southern part of Vietnam from the early seventeenth century. This calendar, which was also calculated using the same method as the *Datong*, became the official calendar of Vietnam in 1802 when the Nguyễn Dynasty began to rule Vietnam (See Subsection 4.5.4).
D	1812 – †	Vietnamese court astronomers calculated the official calendar by themselves using a method called *Hiệp Kỷ*, which is equivalent to the Chinese *Shixian*. The methods used in the two countries were the same throughout the Period, although there are some calendar differences between the two countries, as pointed out by Chang (1940).

*The boundaries between Periods A and B, and Periods B and C, are somewhat uncertain (e.g., Hoàng, 1982). We consider that such uncertainty will have little effect on later discussion because few, if any, of the eclipse records seem to be involved in the uncertainty.
†Period D lasted until the mid-twelfth century.

whether these eclipse records were based on observations or predictions. Some previous studies (e.g., Saito and Ozawa, 1992) suspected that most such brief eclipse records contained in historical sources in East Asian countries would be based on predictions deduced by calendar calculation (see Subsection 4.5.3). In these circumstances, we believe that, to be fair to both kinds of eclipse records, records based clearly on *predictions* should also be collected in our survey. Thus, Appendix 4.1 contains a few such records (#1-55 and #1-61 [#*m*-*nn*: list number *nn* in Appendix 4.*m*]), which were not listed by Ho (1964).

The number of the solar eclipse records collected from the *VSL* is in agreement with that found by Okazaki and Yokoo (1983). The number of the records collected from the *TT&TB* is the sum of 71 records in the *TT* and 18 in the *TB*. The former should be compared with 69 records that Ho (1964) found in the *TT* alone.

In addition to the above solar eclipse records, we collected another 29 solar eclipse records (Appendix 4.2) from the *ĐNTL-TB*, whose period coverage overlaps with that of the *TT&TB*. However, many of these records turned out to be doubtful.

For this reason, we will not use these records for our discussion in Section 4.5 except Subsection 4.5.4, where we will examine why so many doubtful records are contained in the *ĐNTL-TB*.

4.4.2 Lunar Eclipse Records

We collected 55 and 4 lunar eclipse records from the *TT&TB* and *ĐNTL-CB*, respectively, and no records from the *VSL*. The number of the records collected from the *TT&TB* is the sum of 37 records in the *TT* and 18 in the *TB*. The former should be compared with the 34 records that Ho (1964) listed from the *TT* alone. All the lunar eclipse records collected in our survey are presented in Appendix 4.3, which includes a few records (#3-8, #3-56 and #3-57) based clearly on *predictions* for the same reason as mentioned in last subsection.

There are a few confusing records saying: “there was an eclipse of the Sun (日食) on the Full Moon day (望) of the month”. We consider these records are those of a lunar eclipse (月食), so we list them in Appendix 4.3 with remarks to this effect. Such confusion is occasionally found also in East Asian historical sources written in classical Chinese because the two characters “日 (the Sun)” and “月 (the Moon)” are very similar to one another in shape.

4.5 Discussion

4.5.1 Reliability of Eclipse Records in the VSL, TT&TB *and* ĐNTL-CB

4.5.1.1 Reliability of Eclipse Records

For later discussion, we introduce a measure, called here ‘reliability’, to evaluate historical eclipse records. Unless otherwise stated, by the ‘reliability’ we mean the ratio of the number of the records of the eclipses that were observable in the capital of the Vietnamese Dynasty to the number of all the collected eclipse records. In some cases (e.g., *4.5.1.4*), we use the word ‘reliable’ to represent the degree of consistency of some aspects of the eclipse (e.g., eclipse timing, total eclipse) between the records’ description and modern computation results.

To evaluate how an eclipse was seen in the capital on a described date, we utilized the following simulation software programs: For solar eclipse computation, we used the *JavaScript Solar Eclipse Explorer* developed by Espenak and O’Byrne (n.d.-a); For lunar eclipse computation, we employed the *JavaScript Lunar Eclipse Explorer* developed by Espenak and O’Byrne (n.d.-b). We also used the program *Lmap* developed by Takesako (n.d.) for supplementary computations in some cases. As far as lunar eclipses occurred since the twelfth century, which we examined, differences in the results between the above two lunar eclipse computation programs were found to be practically negligible for our purpose.

Fig. 4.2 shows the number of solar and lunar eclipse records collected from the *VSL*, *TT&TB* and *ĐNTL-CB* for every 100 years. We see from the figure that, although the numbers of both the solar and lunar eclipse records vary in a rather similar way since the tenth century, they do not before the tenth century; there are more than 20 solar eclipse records, whereas there are no lunar eclipse records at all.

4.5.1.2 Eclipse Records Before the Tenth Century

In this Sub-subsection, we consider solar eclipse records before the tenth century. Most of them are concentrated in the period between 199 BCE and 100 BCE. To acquire some idea of why they exhibit such a tendency, we surveyed records of another kind of astronomical phenomena—comet apparitions—in the *VSL* and *TT&TB*. Fig. 4.3 represents the number of the collected comet apparition records in the same way as in Fig. 4.2. As seen in the figure, they shows a tendency similar to

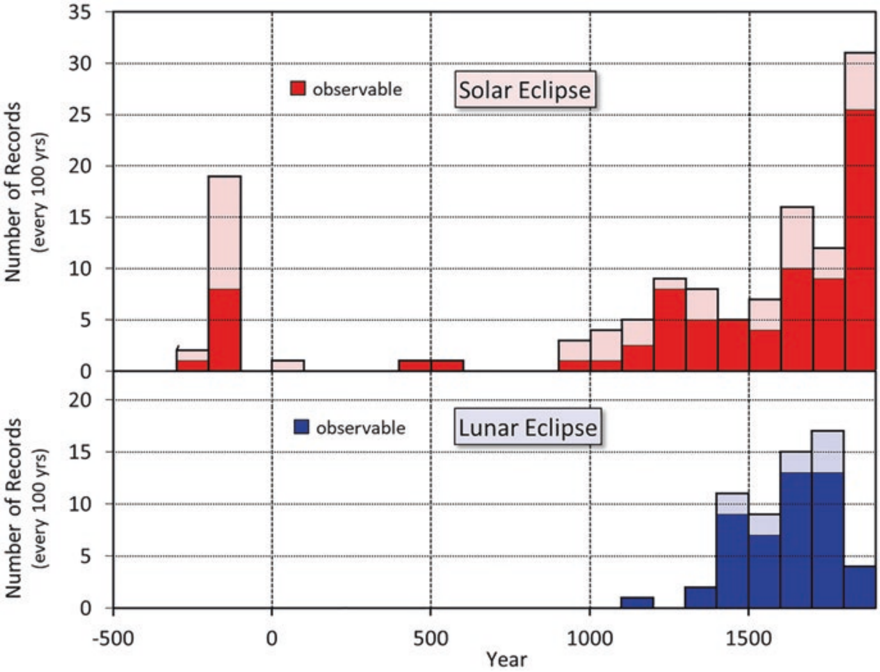

Fig. 4.2 The number of solar eclipse records (top) in the *VSL*, *TT&TB* and *ĐNTL-CB* in every 100 years and of lunar eclipse records (bottom) in the *TT&TB* and *ĐNTL-CB*. For the abscissa, a negative year is equivalent to the year BCE minus 1 year (for example, –200 should read 201 BCE). 'Observable' means that the eclipse described in a record was seen (unless covered with cloud) in the capital of the dynasty of the time.

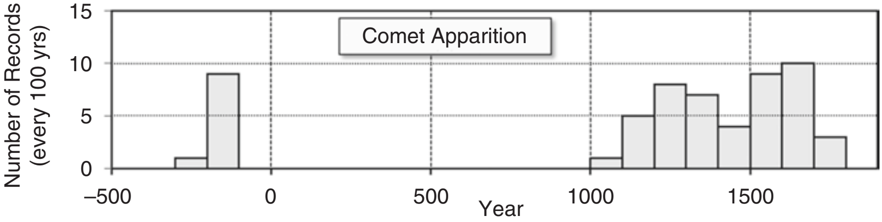

Fig. 4.3 The number of comet apparition records in the *TT&TB* in every 100 years on the same abscissa as in Fig. 4.2. See Sub-subsection *4.5.1.2*.

that of solar eclipse ones in Fig. 4.2: Firstly, most of the comet apparition records before the tenth century fall into the period between 199 BCE and 100 BCE; Secondarily, there is almost a blank from the first century BCE to the ninth century CE, which nearly corresponds to the Chinese domination period.

Ho (1964) suggested that all the solar eclipse and comet apparition records in the BCE era contained in the *TT*, including some mistakes, were faithfully copied from the Chinese historical source *Hanshu* (漢書, Book of Han). We confirmed his suggestion by finding that, for these records, the words used in the *TT* are very similar to those in the *Hanshu,* although there are a few minor differences.

There are another three solar eclipse records in the CE era before the tenth century in the *TT*. Unfortunately, they are so sparse that we can hardly use these records for our purpose. The *VSL* does not contain any solar eclipse records before the tenth century.

In these circumstances, we will confine our attention in later discussion to the 100 solar and 59 lunar eclipses recorded since the tenth century.

4.5.1.3 Eclipse Records since the Tenth Century

We made eclipse computations for all the records since the tenth century, and found that 71.5 of 100 (reliability: 72%) solar eclipses and 48 of 59 (reliability: 81%) lunar ones were observable (Table 4.2) in the capital on the described date (for record #3-56, see the remark in Appendix 4.1). In the computations of the above reliability, we provided a weight of 0.5 to one record of solar eclipse (#1-35) because we regarded its described eclipse dates as ‘moderately’ correct. For more details, see the remarks on the records in Appendix 4.1.

Ho (1964) suggested that Vietnamese astronomical records (after the Chinese domination) before the twelfth century might be unreliable. We see from Table 4.2 that the reliability of the solar eclipse records in Period A, or before 1080, may appear to be much lower than that in the other Periods, although the number of records in Period A is too small to lead to a definitive conclusion.

On the other hand, in Periods C and D, there are some accounts referring to Vietnamese court astronomers who were responsible for predicting solar and lunar eclipses (see Subsections 4.5.2 and 4.5.3). From these accounts, we see that they

Table 4.2 Reliability and ER (eclipse-recorded) ratio of solar and lunar eclipse records in each Period of the Vietnamese luni-solar calendar since the tenth century.

Solar Eclipse Records in the *VSL*, *TT&TB* and *ĐNTL-CB*					
	No. of Records		Total No. of Eclipse occurred	Reliability	ER ratio
	All	Observable†			
Period & Years	(a)	(b)	(c)	(b/a)	(b/c)
A 939* – 1080	6	2	53	(33%)‡	(4%)‡
B 1080 – 1300	15	10.5†	64	70%	16%
C 1301 – 1812	51	36	191	69%	19%
D 1812 – 1888*	28	22.5†	29	80%	78%
Total	100	71	337	71%	21%

Lunar Eclipse Records in the *TT&TB* and *ĐNTL-CB*					
Period & Years	No. of Records		Total No. of Eclipse occurred	Reliability	ER ratio
	All	Observable†			
	(a)	(b)	(c)	(b/a)	(b/c)
A 939* – 1080	0	–	–	–	–
B 1080 – 1300	1	0	–	–	–
C 1301 – 1812	54	44	491	82%	9%
D 1812 – 1888*	4	4	72	(100%)‡	(6%)‡
Total	59	48	–	81%	–

*For Period A, we consider here the period after the Chinese domination. For Period D, our survey extended until 1888.

†Includes a “moderately” correct record. See Sub-subsection *4.5.1.3*.

‡Based on less than ten records.

had started reporting their eclipse predictions to the Emperor at the latest by the early fifteenth century. Besides, one of the solar eclipse records in the seventeenth century clearly demonstrates that its description is due to Vietnamese astronomers: Record #1-74 describes the eclipse on 30 April 1669 in the following words: “there was a total eclipse of the Sun”, while the Chinese historical source *Qingshigao* (清史稿) says: “The Sun was 5.5 tenths eclipsed”. According to *JavaScript Solar Eclipse Explore*r (Espenak and O’Byrne, n.d.-a), the greatest magnitudes of the eclipse observed in Đông Kinh (present Hanoi) and Beijing were 0.97 and 0.54, respectively, as almost exactly described in the two sources.

We will discuss the reliability of eclipse records again in Subsections 4.5.2 in relation to luni-solar calendar-making methods.

4.5.1.4 Eclipse Times and Total Eclipses Described in Records

Let us consider the eclipse records from other points of view.

Firstly, we focus on the eclipse times described in some of the records. Before discussing them, we briefly mention two ways of time expression appearing in these records. One is the ‘double hour’ system, in which the day was divided into twelve equal double hours: each of them was named according to the twelve terrestrial branches used in the Chinese sexagenary cycle [the Chinese name of the double hour is also given in parentheses hereafter]. Some of these names are shown just above the abscissa in Fig. 4.4. Thus, one double hour is equal to a modern two hours. The other system is the 'watch system', in which the night (from dusk to dawn) was divided into five equal 'night watches (*geng*)'. Since the length of the night depends on the season, the length of an individual night watch seasonally varied as well. Each of the above time systems had its subdivision units.

Ten eclipse records (#1-105, #3-2, #3-8, #3-11, #3-14, #3-19, #3-23, #3-34, #3-35 and #3-56) mention their eclipse times. Nine of them express the times in the double hour system: Eight are without any subdivision units, i.e., with a time resolution of 2 hours, while one (#3-56) is with a subdivision unit reaching a resolution of one minute. On the other hand, the remaining one (#3-11) shows its eclipse time in the 'watch system' with a subdivision unit. For more details, see remarks on these records in Appendices 4.1 and 4.3.

We make here the following assumptions based on the discussion in Subsubsection *4.5.5.3*: (1) The errors of both observed and predicted eclipse times were approximately ±0.5 hours in Period C. It was much improved in Period D. (2) The eclipse times described in these records represent the moment when an eclipse started.

Fig. 4.4 displays a comparison between the eclipse times (yellow zones) described in these records in double hours or the watch system and the eclipse times from start to end (red/blue horizontal bars) obtained using solar/lunar eclipse computations with *JavaScript Solar/Lunar Eclipse Explorer* (Espenak and O'Byrne, n.d.-a, n.d.-b). We regard here a described eclipse time as 'reliable' if it overlaps

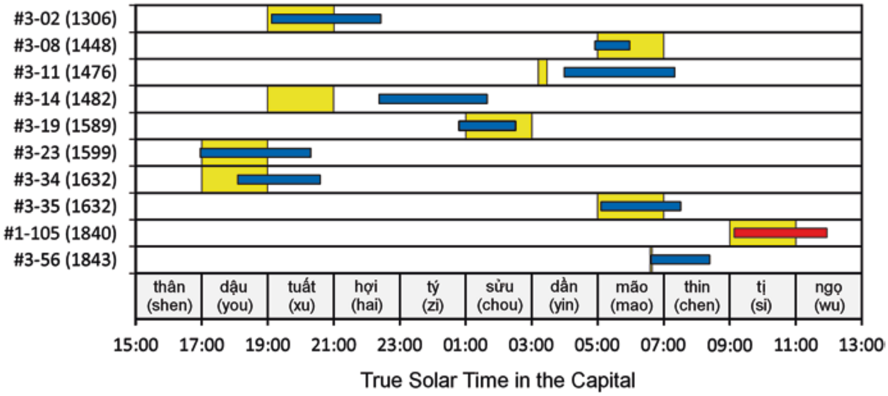

Fig. 4.4 A comparison between the eclipse times (yellow zones) described in some records in the double hours or the watch system and those from start to end (horizontal bars) obtained using modern eclipse computations with *JavaScript Solar/Lunar Eclipse Explorer* developed by Espenak and O'Byrne (n.d.-a, n.d.-b). The red and blue bars represent solar and lunar eclipses, respectively. Time in the double hour system is yielded just above the abscissa, which is true solar time. The name of each double hour is shown in Vietnamese (upper) and Chinese (lower in parentheses). For each record, the list number in Appendices 4.1 and 4.3 and the year in parentheses are given on the left.

with or is less than 0.5 hours away from the eclipse start time obtained using modern computation. We found from the figure that, excepting two records (#3-11 and #3-14), eight of the ten records (80%) are 'reliable'.

The eclipse times described in records #1-105, #3-8 and #3-56 are judged to be predicted ones from their descriptions or the descriptions followed by the records. As for #3-56, the eclipse-starting time predicted by Vietnamese court astronomers is in excellent agreement with that obtained using modern eclipse computations. This suggests that Vietnamese astronomers in those days made their calendar calculations very accurately using the *Hiệp Kỷ* method (equivalent to the *Shixian*).

Next, we consider eight eclipse records that describe their eclipse as "既" (total, #1-42, #1-74, #3-3, #3-9, #3-10 and #3-12), "全分" (full, #3-11) or "殆盡" (almost exhausted, #3-20)". Among them, five records (#3-3, #3-9, #3-10, #3-11 and #3-20) are of real total eclipses according to eclipse computations with *JavaScript Solar/Lunar Eclipse Explorer* developed by Espenak and O'Byrne (n.d.-a, n.d.-b). The remaining three are partial eclipses: one lunar eclipse record (#3-12) is of small magnitude (0.03), while two solar eclipse records (#1-42 and #1-74) are of large magnitude (0.93 and 0.97, respectively) close to totality. Providing a weight of 0.5 to the latter two, we find that six of the eight records (75%) are 'reliable'.

4.5.2 Relation to the Luni-solar Calendar-making Method

In this Subsection, we discuss a possible effect of differences in the calendar-making method upon the eclipse records. In general, in order to complete a luni-solar calendar for a year, it is necessary to calculate predicted positions of the Sun and Moon in the sky over the entire year by using a certain astronomical calculation method in those days, i.e., a calendar-making method. Since a prediction of a solar or lunar eclipse is determined by the relative distance of the Sun and Moon on the sky, the accuracy of eclipse predictions should tell us how properly their calendar calculations were being made in those days.

For later discussion, we introduce another measure, called here the 'eclipse-recorded ratio (ER ratio)', which evaluates the ratio of the number of (reliable) recorded eclipses to the total number of eclipses that occurred in the capital. We obtained the number of the latter in each Period by using *JavaScript Solar/Lunar Eclipse Explorer* (Espenak and O'Byrne, n.d.-a, n.d.-b).

Table 4.2 and Fig. 4.5 show the reliability and the ER ratio of eclipse records in each Period of the Vietnamese luni-solar calendar (see Table 4.1). In some Periods, we have no or few available eclipse records for the reliability or the ER ratio. In the case of lunar eclipse records, we have substantially only one Period providing both the measures, so that we cannot make any comparison of these measures among Periods. Then, in this subsection, we confine our attention to solar eclipse records for Period B through to D.

Now, let us consider the reliability. Firstly, we see that the reliability of solar eclipse records in Periods B and C are nearly equal. It should be remembered here

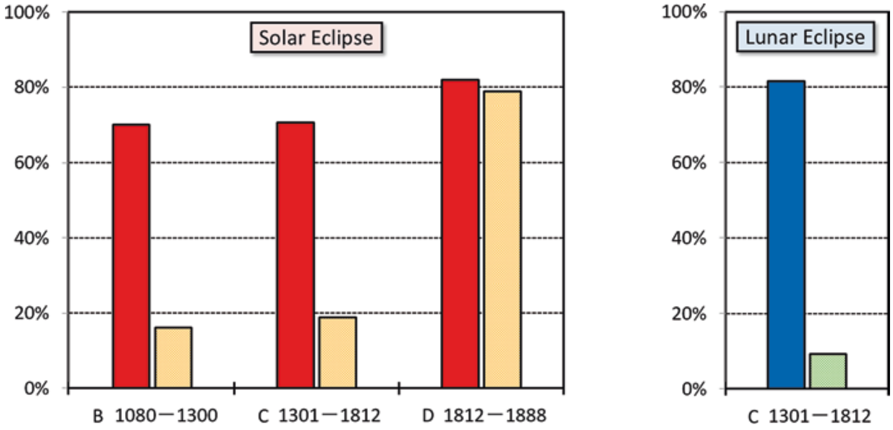

Fig. 4.5 The left panel displays the reliability (red) and the ER ratio (yellow) of solar eclipse records in Period B through to D of the Vietnamese luni-solar calendar (see Table 4.1). The right panel shows the reliability (blue) and the ER ratio (green) of lunar eclipse records in Period C.

that, in Period B, when the Vietnamese and Chinese calendars were different, we have adopted the Chinese calendar to convert eclipse dates into the Julian one. Moreover, in a large part of Period C, or in 1301–1644, the same calendar-making method was used in both Vietnam and China. Hence, if many of these eclipse records were based on predictions, the little difference in the reliability between Periods B and C leads to the following two suggestions: (1) The Vietnamese calendar used in Period B would not be significantly different from the Chinese one in the same period; and (2) The accuracy of Vietnamese calendar calculations in Period B would be comparable to that in Period C.

Secondarily, we see that the reliability in Period D is higher than that in Periods B and C. This seems to be closely connected with the fact that the accuracy of calendar calculation was much improved in 1812 when the *Hiệp Kỷ* calendar was introduced in Vietnam. This will be discussed in Sub-subsection *4.5.3.2*.

Next, we turn to the ER ratio. The ER ratio (79%) in Period D is much larger than that (< 20%) in Periods B and C. We consider that this high ER ratio is also connected with accuracy improvement due to the introduction of the *Hiệp Kỷ* calendar. We will discuss the high ER ratio in Period D in Sub-subsection *4.5.3.2* in terms of whether a large number of solar eclipse records in Period D were based on observations or predictions.

Finally in this Subsection, we deal with differences between the Vietnamese and Chinese calendars. As mentioned in Section 4.3, in the period 1644–1812 and in Period B, the calendar-making methods used in Vietnam and China were not the same. For these periods, we must keep in mind that, due to a possible difference in positioning an intercalary month, an apparent one-month difference could happen between the Vietnamese and Chinese calendars.

We present here one of the examples that confirms such a difference between both the calendars: For the lunar eclipse of 8 June 1732, record #3-42 says: “Vĩnh

Khánh reign period, 4th year, intercalary 4th month, Full Moon day of the month, there was an eclipse of the Moon". On the other hand, a record in the Chinese historical source *Qingchao Wenxian Tongkao* (清朝文献通考) says: "Yongzheng reign period, 10th year, 5th month, day *ren-shen*, Full Moon day of the month, there was an eclipse of the Moon". According to Lê's (2007) and Chen's (1956) conversion tables, in that year, the Vietnamese calendar placed an intercalary month between the fourth and fifth months as the "intercalary fourth month", while the Chinese calendar laid it after the fifth month, so that the intercalary fourth month in the Vietnamese calendar corresponds to the fifth month in the Chinese calendar.

We may expect such a case also in Period B, when the Vietnamese calendar method was considered not the same as the one used in China in the same period (the Vietnamese calendar in Period B has not been restored yet). From this point of view, solar eclipse record #1-35 [24 August 1188] attracts attention. While the record says: "Thiên Tư Gia Thụy reign period, 3rd year, autumn, 7th month, *giáp-tý* (*jia-zi* in Chinese), 1st day of the month, there was an eclipse of the Sun", the Chinese historical source *Songshi* (宋史) says: "Chunxi reign period, 15th year, 8th month, day *jia-zi*, 1st day of the month, there was an eclipse of the Sun, …" Both Vietnamese and Chinese records yield the same day specified by the Chinese sexagenary cycle even though the months of both calendars differ from one another by one month. Thus, it is very likely that the one-month difference in this case has arisen from a calendar difference between Vietnam and China in that year, as found in the above record (#3-42) of 1732.

4.5.3 Are Eclipse Records Based on Observations or Predictions?

As mentioned in Section 4.3, some studies (e.g., Saito and Ozawa, 1992) claimed that many historical records of solar and lunar eclipses in East Asian countries would be based on predictions deduced by calendar calculation, while other studies (e.g., Zhang, 1993) suggested that most of these records would be of reliable eclipse observations. Let us examine the eclipse records collected in our survey from this point of view.

4.5.3.1 Eclipse Records in Periods B and C

As mentioned in Subsections 4.4.1 and 4.4.2, we found some records (and their related accounts) describing eclipse predictions, the first of which appeared in the fifteenth century.

Record #1-55 [June, 1434] says: "Business at the Imperial Court was suspended. Before that, the Astrologer Bùi Thì Hanh had confidentially reported that, on 1st day of the fifth month, the specter of a black monkey would eat the Sun, so that there would be an eclipse of the Sun on that day".

Record #1-56 [November, 1435] says: "Thiệu Bình reign period, 2nd year, 11th month, day *mậu-thìn* (*wu-chen*), 1st day of the month, there was an eclipse of the Sun". More than one month before, a prediction of this eclipse was reported: "(The same year,) 9th month, 26th day, the Astrologer Bùi Thì Hanh confidentially reported that there would be an eclipse of the Sun on the 1st day of the 11th month…".

Moreover, record #3-8 [September, 1448] says: "..., (Bùi) Thi Hanh gave an absurd report (to the Emperor) that there would be an eclipse of the Moon in the hour of *mẹo* (*mao*, 5:00–7:00) on 16th day of the month... The eclipse was not seen". This record is followed by a description about Bùi Thì Hanh, who was falsely charged with a crime of this 'absurd' report. Actually, a slight partial eclipse occurred at low altitude in Đông Kinh (present Hanoi) at the time almost exactly predicted by Thi Hanh (see Fig. 4.6).

From the above three records, we can safely say that eclipse predictions began to be reported to the Emperor in Vietnam at the latest by the early fifteenth century. It is noted that, among the above-mentioned three eclipses, we found no records of two of them (#1-55 and #3-8) in Chinese, Korean or Japanese historical sources. This seems to support Hoàng's (1982) suggestion that Vietnamese astronomers calculated their own luni-solar calendar by using a Chinese calendar-making method, which allowed them to make eclipse predictions in Period C.

Several records in later centuries in Period C also suggest that eclipse predictions were definitely reported prior to their eclipse dates. For example, record #1-61 [May, 1527] says: "The Astronomical Bureau reported that there would be an eclipse of the Sun. (The eclipse was) not verified". Record #3-21 [May, 1594] says: "There was an eclipse of the Moon. It rained heavily". Record #1-64 [September, 1596] says: "There was an eclipse of the Sun. It rained". Record #3-32 [May, 1631] says: "There was an eclipse of the Moon. It was rainy, windy and dark. (The eclipse) was not seen". All of these records tell us, explicitly or implicitly, that their predicted eclipses were not observed due to bad weather (#3-21, #1-64 and #3-32) or other reason (#1-61).

However, most of the other eclipse records in Period C, as well as all the records in Period B, are very brief: They say nothing more than "there was an eclipse of the Sun/the Moon." Such a brief description makes it difficult to determine whether these records were based on observations or predictions.

4.5.3.2 Eclipse Records in Period D

In Period D, there also are some records or accounts of solar and lunar eclipse predictions. For example, two solar eclipses (described in #1-99 and #1-100) were predicted more than a year and half before in the following words: "Gia Long reign period, 14th year, 11th month (December, 1815), … [Nguyễn] Hữu Thận reported that his retainers' calculation of the movement of celestial bodies leads to the

月上疏言國舅阮輔胥等不可令參知詞訟忤太后旨托疾求辭職故免之○陞裴寺亨職為太史令如故寺亨妄奏是月十六日卯寺月食詔百官詣象天門救月不見食監察御史同亨婁劾其罪寺亨無憂色私謂親人曰不過罰錢昔救中丞老手猶不撼動我亨發小輩夫能何為明日上鐵狀文縛自若亨發奏曰臣職忝言官凡政事得失用人是非皆論爭其可否故古語云言及乘輿則天子改容事關廊廟則宰相

Fig. 4.6 Block print page of the *TT* containing Bùi Thì Hanh’s episode about his ‘absurd’ report of lunar eclipse in September, 1448. The phrases shown in yellow are those given in Appendix 4.3 (#3-8). (courtesy: The Vietnamese Nôm Preservation Foundation).

occurrence of a solar eclipse on 1st day of 4th month and of 10th month in the year *đinh-sửu* (*ding-chou*)”. Nguyễn Hữu Thận was a key person in the introduction of the *Hiệp Kỷ* calendar in Vietnam about three years before this prediction. Several other eclipses (#1-105, #1-109, #1-110, #1-112, #3-56 and #3-57) were also predicted before their eclipse dates. Among them, two eclipses (#1-105 and #3-56) were not easily observed due to bad weather or because it was daytime (see their remarks).

On the other hand, a few records were based clearly on observations: records #1-111, #1-113, #3-58 and #3-59 are all followed by saying: "the Astronomical Bureau had not reported any prediction of the eclipse".

Most of the eclipse records in Period D are, however, very brief as found in Periods B and C. Again, we can hardly determine from their description whether they were based on observations or predictions. Even so, we attempt here to resolve this issue by using the ER ratio of solar eclipse records.

As mentioned in Subsection 4.5.2, the ER ratio (79%) of solar eclipse records in Period D is much larger than that (< 20%) in Periods B and C. If many of the eclipse records were based on predictions using more accurate calendar calculations, then this would have led to more accurate eclipse calculations, resulting in an increase in the ER ratio. If many of the eclipse records were based on observations, accurate predictions should have led court astronomers to notice solar eclipses much more often, so that the ER ratio increased, too. Thus, both of these seem acceptable to explain the high ER ratio in Period D. However, if most of these eclipse records were based on observations and if the climate in Huế, the capital of the Nguyễn Dynasty, has not varied significantly since the early nineteenth century, the high ER ratio (79%) should be unacceptable. This is because an annually averaged percentage of sunshine, which can be roughly regarded as an upper limit of the ER ratio for solar eclipses, in Huế is estimated to be merely 41± 4%, or ~40%, from the climate data provided by the General Statistics Office of Vietnam (http://www.gso.gov.vn/default_en.aspx?tabid=773). Therefore, we may conclude that a large fraction of the records in Period D must have been based on predictions.

4.5.4 *Solar Eclipse Records in the* ĐNTL-TB

4.5.4.1 Two Vietnamese Calendars Used in the TT and ĐNTL-TB

Now, we deal with solar eclipse records in the *ĐNTL-TB*, which we have not discussed up to this point. As mentioned in Section 4.2, the *ĐNTL-TB* describes the history of the Nguyễn Lords and contains some astronomical records from the mid-sixteenth through to the late eighteenth century. During this period, the Late Lê Dynasty had little power in Vietnam: while the Late Lê Dynasty, which was controlled by the Trịnh Lords, governed the northern part of Vietnam, the Nguyễn Lords ruled the southern part.

The Late Lê Dynasty (and Trịnh Lords) had its calendar, i.e., the official calendar, the *Khâm Thụ calendar* (欽授曆), which was used in the *TT&TB*. As pointed out by Hoàng (1982), the Nguyễn Lords also had their own calendar, the *Vạn Toàn calendar* (萬全曆), which was used in the *ĐNTL-TB*. It is believed that the Lê Dynasty and the Nguyễn Lords calculated their own respective calendars using the same method as the Chinese *Datong* calendar. Lê (2007) restored the *Khâm Thụ calendar* from 1544 to 1788 and the *Vạn Toàn calendar* from 1631 to 1812. They are contained in his *Conversion Table* (Lê, 2007), which we used in this chapter. Table 4.3 summarizes both the calendars.

As mentioned in Subsection 4.5.3, some previous studies suggested that many eclipse records in historical sources would be based on predictions deduced from calendar calculations. Keeping in mind such a possibility, we compare the solar eclipse records in the *TT&TB* and *ĐNTL-TB* in relation to the above-mentioned two luni-solar calendars.

4.5.4.2 The Low Reliability of Solar Eclipse Records in the ĐNTL-TB

As mentioned in Section 4.3, we collected 29 solar eclipse records from the *ĐNTL-TB* (Appendix 4.2). We also collected 32 solar eclipse records from the *TT&TB* in the period overlapping with the *ĐNTL-TB*. Among them, eight eclipses are the same as those described in the *ĐNTL-TB*. As seen in Table 4.4, the reliability of solar eclipse records in the *TT&TB* is 72% (23/32) while that in the *ĐNTL-TB* is only 31% (9/29) for the overlapping period.

Let us examine the difference in the reliability of solar eclipse records between the *TT&TB* and *ĐNTL-TB* in more detail. In the *TT&TB*, among nine doubtful (unreliable) solar eclipse records, four records are in *serious error* (the third category records, as mentioned below). On the other hand, in the *ĐNTL-TB*, among 20 doubtful solar eclipse records, 17 are in *serious error*.

Fig. 4.7 displays (lunar) month discrepancies between the date given in eclipse records in the historical sources and the nearest date when an eclipse actually occurred (somewhere on the Earth, not necessarily in Vietnam) according to modern eclipse computations. We classify these solar eclipse records into three categories as follows: The first category records (open circles on the zero-line in the figure) are those of solar eclipses that were observable in the capital on the date given in records, i.e., they are reliable records. The second category records (red filled circles on the zero-line) are those of eclipses that were not observable in the capital on the given date but were visible somewhere else on the Earth. The third category records (red filled circles off the zero-line) are those of eclipses that did not occur anywhere on the Earth on the given date, but occurred one, two or three month(s) earlier or later. Such a discrepancy is indicated as a vertical shift from the zero-line in the sense that "the eclipse month given in the record" minus "the nearest eclipse month

Table 4.3 Two calendars used in Vietnam from the sixteenth century through to the nineteenth century.

Calendar	Calculated and used by	Used in	Restored for years
Khâm Thụ calendar	Lê Dynasty (& Trịnh Lords)	*TT&TB*	1544 – 1788
Vạn Toàn calendar	Nguyễn Lords	*ĐNTL-TB*	1631 – 1812

Table 4.4 Comparison of the reliability of solar eclipse records between the *TT&TB* and *ĐNTL-TB*.

	No. of Records in the *TT&TB*			No. of Records in the *ĐNTL-TB*		
Period	All	Observable*	Reliability	All	Observable*	Reliability
1558 – 1777 (the overlapping period)	32	23	72%	29	9	31%
1660 –1720 (see text)	11	7	64%	21	1	5%

*Eclipses described in these records were observable in the capitals Đông Kinh (for the *TT&TB*) and Huế (for the *ĐNTL-TB*).

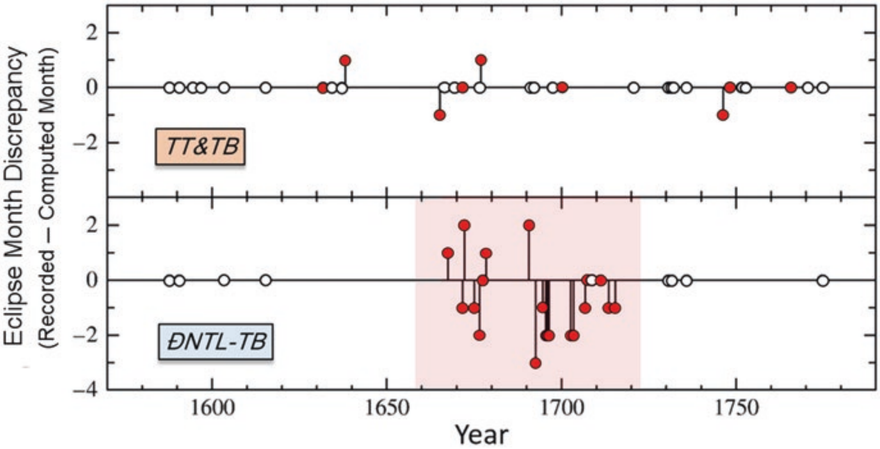

Fig. 4.7 Lunar month discrepancies between the date given in solar eclipse records and the nearest date when an eclipse occurred (somewhere on the Earth, not necessarily in Vietnam) according to modern computations for the *TT&TB* (upper panel) and the *ĐNTL-TB* (lower panel). Open circles *on the zero-line* represent the records of solar eclipses that were observable in the capital on the described date. Red filled circles *on the zero-line* are the records of eclipses that were not observable in the capital on the given date but were visible somewhere else on the Earth. Red filled circles *off the zero-line* (called here *in serious error*) are the records of eclipses that did not occur anywhere on the Earth on the given date, but occurred one, two or three month(s) earlier (−) or later (+), as shown by the length of vertical lines. The region highlighted in pale red in the *ĐNTL-TB* represents the period (from about 1660 to 1720) when all the doubtful records are concentrated. See the caption of Fig. 4.8 and text.

when an eclipse actually occurred (according to modern computation)". Here we refer to a record of the third category as one in *serious error*.

It should be noted that, in the *ĐNTL-TB*, all of the doubtful solar eclipse records (including those in *serious error*) are concentrated in the period from about 1660 to 1720. On the contrary, in the *TT&TB*, doubtful records, which are much less than those in the *ĐNTL-TB*, are distributed rather sparsely and randomly over the overlapping period. Moreover, in the *TT&TB*, none of the records in *serious error* shows a discrepancy of more than one month, as seen in Fig. 4.7.

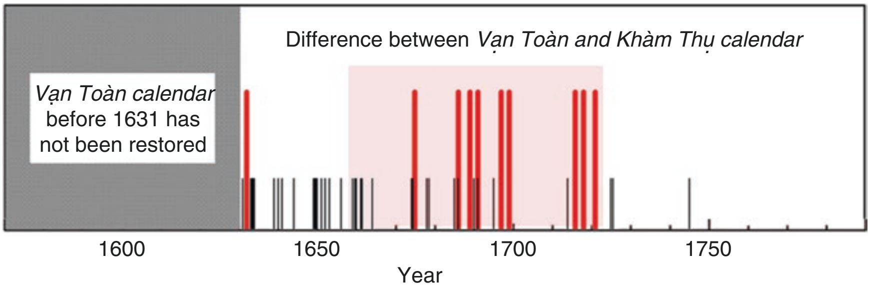

Fig. 4.8 Differences between the *Khâm Thụ calendar* used in the *TT&TB* and the *Vạn Toàn calendar* used in the *ĐNTL-TB* based on Lê's (2007) *Conversion Table*. Long red vertical bars represent intercalary month differences while short black bars show long/short lunar month differences. The region highlighted in pale red represents the period from about 1660 to 1720 where most of the intercalary month differences are concentrated. See the caption of Fig. 4.7 and text.

4.5.4.3 Possible Explanation for the Low Reliability of the Solar Eclipse Records

Now we discuss why solar eclipse records in the *ĐNTL-TB* have such a low reliability compared with the *TT&TB*, in particular, in the period from about 1660 to 1720. Let us consider the following two possibilities: (1) Since the Nguyễn Lords were once almost ruined in the late eighteenth century, many of their official documents of astronomical records, in particular, for the period (the region highlighted in pale red in the lower panel of Fig. 4.7) from about 1660 to 1720 may have been confused before the Nguyễn Dynasty (their descendants) first compiled the *ĐNTL-TB* in the early nineteenth century. (2) If many of the solar eclipse records were based on predictions deduced by calculations for the *Vạn Toàn calendar*, which was used by the Nguyễn Lords, it may not have been properly made, in particular, during the above-mentioned period. Then, let us consider which of the above possible explanations is more likely.

Possibility (1) will be reasonably acceptable if records of other astronomical phenomena in the *ĐNTL-TB* also show such a low reliability in the period. From this viewpoint, we compared all comet apparition records within the period in the *TT&TB* and the *ĐNTL-TB* with those in China, Korea and Japan that had a similar astronomical observation system in those days. We found that ~70% (5.5/8) of them in the *TT&TB* and ~60% (2.5/4) in the *ĐNTL-TB* are consistent with those in at least one of the three countries. Here we consider that these percentage values correspond to 'reliability'. Although the available comet records are too few to allow definitive conclusions, it seems unlikely that those in the *ĐNTL-TB* show the signs of extremely low 'reliability' (~5%) such as found in the solar eclipse records. It is noted that any comet apparition record in those days, which was unable to be predicted by court astronomers, obviously was based on observations.

Next, we turn to possibility (2). We make a comparison between the *Khâm Thụ calendar* used in the *TT&TB* and the *Vạn Toàn calendar* used in the

ĐNTL-TB. According to Lê's (2007) *Conversion Table*, there are 36 long/short (or 30-day/29-day) lunar month differences and 11 intercalary month differences between these two calendars for the period from 1631 to 1788, for which both calendars have been restored. Fig. 4.8 displays how these differences are distributed over the period on the same abscissa in Fig. 4.7. We see from the figure that most of the intercalary month differences, which may be considered as more serious than the long/short differences, are concentrated in the period from about 1660 to 1720, which is where all of the records in *serious error* in the *ĐNTL-TB* are concentrated as well. As for the long/short lunar month differences, they are rather concentrated in the period from 1631 to the early 1660s, in which we see no data in Fig. 4.7 (lower panel) since there are no solar eclipse records in the *ĐNTL-TB*.

As mentioned in Section 4.3, the same calendar-making method was used in Vietnam and China until 1644 in Period C. Then, we compare the *Khâm Thụ* calendar used in the *TT&TB* and the *Vạn Toàn* calendar used in the *ĐNTL-TB*, respectively, with the Chinese *Datong calendar* for the period from 1631 to 1644, for which all of the three restored calendars are available. We find 10 long/short lunar month differences and one intercalary month difference in the *Vạn Toàn calendar* and only one long/short lunar month difference in the *Khâm Thụ calendar*. This fact implies that the *Vạn Toàn calendar* was calculated much less properly than the *Khâm Thụ* for the period we compared. Thus, it is reasonable to consider that significant differences shown in Fig. 4.8 are reflected mainly by an improper calculation of the *Vạn Toàn calendar*.

It is noted that all of the solar eclipse records in *serious error* and most of the intercalary month differences fall within the period from about 1660 to 1720, as highlighted in both Fig. 4.7 (lower panel) and Fig. 4.8. Such a close correspondence seems to suggest that possibility (2) is much more likely.

In conclusion, we suggest that many of the solar eclipse records in the *ĐNTL-TB* were based on predictions deduced by calendar calculations and that the *Vạn Toàn* calendar of the Nguyễn Lords had been improperly calculated, in particular, from about 1660 (or possibly as early as 1630, as indicated by the long/short month differences) to 1720, so that many solar eclipse records during this period in the *ĐNTL-TB* are in *serious error*.

4.5.5 The Beginning Time of the Day

4.5.5.1 The Dates Used for Lunar Eclipse Records

Historical records of astronomical phenomena that took place at night sometimes provide us with a clue to the beginning time of the day adopted by people in earlier times. For example, by examining the dates used in the historical records of lunar occultation or lunar eclipses, Saito (1980a, 1980b), Zhang (1993) and Ahn and Park (2004) discussed the beginning time of the day in the medieval and/or the premodern era in Japan, China and Korea, respectively.

Here, we attempt to acquire some idea of the beginning time of the day adopted by Vietnamese people, more exactly, by Vietnamese astronomers (from the

Astronomical Bureau) based on lunar eclipse records in Appendix 4.3. For this purpose, we selected 34 records for which the eclipse dates are specified by day number of the month or by the Chinese sexagenary cycle. Among them, 30 records are in Period C and contained in the *TT&TB*, and four are in Period D and in the *ĐNTL-CB*.

Fig. 4.9 displays a timing diagram of these 34 lunar eclipses (the upper and the lower panels: those in Periods C and D, respectively) based on eclipse computations with *JavaScript Lunar Eclipse Explorer* developed by Espenak and O'Byrne (n.d.-b). The abscissa is expressed in true solar time in the capital of the Dynasty in those

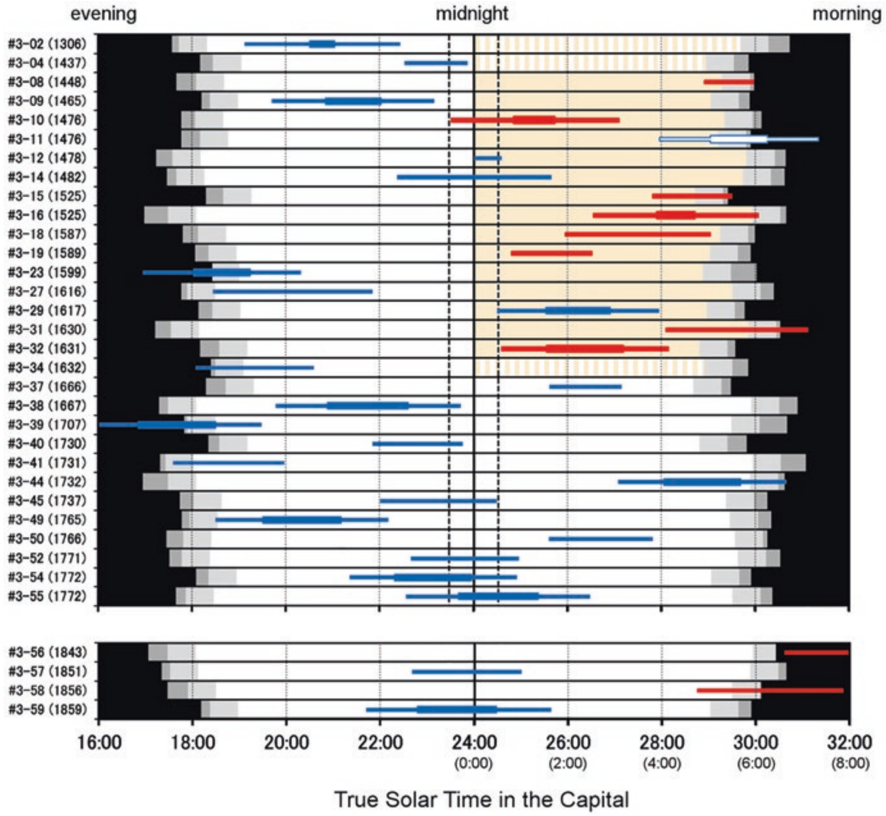

Fig. 4.9 A timing diagram of 30 lunar eclipse records in Period C (upper panel) and four records in Period D (lower panel). For the abscissa, true solar time after midnight is expressed using a clock with more than 24 hours. For each record, the list number in Appendix 4.3 and the year in parentheses are given on the left. Narrow horizontal bars show the timing of a partial eclipse and broad horizontal bars represent those of a total eclipse. These eclipse timings were computed using *JavaScript Lunar Eclipse Explorer* developed by Espenak and O'Byrne (n.d.-b). Blue bars show records dated *the same day* and red bars *the following day*. Two vertical broken lines around the midnight in the upper panel indicate the range of the assumed mean error of the eclipse time at midnight in Period C. Zones in light gray, gray and black show twilight, daytime and the time when the Moon was below the horizon, respectively. For records #3-11 shown with an outlined bar and for the regions in filled pale brown and in vertical striped pale brown, see Sub-subsection *4.5.5.3*.

days. We use a clock-time of more than 24 hour after midnight to avoid possible confusion caused by date change at midnight. In the figure, narrow and broad horizontal bars represent the timing of a partial and a total eclipse, respectively. Blue bars show the eclipse records dated the same day as the daytime before a lunar eclipse occurred at night (hereafter, *the same day*), and red bars indicate those dated the day following *the same day* (hereafter, *the following day*).

As seen in the figure, all the eclipses that ended clearly before midnight (hereafter, *before-midnight* eclipses) are dated *the same day*. However, as for those eclipses that started clearly after midnight (hereafter, *after-midnight* eclipses), some of them are dated *the same day*, and the others are dated *the following day*. As for those eclipses that run over the midnight (hereafter, *across-midnight* eclipses), most of them are dated *the same day*.

4.5.5.2 The Accuracy of Lunar Eclipse Timings

Before further discussion, we have to mention the accuracy of eclipse timings in those days. According to Stephenson (1997) and Steele (2000), the mean errors of both observed (measured) and predicted eclipse times were 0.25–0.30 hours in China in the period when they used the *Shoushi* calendar. Moreover, Li and Zhang (1999) reported that the mean error of the solar eclipse times deduced from the *Shoushi* calendar calculation were 0.30–0.66 hours for the period from 1280 to 1785. Thus, we should keep in mind that eclipse times described in Vietnamese records in Period C should also have an error at least comparable to that of China. In Period D, the accuracy of eclipse times seems considerably higher than that in Period C, as reasoned from record #3-56 (see Sub-subsection *4.5.1.4*).

On the other hand, we have little idea which moment in the time span of an eclipse was adopted to determine the eclipse date (*the same day* or *the following day*) by Vietnamese astronomers in those days. Let us remember here that all of the *across-midnight* eclipses but one are dated *the same day*. This leads us to the idea that the moment when an eclipse started may have been adopted to determine the eclipse date. The exceptional eclipse (#3-10), which is dated *the following day,* started about 0.5 hours before midnight. This discrepancy can be resolved if we assume that it is due to the above-mentioned error of the eclipse time in Period C.

For later discussion, we assume that, in a certain period in Period C (see below), the choice of the eclipse date (*the same day* or *the following day*) depended on the time when an eclipse started, and that the mean error of the eclipse times in Period C is approximately ±0.5 hours. In the upper panel of Fig. 4.9, two vertical broken lines on both sides of the midnight line indicate the range of the assumed mean error of the eclipse time at midnight.

4.5.5.3 The Beginning of the Day Inferred from Lunar Eclipse Records

Firstly, we consider lunar eclipses in Period C (Fig. 4.9, upper panel), which ranged over about four hundred years. Let us consider ten *after-midnight* eclipses before the early seventeenth century (before #3-37), which are highlighted in pale brown in the figure. We find that, among them, seven eclipses (#3-8, #3-15, #3-16, #3-18, #3-19, #3-31 and #3-32) are dated *the following day*, and two eclipses (#3-11 and #3-29) *the same day*. Of the latter two, record #3-11 (shown as an outlined bar in the figure) is regarded as an exceptional case because it describes an eclipse time in the "five watch system", as mentioned in Subsection *4.5.1.4*. Since, in this system, time is counted successively over a night, it seems reasonable not to change a date midway through the night. As for record #3-29, it is noted that the eclipse started around midnight within the mean error of the eclipse time. In addition, there is another eclipse (#3-12) dated *the same day*. This eclipse started almost at midnight within the mean error as well.

We turn to three *after-midnight* eclipses after the early seventeenth century (#3-37 and after). In contrast to the above, all three eclipses (#3-37, #3-44 and #3-50), which started after midnight (beyond the mean error), are dated *the same day*. Thus, we see a distinct difference in use of *the same day*/*the following day* for the dates of *after-midnight* eclipses between the periods before and after the mid-seventeenth century in Period C. It is difficult, however, to determine exactly when the usage was changed because there are no records of *after-midnight* eclipses between 1631 (#3-32) and 1666 (#3-37). Similarly, no records of those eclipses before 1448 (#3-08) allow us to determine exactly when *the following day* began to be used to express the dates after midnight.

In Fig. 4.9 (upper panel), the region in filled pale brown corresponds to the period during which *the following day* was used to express the dates after midnight. The regions in vertical striped pale brown represent the periods during which *the following day* may have been used.

By the way, when we discuss eclipse dates for the period before 1544, we have to remember that we used the Chinese calendar instead of the Vietnamese calendar unavailable to us for conversion to the Julian dates. This means that a one-day discrepancy in converted dates could happen due to a possible long/short month difference between both the calendars. But the probability of such a case is considered as very low because there is no such a case in 20 lunar eclipse records with specified dates after 1544 (#3-18 and after) in Period C.

Secondarily, we consider four lunar eclipse records in Period D (Fig. 4.9, lower panel). As seen in the figure, two records (#3-57 and #3-59) are *across-midnight* eclipses dated *the same day*, and another two (#3-56 and 3-58) are *after-midnight* eclipses dated *the following day*. The use of *the following day* in record #3-58, which describes an *after-midnight* eclipse started before dawn, seems to be in contradiction with the above-mentioned case after the early seventeenth century in Period C. However, this should not be unreasonable if we take account of the fact that most *after-midnight* eclipses are dated *the following day* in Chinese lunar eclipse records in the period when the *Shixian calendar* was used. Thus, it is very likely that the same usage was also adopted in Vietnam in Period D when they used the *Hiệp Kỷ calendar* (equivalent to the *Shixian calendar*).

In conclusion, we suggest that the beginning of the day in Period C was at midnight before the mid-seventeenth century and at dawn after this, and that it was at midnight again in Period D.

4.5.5.4 Comparison with China, Korea and Japan

Now we compare the beginning of the day in Vietnam with that in East Asian counties that used similar calendars in those days, i.e., China, Korea and Japan. In China, the beginning of the day was at dawn according to Zhang (1993), who analyzed historical records of lunar eclipse from ancient times through the mid-seventeenth century (the end of the Ming Dynasty). On the other hand, Kiang (1980) suggested, based on occultation records from ancient times through the mid-sixteenth century, that in China it was around 27:00 (3:00) or later, except for the periods of 300—550 and 1000—1200, when it was at dawn. In Korea, the beginning of the day also was at dawn according to Saito (1980a) and Ahn and Park (2004). They examined historical records of occultations and lunar eclipses, respectively, from the early third century through to the mid-eighteenth century. On the other hand, in Japan, the beginning of the day would be at 27:00 (3:00) according to Saito (1980b), who investigated historical occultation records from the mid-seventh century through to the late sixteenth century.

Thus, the beginning of the day in Vietnam before the mid-seventeenth century in Period C was different from that in China, Korea or Japan around the same time.

4.6 Summary

We presented 124 solar and 59 lunar eclipse records ranging from the third century BCE to 1888 CE, which were collected from the three Vietnamese historical sources *VSL*, *TT&TB* and *ĐNTL-CB*. In addition, we presented another 29 solar eclipse records (eight of them are the same as those in the *TT&TB*) contained in the *ĐNTL-TB*.

We examined these records by using modern eclipse simulation software programs (the *JavaScript Solar/Lunar Eclipse Explorer* by Espenak and O'Byrne (n.d.-a, n.d.-b), and the *Lmap* by Takesako (n.d.)). Our conclusions are summarized as follows:

(1) The average reliabilities of the solar and the lunar eclipse records since the tenth century are found to be 72% and 81%, respectively, except for the records in the *ĐNTL-TB*. For the records referring to eclipse times and total eclipses, 75–80% of them are found to be reliable in their description. Concerning the eclipse

records in the BCE era, our examination confirmed Ho's (1964) suggestion that they were copied from the *Hanshu*.

(2) We can safely say that from the early fifteenth century Vietnamese court astronomers sometimes presented eclipse predictions to the Emperor. However, most of the eclipse records provide very brief descriptions: they only tell us that there was an eclipse on a certain date. From these records, we cannot determine whether they were based on predictions or observations.

(3) In relation to calendar-making methods, in Period D or in the period after the introduction of the *Hiệp Kỷ* (the same as the Chinese *Shixian*) calendar, both the reliability and the ER ratio of solar eclipse records increased. The latter reached 79%, which is unexpectedly high if most of the records were based on observations because an annually averaged percentage of sunshine, which may be regarded as a possible maximum ER ratio for solar eclipses, in Huế was estimated to be merely ~40%. Therefore, we consider that a large fraction of records in Period D were based on predictions.

(4) As for the solar eclipse records in the *ĐNTL-TB*, we found that their reliability was very low (31%). Moreover, all of the doubtful records in *serious error* fall within the period from about 1660 to 1720. Meanwhile, intercalary month differences in the *Vạn Toàn Calendar* used in the *ĐNTL-TB* and the *Khâm Thụ Calendar* used in the *TT&TB* also are mostly concentrated in this period. This suggests that the *Vạn Toàn Calendar* was not properly calculated from about 1660 (but possibly as early as 1630) to 1720, and also that most of the solar eclipse records were based on predictions and not on observations.

(5) After examining lunar eclipse records that have specified dates in Periods C and D, we suggest that the beginning of the day in Period C was at midnight before the mid-seventeenth century and at dawn after this, and also that it was at midnight again in Period D. The beginning of the day in Vietnam before the mid-seventeenth century in Period C was different from that found in East Asian counties that used similar calendars, i.e., China, Korea or Japan around the same time. On the other hand, the beginning of the day in Period D was the same as that in China where the same calendar-making method was used.

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Appendix 4.1

Solar Eclipse Records in the *VSL*, *TT&TB* and *ĐNTL-CB*

We provide the original texts in classical Chinese and their English translation of the solar eclipse records collected from the Vietnamese historical sources; the *Việt*

Sử Lược (*VSL*), the *Đại Việt Sử Ký Toan Thư* (*TT*) supplemented by the *Đại Việt Sử Ký Tục Biên* (*TB*), and the *Đại Nam Thực Lục Chính Biên* (*ĐNTL-CB*). For the translation of the Chinese sexagenary cycle used for a day and so on, we also give its Chinese name in parentheses. We omit the Chinese sexagenary cycle used for a year in the sources unless necessary. It is noticed that, in the Chinese calendar during a period between 221 BCE and 105 BCE, a year started with the tenth month, followed by the eleventh, the twelfth, the first, …, and ended with the ninth month and that, in historical sources in those days, the months of the year were arranged in order from the first month to twelfth month. Thus, during the period, the tenth, the eleventh and the twelfth month of a year are equivalent to those months of the previous year in ordinary calendars, respectively.

For each record, we provide the following: its described eclipse date converted into the Julian/Gregorian calendar, an English translation of the text, the original text in classical Chinese followed by an abbreviation for the historical source name. For the source name abbreviations, see Table 4.A1. Moreover, we give the catalog numbers of Oppolzer's (1887) *Canon of Solar Eclipses* (Oplzr.SE) and of Espenak and Meeus's (n.d.-a) *Five Millennium Catalog of Solar Eclipses: –1999 to +3000* (5MCSE). As far as records in the *TT*, we also give Ho's (1964) list number (Ho #iv) of solar eclipse records. We also remark how the eclipse was seen (unless covered with cloud) in the capital of the dynasty on the described date according to the *JavaScript Solar Eclipse Explorer* developed by Espenak and O'Byrne (n.d.-a). The magnitude at mid-eclipse (or that at moonrise or moonset if a mid-eclipse occurred below the horizon) is shown in parentheses: for example, "a partial eclipse (0.*nn*) was observable in Đông Kinh".

Table 4.A2 lists the geographical coordinates of the capitals of historical Vietnamese dynasties that related to eclipse records appearing in Appendices 4.1 through 4.3. Since we do not have so accurate information on the positions of some of the palaces, more precisely, of most of the observation sites, the coordinates listed in the table are rather tentative, and have some uncertainty (probably up to ~0.1 deg), which is considered, however, as negligible for our purposes.

Phiên Ngung, Mê Linh and Long Biên were the capitals of the Triệu Dynasty (207 BCE–111 BCE), Trưng Sisters (CE 40–43) and Early Lý (Tiền Lý) Dynasty

Table 4.A1 Examples of the abbreviation for the names of the historical sources used in Appendices 4.1 through 4.3.

Example	Explanation
VSL-1	*Việt Sử Lược*, chapter 1
TT (NK)-2	*Đại Việt Sử Ký Toan Thư Ngoại Kỷ* (*The Outer Annals*, 外紀), chapter 2
TT (BK)-7	*Đại Việt Sử Ký Toan Thư Bản Kỷ* (*The Basic Annals*, 本紀), chapter 7
TB-4	*Đại Việt Sử Ký Tục Biên*, chapter 4
ĐNTL-TB-7	*Đại Nam Thực Lục Tiền Biên*, chapter 7
ĐNTL-CB-IV.21	*Đại Nam Thực Lục Chính Biên*, annals No.4 (第四紀), chapter 21

Table 4.A2 The capitals of Vietnamese Dynasties that are related to the eclipse records listed in Appendices 4.1 through 4.3. The geographical coordinates given here are those adopted in this chapter. They have some uncertainty. See the text.

Place name	Modern name (in English)	Lat. (deg)	Long. (deg)
Đông Kinh	Hanoi	N 21.04	E 105.84
Hoa Lư	Ninh Bình	N 20.29	E 105.91
Huế	Hue	N 16.47	E 107.58
Long Biên	Hanoi	N 21.04	E 105.84
Mê Linh	near Hanoi	N 21.16	E 105.73
Phiên Ngung	Guangzhou, China	N 23.13	E 113.27
Thăng Long	Hanoi	N 21.04	E 105.84
Vạn Lại	Tho Xuan District, Thanh Hoa Province	N 19.91	E 105.48

(544–602), respectively. Hoa Lư was the capital of the Early Lê and Lý Dynasties (before moving the capital) (980–1010), and Thăng Long was the capital of the Lý and Trần Dynasties (1010–1400). Đông Kinh was the capital of the Lê Dynasty (1428–1527, 1533–1789) except for 1533–1597, during which the capital was Vạn Lại. Huế was the capital of the Nguyễn Dynasty (1802–1945).

(1-1) 20 December 205 BCE
(Emperor Vũ of Triệu,) 4th year, winter, 10th month, the last day of the month. There was an eclipse of the Sun.
(趙 武帝)四年冬十月晦, 日食. [TT (NK)-2]
Oplzr.SE #2387, 5MCSE #04277, Ho #iv-01. A partial eclipse (0.40) was observable in Phiên Ngung.

(1-2) 18 January 204 BCE
(Emperor Vũ of Triệu,) 4th year, 11th month, the last day of the month. There was an eclipse of the Sun.
(趙 武帝)四年十一月晦, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-02. No eclipse occurred anywhere on the Earth.

(1-3) 21 February 188 BCE
(Emperor Vũ of Triệu,) 20th year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.
(趙 武帝)二十年春正月朔, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-03. No eclipse occurred anywhere on the Earth.

(1-4) 17 July 188 BCE
(Emperor Vũ of Triệu,) 20th year, summer, 5th month, there was a total eclipse of the Sun.
(趙 武帝)二十年夏五月, 日食, 既. [TT (NK)-2]
Oplzr.SE #2425, 5MCSE #04315, Ho #iv-04. Since the record gives the eclipse month only, we assumed the eclipse occurred on the last day of the month. A partial eclipse (0.93) was observable in Phiên Ngung on the last day of the month.

(1-5) 26 July 186 BCE
(Emperor Vũ of Triệu,) 22nd year, summer, 6th month, the last day of the month. There was an eclipse of the Sun.
(趙 武帝)二十二年夏六月晦, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-05. No eclipse occurred anywhere on the Earth.

(1-6) 4 December 179 BCE
(Emperor Vũ of Triệu,) 30th year, winter, 10th month, the last day of the month. There was an eclipse of the Sun.
(趙 武帝)三十年冬十月晦, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-06. No eclipse occurred anywhere on the Earth. The *Hanshu* says: "11th month" instead of "10th month". See Subsubsection 4.5.1.2.

(1-7) 22 December 178 BCE
(Emperor Vũ of Triệu,) 31st year, winter, 10th month, the last day of the month. There was an eclipse of the Sun.
(趙 武帝)三十一年冬十月晦, 日食. [TT (NK)-2]
Oplzr.SE #2449, 5MCSE #04339, Ho #iv-07. A partial eclipse (0.61) was observable in Phiên Ngung.

(1-8) 21 January 177 BCE
(Emperor Vũ of Triệu,) 31st year, 11th month, the last day of the month. There was an eclipse of the Sun.
(趙 武帝)三十一年十一月晦, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-08. No eclipse occurred anywhere on the Earth.

(1-9) 9 June 160 BCE
(Emperor Vũ of Triệu,) 48th year, summer, 4th month, the last day of the month. There was an eclipse of the Sun.
(趙 武帝)四十八年夏四月晦, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-09. No eclipse occurred anywhere on the Earth.

(1-10) 6 March 154 BCE
(Emperor Vũ of Triệu,) 54th year, spring, 1st month … the last day of the month. There was an eclipse of the Sun.
(趙 武帝)五十四年春正月, ……是月晦, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-10. No eclipse occurred anywhere on the Earth. The *Hanshu* says: "2nd month". instead of "1st month". See Subsubsection 4.5.1.2.

(1-11) 27 November 154 BCE
(Emperor Vũ of Triệu,) 55th year, winter, 10th month, the last day of the month. There was an eclipse of the Sun
(趙 武帝)五十五年冬十月晦, 日食. [TT (NK)-2]
Oplzr.SE —, 5MCSE —, Ho #iv-11. No eclipse occurred anywhere on the Earth. Ho (1968) gave a wrong converted date.

(1-12) 22 October 148 BCE

(Emperor Vũ of Triệu,) 60th year, autumn, 9th month, the last day of the month. There was an eclipse of the Sun.

(趙 武帝)六十年秋九月晦, 日食. [TT (NK)-2]

Oplzr.SE —, 5MCSE —, Ho #iv-12. No eclipse occurred anywhere on the Earth.

(1-13) 10 November 147 BCE

(Emperor Vũ of Triệu,) 61st year, autumn, 9th month, …, the last day of the month. There was an eclipse of the Sun.

(趙 武帝)六十一年秋九月, ……是月晦, 日食. [TT (NK)-2]

Oplzr.SE #2523, 5MCSE #04413, Ho #iv-13. A partial eclipse (0.56) was observable in Phiên Ngung.

(1-14) 10 December 147 BCE

(Emperor Vũ of Triệu,) 62nd year, winter, 10th month, the last day of the month. There was an eclipse of the Sun.

(趙 武帝)六十二年冬十月晦, 日食. [TT (NK)-2]

Oplzr.SE —, 5MCSE —, Ho #iv-14. No eclipse occurred anywhere on the Earth.

(1-15) 8 September 144 BCE

(Emperor Vũ of Triệu,) 64th year, autumn, 7th month, the last day of the month. There was an eclipse of the Sun.

(趙 武帝)六十四年秋七月晦, 日食. [TT (NK)-2]

Oplzr.SE #2530, 5MCSE #04420, Ho #iv-15. An annular eclipse (0.94) was observable in Phiên Ngung. The Sun rose after the eclipse started.

(1-16) 28 August 143 BCE

(Emperor Vũ of Triệu,) 65th year, autumn, 7th month, the last day of the month. There was an eclipse of the Sun.

(趙 武帝)六十五年秋七月晦, 日食. [TT (NK)-2]

Oplzr.SE #2532, 5MCSE #04422, Ho #iv-16. A partial eclipse (0.43) was observable in Phiên Ngung.

(1-17) 20 March 139 BCE

(Emperor Vũ of Triệu,) 69th year, spring, 1st month, the last day of the month. There was an eclipse of the Sun.

(趙 武帝)六十九年春正月晦, 日食. [TT (NK)-2]

Oplzr.SE —, 5MCSE —, Ho #iv-17. No eclipse occurred anywhere on the Earth.

(1-18) 1 November 138 BCE

(Emperor Vũ of Triệu,) 70th year, 9th month, the last day of the month. There was an eclipse of the Sun.

(趙 武帝)七十年九月晦, 日食. [TT (NK)-2]

Oplzr.SE #2545, 5MCSE #04435, Ho #iv-18. A partial eclipse (0.33) was observable in Phiên Ngung.

(1-19) 19 August 134 BCE

(King Văn of Triệu,) 3rd year, autumn, 7th month, the last day of the month. There was an eclipse of the Sun.

(趙 文王)三年秋七月晦, 日食.[TT (NK)-2]

Oplzr.SE #2555, 5MCSE #04445, Ho #iv-19. A partial eclipse (0.57) was observable in Phiên Ngung.

(1-20) 6 May 127 BCE

(King Văn of Triệu,) 10th year, spring, 3rd month, the last day of the month. There was an eclipse of the Sun.

(趙 文王)十年春三月晦, 日食. [TT (NK)-2]

Oplzr.SE —, 5MCSE —, Ho #iv-20. No eclipse occurred anywhere on the Earth.

(1-21) 9 July 122 BCE

(King Minh of Triệu,) 3rd year, summer, 5th month, the last day of the month. There was an eclipse of the Sun.

(趙 明王)三年夏五月晦, 日食. [TT (NK)-2]

Oplzr.SE #2582, 5MCSE #04472, Ho #iv-21. A partial eclipse (0.70) was observable in Phiên Ngung.

(1-22) 19 April 41 CE

(King Trưng,) 2nd year, spring, 2nd month, the last day of the month. There was an eclipse of the Sun.

(徵王)二年春二月晦, 日食.[TT (NK)-3]

Oplzr.SE #2986, 5MCSE #04876, Ho #iv-22. A partial eclipse (0.90) was observable in Mê Linh.

(1-23) 8 April 479

(Year) *kỷ-mùi* (*ji-wei*), spring, 3rd month, 1st day of the month, there was an eclipse of the Sun.

己未*春三月朔, 日食. [TT (NK)-4]

Oplzr.SE #4003, 5MCSE #05889, Ho #iv-23. A partial eclipse (0.64) was observable in Vietnam**.

* The year is also given in the Chinese calendar as "Shengming reign period, 3rd year".

** Vietnam was under the Chinese domination. We assumed the observation site was present Hanoi.

(1-24) 6 February 547

Thiên Đức reign period, 4th year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.

天德四年春正月朔, 日食. [TT (NK)-4]

Oplzr.SE #4170, 5MCSE #06056, Ho #iv-24. A partial eclipse (0.51) was observable in Long Biên.

(1-25) 24 February 993

Hưng Thống reign period, 5th year, spring, 2nd month, day *kỷ-mùi* (*ji-wei*), 1st day of the month. There was an eclipse of the Sun.

興統五年春二月己未朔, 日食. [TT (BK)-1]

Oplzr.SE #5225, 5MCSE #07108, Ho #iv-25. A partial eclipse (0.31 at sunset) was observable in Hoa Lư. The Sun set before mid-eclipse.

(1-26) 28 May 998
Ứng Thiên reign period, 5th year, summer, 5th month, day *mậu-ngọ* (*wu-wu*), 1st day of the month. There was an eclipse of the Sun.
應天五年夏五月戊午朔, 日食. [TT (BK)-1]
Oplzr.SE #5237, 5MCSE #07120, Ho #iv-26. The eclipse was not observable in Hoa Lư.

(1-27) 23 October 998
Ứng Thiên reign period, 5th year, winter, 10th month, day *bính-tuất* (*bing-xu*), 1st day of the month. There was an eclipse of the Sun.
應天五年冬十月丙戌朔, 日食. [TT (BK)-1]
Oplzr.SE #5238, 5MCSE #07121, Ho #iv-27. The eclipse was not observable in Hoa Lư.

(1-28) 29 March 1028
Thiên Thành reign period, 1st year, spring, 3rd month, day *bính-thân* (*bing-shen*), 1st day of the month. There was an eclipse of the Sun.
天成元年春三月丙申朔, 日食. [TT (BK)-2]
Oplzr.SE #5307, 5MCSE #07190, Ho #iv-28. The eclipse was not observable in Thăng Long.

(1-29) 15 February 1040
Càn Phù Hữu Đạo reign period, 2nd year, spring, 1st month, day *đinh-hợi* (*ding-hai*), 1st day of the month. There was an eclipse of the Sun.
乾符有道二年春正月丁亥朔, 日食. [TT (BK)-2] and [VSL-1]*
Oplzr.SE #5334, 5MCSE #07217, Ho #iv-29. A partial eclipse (0.88) was observable in Thăng Long.
* The *VSL* says: "日有食之" instead of "日食".

(1-30) 13 September 1075
Thái Ninh reign period, 4th year, autumn, 8th month, day *canh-dần* (*geng-yin*), 1st day of the month. There was an eclipse of the Sun.
太寧四年秋八月庚寅朔, 日食. [TT (BK)-3]
Oplzr.SE #5420, 5MCSE #07303, Ho #iv-30. The eclipse was not observable in Thăng Long.

(1-31) 23 October 1093
Hội Phong reign period, 2nd year, winter, 10th month, 1st day of the month. There was an eclipse of the Sun.
會豐二年冬十月朔, 日有食之. [VSL-2]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(1-32) 9 December 1105
Long Phù Nguyên Hóa reign period, 5th year, 11th month, 1st day of the month. The Sun was over half eclipsed.
龍符元化五年十一月朔, 日食過半. [VSL-2]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(1-33) 17 November 1183
Trinh Phù reign period, 8th year, winter, 11th month, day *nhâm-ngọ* (*ren-wu*), 1st day of the month. There was an eclipse of the Sun.
貞符八年冬十一月壬午朔, 日食. [TT (BK)-4]

Oplzr.SE #5691, 5MCSE #07574, Ho #iv-31. A partial eclipse (0.31) was observable in Thăng Long.

(1-34) 29 February 1188

Thiên Tư Gia Thụy reign period, 3rd year, spring, 2nd month, day *đinh-mão* (*ding-mao*), 1st day of the month. There was an eclipse of the Sun.

天資嘉瑞三年春二月丁卯朔, 日有食之. [VSL-3]

Oplzr.SE #5702, 5MCSE #07585. The eclipse was not observable in Thăng Long.

(1-35) 26 July 1188

Thiên Tư Gia Thụy reign period, 3rd year, autumn, 7th month, day *giáp-tý* (*jia-zi*), 1st day of the month. There was an eclipse of the Sun.

天資嘉瑞三年秋七月甲子朔, 日食. [TT (BK)-4]

Oplzr.SE (#5703), 5MCSE (#07586), Ho #iv-32. No eclipse occurred anywhere on the Earth. Day *giáp-tý* (*jia-zi*) is not the first day of the 7th month but of the 8th month according to Chinese calendar we use. On that day, a partial eclipse (0.90) was observable in Thăng Long. This one-month discrepancy can be explained by a difference in positioning an intercalary month in the year between the Vietnamese and Chinese calendars, as discussed in Sub-subsection *4.5.1.3*. Therefore, we consider that this record is 'moderately' correct.

(1-36) 17 February 1189

Thiên Tư Gia Thụy reign period, 4th year, spring, 2nd month, day *tân-dậu* (*xin-you*), 1st day of the month. There was an eclipse of the Sun.

天資嘉瑞四年春二月辛酉朔, 日食. [TT (BK)-4] and [VSL-3]*

Oplzr.SE #5704, 5MCSE #07587, Ho #iv-33. A partial eclipse (0.88) was observable in Thăng Long.

* "辛酉 (*tân-dậu*)" is not included in the *VSL*.

(1-37) 11 March 1206

Trị Bình Long Ứng reign period, 2nd year, 2nd month, day *nhâm-tý* (*ren-zi*), 1st day of the month. There was an eclipse of the Sun.

治平龍應二年二月壬子朔, 日有食之. [VSL-3]

Oplzr.SE #5747, 5MCSE #07630. A partial eclipse (0.47 at sunset) was observable in Thăng Long. The Sun set before mid-eclipse.

(1-38) 27 March 1229

Kiến Trung reign period, 5th year, spring, 3rd month. There was an eclipse of the Sun.

建中五年春三月, 日有食之. [TT (BK)-5]

Oplzr.SE —, 5MCSE —, Ho #iv-34. Since the record gives the eclipse month only, we assumed the eclipse occurred on the 1st day of the month. No eclipse occurred anywhere on the Earth.

(1-39) 26 September 1242

Thiên Ứng Chính Bình reign period, 11th year, 9th month, day *canh-thìn* (*geng-chen*), 1st day of the month. There was an eclipse of the Sun.

天應政平十一年九月庚辰朔, 日食. [TT (BK)-5]

Oplzr.SE #5840, 5MCSE #07722, Ho #iv-35. A partial eclipse (0.81) was observable in Thăng Long.

(1-40) 14 May 1249
Thiên Ứng Chính Bình reign period, 18th year, summer, 4th month, day *nhâm-dần* (*ren-yin*), 1st day of the month. There was an eclipse of the Sun.
天應政平十八年夏四月壬寅朔, 日食. [TT (BK)-5]
Oplzr.SE #5857, 5MCSE #07739, Ho #iv-36. A partial (0.99) was observable in Thăng Long.

(1-41) 12 April 1260
Thiệu Long reign period, 3rd year, spring, 3rd month, day *mậu-thìn* (*wu-chen*), 1st day of the month. There was a total eclipse of the Sun.
紹隆三年春三月戊辰朔, 日食. [TT (BK)-5]
Oplzr.SE #5884, 5MCSE #07765, Ho #iv-37. A partial eclipse (0.83) was observable in Thăng Long.

(1-42) 25 June 1275
Bảo Phù reign period, 3rd year, summer, 6th month, day *canh-tý* (*geng-zi*), 1st day of the month. There was a total eclipse of the Sun.
寶符三年夏六月庚子朔, 日有食之, 既. [TT (BK)-5]
Oplzr.SE #5922, 5MCSE #07803, Ho #iv-38. A partial eclipse (0.93), not a total one, was observable in Thăng Long.

(1-43) 7 November 1287
Trùng Hưng reign period, 3rd year, winter, 10th month, 1st day of the month. There was an eclipse of the Sun.
重興三年冬十月朔, 日食. [TT (BK)-5]
Oplzr.SE #5951, 5MCSE #07832, Ho #iv-39. A partial eclipse (0.06) was observable in Thăng Long.

(1-44) 23 March 1289
Trùng Hưng reign period, 5th year, 3rd month, 1st day of the month. There was an eclipse of the Sun.
重興五年三月朔, 日食. [TT (BK)-5]
Oplzr.SE #5954, 5MCSE #07835, Ho #iv-40. A partial eclipse (0.23) was observable in Thăng Long.

(1-45) 21 January 1292
Trùng Hưng reign period, 8th year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.
重興八年春正月朔, 日食. [TT (BK)-5]
Oplzr.SE #5962, 5MCSE #07843, Ho #iv-41. A partial eclipse (0.68) was observable in Thăng Long.

(1-46) 25 April 1343
Thiệu Phong reign period, 3rd year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.
紹豐三年夏四月朔, 日食. [TT (BK)-7]
Oplzr.SE #6080, 5MCSE #07960, Ho #iv-42. A partial eclipse (0.77) was observable in Thăng Long.

(1-47) 22 February 1346
Thiệu Phong reign period, 6th year, spring, 2nd month, 1st day of the month. There was an eclipse of the Sun.
紹豐六年春二月朔, 日食. [TT (BK)-7]
Oplzr.SE #6087, 5MCSE #07967, Ho #iv-43. A partial eclipse (0.36) was observable in Thăng Long.

(1-48) 11 February 1347
Thiệu Phong reign period, 7th year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.
紹豐七年春正月朔, 日食. [TT (BK)-7]
Oplzr.SE #6089, 5MCSE #07969, Ho #iv-44. A partial eclipse (0.30) was observable in Thăng Long.

(1-49) 11 December 1349
Thiệu Phong reign period, 9th year, 11th month, 1st day of the month. There was an eclipse of the Sun.
紹豐九年十一月朔, 日食. [TT (BK)-7]
Oplzr.SE #6096, 5MCSE #07976, Ho #iv-45. The eclipse was not observable in Thăng Long.

(1-50) 26 May 1351
Thiệu Phong reign period, 11th year, summer, 5th month, 1st day of the month. There was an eclipse of the Sun.
紹豐十一年夏五月朔, 日食. [TT (BK)-7]
Oplzr.SE #6099, 5MCSE #07979, Ho #iv-46. The eclipse was not observable in Thăng Long.

(1-51) 25 March 1354
Thiệu Phong reign period, 14th year, 3rd month, 1st day of the month. There was an eclipse of the Sun.
紹豐十四年三月朔, 日食. [TT (BK)-7]
Oplzr.SE #6105, 5MCSE #07985, Ho #iv-47. A partial eclipse (0.93) was observable in Thăng Long. The Sun set before the eclipse ended. The mid-eclipse occurred before sunset.

(1-52) 16 May 1360
Đại Trị reign period, 3rd year, summer, 5th month, 1st day of the month. There was an eclipse of the Sun.
大治三年夏五月朔, 日食. [TT (BK)-7]
Oplzr.SE #6119, 5MCSE #07999, Ho #iv-48. The eclipse was not observable in Thăng Long.

(1-53) 5 June 1369
Đại Trị reign period, 12th year, summer, 5th month, 1st day of the month. There was an eclipse of the Sun.
大治十二年夏五月朔, 日食. [TT (BK)-7]
Oplzr.SE #6140, 5MCSE #08020, Ho #iv-49. A partial eclipse (0.94) was observable in Thăng Long.

(1-54) 23 January 1422
Yongle reign period of Ming, 20th year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.
明 永楽二十年春正月朔, 日食. [TT (BK)-10]
Oplzr.SE #6258, 5MCSE #08138, Ho #iv-50. A partial eclipse (0.54) was observable in Vietnam (Hanoi)*.
* Vietnam was dominated by the Chinese Ming dynasty. Here, we assume that the observation was made in Thăng Long.

(1-55) 7 June 1434
Thiệu Bình reign period, 1st year, 5th month, day *đinh-sửu* (d*ing-chou*), 1st day of the month. Business at the Imperial Court was suspended. Before that, the Astrologer Bùi Thì Hanh confidentially reported that, on 1st day of the fifth month, the spirit of a black monkey would eat the Sun, so there would be an eclipse of the Sun on that day.
紹平元年五月丁丑朔, 輟朝.先是, 太史裴時亨密奏, 五月初一日有黒猿精啖日, 日當食, …… [TT (BK)-10]
Oplzr.SE #6286, 5MCSE #08166, Ho —. This is a record of an eclipse prediction. A partial eclipse (0.30) was observable in Đông Kinh.

(1-56) 20 November 1435
Thiệu Bình reign period, 2nd year, 11th month, day *mậu-thìn* (*wu-chen*), 1st day of the month. There was an eclipse of the Sun.
紹平二年, 十一月戊辰朔, 日有食. [TT (BK)-11]
Oplzr.SE #6289, 5MCSE #08169, Ho #iv-51. A partial eclipse (0.41) was observable in Đông Kinh. This eclipse was predicted about one month before: "(The same year,) the 9th month, 26th day. The Astrologer Bùi Thì Hanh confidentially reported that there would be an eclipse of the Sun on the first day of the eleventh month… (九月……二十六日, 太史裴時亨密奏, 十一月朔日有食……)".

(1-57) 10 November 1444
Thái Hòa reign period, 2nd year, winter, 10th month. … There was an eclipse of the Sun.
太和二年冬十月, ……日有食之. [TT (BK)-11]
Oplzr.SE #6309, 5MCSE #08189, Ho #iv-52. Since the record gives the eclipse month only, we assumed the eclipse occurred on the 1st day of the month. A partial eclipse (0.82) was observable in Đông Kinh.

(1-58) 6 March 1467
Quang Thuận reign period, 8th year, 2nd month, day *đinh-dậu* (d*ing-you*), 1st day of the month. There was an eclipse of the Sun.
光順八年二月丁酉朔, 日食. [TT (BK)-12]
Oplzr.SE #6358, 5MCSE #08238, Ho #iv-53. A partial eclipse (0.54) was observable in Đông Kinh.

(1-59) 4 February 1505
Đoan Khánh reign period, 1st year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.
端慶元年春正月朔, 日食. [TT (BK)-14]

Oplzr.SE #6443, 5MCSE #08323, Ho #iv-54. The eclipse was not observable in Đông Kinh.

(1-60) 29 January 1511

Hồng Thuận reign period, 3rd year, spring, 1st month, 1st day of the month. There was an eclipse of the sun.

洪順三年春正月朔, 日有食之. [TT (BK)-15]

Oplzr.SE —, 5MCSE —, Ho #iv-55. No eclipse occurred anywhere on the Earth.

(1-61) 30 May 1527

Thống Nguyên reign period, 6th year, 5th month, 1st day of the month. The astronomical bureau reported that there would be an eclipse of the Sun. (The eclipse was) not verified.

統元六年五月初一日, 司天奏日食, 不驗. [TT (BK)-15]

Oplzr.SE #6495, 5MCSE #08375, Ho —. The eclipse was not observable in Vạn Lại. This is a record of an eclipse prediction.

(1-62) 2 October 1587

Quang Hưng reign period, 10th year, 9th month, day *đinh-hợi* (*ding-hai*), 1st day of the month. There was an eclipse of the Sun.

光興十年九月丁亥朔, 日食. [TT (BK)-17]

Oplzr.SE #6632, 5MCSE #08512, Ho #iv-56. A partial eclipse (0.12) was observable in Vạn Lại.

(1-63) 31 July 1590

Quang Hưng reign period, 13th year, 7th month, 1st day of the month. There was an eclipse of the Sun.

光興十三年七月朔, 日食. [TT (BK)-17]

Oplzr.SE #6638, 5MCSE #08518, Ho #iv-57. A partial eclipse (0.89) was observable in Vạn Lại.

(1-64) 20 May, 1594

Quang Hưng reign period, 17th year, 4th month, day *kỷ-dậu* (*ji-you*), 1st day of the month. There was an eclipse of the Sun. But it was rainy.

光興十七年四月己酉朔, 日蝕, 天雨. [TT (BK)-17]

Oplzr.SE #6647, 5MCSE #08527, Ho #iv-58. A partial eclipse (0.02) was observable in Vạn Lại.

(1-65) 22 September 1596

Quang Hưng reign period, 19th year, 8th month, …, intercalary (8th) month, …, 1st day of the month. There was an eclipse of the Sun.

光興十九年八月, ……閏月朔, 日有食之. [TT (BK)-17]

Oplzr.SE #6653, 5MCSE #08533, Ho #iv-59. A partial eclipse (0.17) was observable in Vạn Lại.

(1-66) 11 May 1603

Hoằng Định reign period, 4th year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.

弘定四年夏四月朔, 日有食之. [TT (BK)-18]

Oplzr.SE #6669, 5MCSE #08548, Ho #iv-60. A partial eclipse (0.61) was observable in Đông Kinh.

(1-67) 29 March 1615

Hoằng Định reign period, 16th year, 3rd month, 1st day of the month. There was an eclipse of the Sun.

弘定十六年三月朔, 日有食之. [TT (BK)-18]

Oplzr.SE #6696, 5MCSE #08575, Ho #iv-61. A partial eclipse (0.60) was observable in Đông Kinh.

(1-68) 25 October 1631

Đức Long reign period, 3rd year, winter, 10th month, 1st day of the month. There was an eclipse of the Sun.

德隆三年冬十月朔, 日有食之. [TT (BK)-18]

Oplzr.SE #6736, 5MCSE #08615, Ho #iv-62. The eclipse was not observable in Đông Kinh.

(1-69) 29 March 1634

Đức Long reign period, 6th year, 3rd month, 1st day of the month. There was an eclipse of the Sun.

德隆六年三月朔, 日食. [TT (BK)-18]

Oplzr.SE #6742, 5MCSE #08621, Ho #iv-63. A partial eclipse (0.69) was observable in Đông Kinh.

(1-70) 26 Janurary 1637

Dương Hòa reign period, 3rd year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.

陽和三年春正月朔, 日有食之. [TT (BK)-18]

Oplzr.SE #6749, 5MCSE #08628, Ho #iv-64. A partial eclipse (0.37) was observable in Đông Kinh.

(1-71) 13 February 1638

Dương Hòa reign period, 3rd year, 12th month, the last day of the month. There was an eclipse of the Sun.

陽和三年十二月晦, 日食. [TT (BK)-18]

Oplzr.SE —, 5MCSE —, Ho #iv-65. No eclipse occurred anywhere on the Earth.

(1-72) 17 December 1664

Cảnh Trị reign period, 2nd year, 11th month, day *mậu-tý* (*wu-zi*), 1st day of the month. There was an eclipse of the Sun.

景治二年十一月戊子朔, 日有食之. [TT (BK)-19]

Oplzr.SE —, 5MCSE —, Ho #iv-66. No eclipse occurred anywhere on the Earth.

(1-73) 2 July 1666

Cảnh Trị reign period, 4th year, 6th month, day *canh-tuất* (*geng-xu*), 1st day of the month. There was an eclipse of the Sun.

景治四年六月庚戌朔, 日有食之. [TT (BK)-19]

Oplzr.SE #6824, 5MCSE #08702, Ho #iv-67. A partial eclipse (0.43) was observable in Đông Kinh.

(1-74) 30 April 1669

Cảnh Trị reign period, 7th year, summer, 4th month, 1st day of the month. There was a total eclipse of the Sun.

景治七年夏四月朔, 日食, 既. [TT (BK)-19]
Oplzr.SE #6832, 5MCSE #08710, Ho #iv-68. A partial eclipse (0.97) was observable in Đông Kinh.

(1-75) 3 September 1671
Cảnh Trị reign period, 9th year, 8th month, day *kỷ-dậu* (*ji-you*), 1st day of the month. There was an eclipse of the Sun.
景治九年八月己酉朔, 日有食之. [TT (BK)-19]
Oplzr.SE #6838, 5MCSE #08716, Ho #iv-69. The eclipse was not observable in Đông Kinh.

(1-76) 11 June 1676
Vĩnh Trị reign period, 1st year, summer, 5th month, 1st day of the month. There was an eclipse of the Sun.
永治元年夏五月朔, 日食. [TB-1]
Oplzr.SE #6850, 5MCSE #08728. A partial eclipse (0.55) was observable in Đông Kinh.

(1-77) 4 January 1677
Vĩnh Trị reign period, 1st year, 12th month, 1st day of the month.永治元年十二月朔, 日食. [TB-1] There was an eclipse of the Sun.
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(1-78) 28 February 1691
Chính Hòa reign period, 12th year, 2nd month, day *đinh-tị* (*ding-si*). There was an eclipse of the Sun.
正和十二年二月丁巳, 日食. [TB-1]
Oplzr.SE #6887, 5MCSE #08765. A partial eclipse (0.53) was observable in Đông Kinh.

(1-79) 17 February 1692
Chính Hòa reign period, 13th year, spring, 1st month, day *tân-hợi* (*xin-hai*), 1st day of the month. There was an eclipse of the Sun.
正和十三年春正月辛亥朔, 日食. [TB-1]
Oplzr.SE #6889, 5MCSE #08767. A partial eclipse (0.42) was observable in Đông Kinh.

(1-80) 21 April 1697
Chính Hòa reign period, 18th year, 3rd month, day *tân-tị* (*xin-si*), 1st day of the month. There was an eclipse of the Sun.
正和十八年三月辛巳朔, 日食. [TB-1]
Oplzr.SE #6903, 5MCSE #08781. A partial eclipse (0.69) was observable in Đông Kinh.

(1-81) 19 February 1700
Chính Hòa reign period, 21st year, spring, 1st month, day *ất-mùi* (*yi-wei*), 1st day of the month. There was an eclipse of the Sun.
正和二十一年春正月乙未朔, 日食. [TB-1]
Oplzr.SE #6909, 5MCSE #08787. The eclipse was not observable in Đông Kinh.

(1-82) 4 August 1720
Bảo Thái reign period, 1st year, autumn, 9th [7th]* month, day *bính-dần* (*bing-yin*), 1st day of the month. There was an eclipse of the Sun.
保泰元年, 秋九[七]*月丙寅朔, 日食. [TB-2]
Oplzr.SE #6961, 5MCSE #08838. A partial eclipse (0.62) was observable in Đông Kinh.
* The day *bính-dần* (*bing-yin*) is 1st day of 7th month of the year, not of 9th month. According to Chen (1984–86), one of the several versions of TB gives "7th month", which is adopted in this chapter.

(1-83) 15 July 1730
Vĩnh Khánh reign period, 2nd year, 6th month, day *giáp-tuất* (*jia-xu*), 1st day of the month. There was an eclipse of the Sun.
永慶二年六月甲戌*朔, 日食. [TB-2]
Oplzr.SE #6987, 5MCSE #08864. A partial eclipse (0.11) was observable in Đông Kinh.
* first day of sixth month of the year should be *mậu-tuất* (*wu-xu*) in the Chinese sexagenary cycle. According to Chen (1984–86), another historical source *Lê Sử Toản Yếu* (黎史纂要) gives day *mậu-tuất* (*wu-xu*).

(1-84) 4 July 1731
Vĩnh Khánh reign period, 3rd year, 6th month, day *nhâm-thìn* (*ren-chen*), 1st day of the month. There was an eclipse of the Sun.
永慶三年六月壬辰朔, 日食. [TB-2]
Oplzr.SE #6989, 5MCSE #08866. A partial eclipse (0.21) was observable in Đông Kinh.

(1-85) 29 December 1731
Vĩnh Khánh reign period, 3rd year, 12th month, day *canh-dần* (*geng-yin*), 1st day of the month. There was an eclipse of the Sun.
永慶三年十二月庚寅朔, 日食. [TB-2]
Oplzr.SE #6990, 5MCSE #08867. A partial eclipse (0.50 at sunrise) was observable in Đông Kinh. The Sun rose after the eclipse started. The mid-eclipse occurred before sunrise.

(1-86) 16 October 1735
Vĩnh Hựu reign period, 1st year, 9th month, day *đinh-dậu* (*ding-you*), 1st day of the month. There was an eclipse of the Sun.
永祐元年九月丁酉朔, 日食. [TB-3]
Oplzr.SE #6999, 5MCSE #08876. A partial eclipse (0.18) was observable in Đông Kinh.

(1-87) 20 February 1746
Cảnh Hưng reign period, 7th year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.
景興七年春正月朔, 日食. [TB-4]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(1-88) 30 January 1748
Cảnh Hưng reign period, 9th year, spring, 1st month, 1st day of the month. There was an eclipse of the Sun.

景興九年春正月朔, 日有食之. [TB-4]
Oplzr.SE #7032, 5MCSE #08909. The eclipse was not observable in Đông Kinh.

(1-89) 25 May 1751
Cảnh Hưng reign period, 12th year, 5th month, 1st day of the month. There was an eclipse of the Sun.
景興十二年五月朔, 日食. [TB-4]
Oplzr.SE #7040, 5MCSE #08917. A partial eclipse (0.15) was observable in Đông Kinh.

(1-90) 6 November 1752
Cảnh Hưng reign period, 13th year, winter, 10th month, 1st day of the month. There was an eclipse of the Sun.
景興十三年冬十月朔, 日有食之. [TB-4]
Oplzr.SE #7043, 5MCSE #08920. A partial eclipse (0.34) was observable in Đông Kinh.

(1-91) 16 August 1765
Cảnh Hưng reign period, 26th year, autumn, 7th month, 1st day of the month. There was an eclipse of the Sun.
景興二十六年秋七月朔, 日食. [TB-5]
Oplzr.SE #7076, 5MCSE #08952. The eclipse was not observable in Đông Kinh.

(1-92) 25 May 1770
Cảnh Hưng reign period, 31st year, 5th month, 1st day of the month. There was an eclipse of the Sun.
景興三十一年五月朔, 日食. [TB-5]
Oplzr.SE #7088, 5MCSE #08964. A partial eclipse (0.76) was observable in Đông Kinh.

(1-93) 6 September 1774
Cảnh Hưng reign period, 35th year, 8th month, 1st day of the month. There was an eclipse of the Sun.
景興三十五年八月朔, 日食. [TB-5]
Oplzr.SE #7099, 5MCSE #08975. A partial eclipse (0.96) was observable in Đông Kinh.

(1-94) 28 August 1802
Gia Long reign period, 1st year, 8th month, day *kỷ-hợi* (*ji-hai*), 1st day of the month. There was an eclipse of the Sun.
嘉隆元年八月己亥朔, 日有食之. [ĐNTL-CB-I.18]
Oplzr.SE #7171, 5MCSE #09046. A partial eclipse (0.55) was observable in Huế.

(1-95) 6 June 1807
Gia Long reign period, 6th year, 5th month, day *nhâm-dần* (*ren-yin*), 1st day of the month. There was an eclipse of the Sun.
嘉隆六年五月壬寅朔, 日有食之. [ĐNTL-CB-I.32]

Oplzr.SE #7183, 5MCSE #09058. A partial eclipse (0.35) was observable in Huế.

(1-96) 4 April 1810

Gia Long reign period, 9th year, 3rd month, *ất-mão* (*yi-mao*), 1st day of the month. There was an eclipse of the Sun.

嘉隆九年三月乙卯朔, 日有食之. [ĐNTL-CB-I.40]

Oplzr.SE #7190, 5MCSE #09065. A partial eclipse (0.27) was observable in Huế.

(1-97) 1 February 1813

Gia Long reign period, 12th year, spring, 1st month, day *kỷ-tị* (*ji-si*), 1st day of the month. There was an eclipse of the Sun.

嘉隆十二年春正月己巳朔, 日有食之. [ĐNTL-CB-I.46]

Oplzr.SE #7198, 5MCSE #09073. The eclipse was not observable in Huế.

(1-98) 17 July 1814

Gia Long reign period, 13th year, 6th month, day *canh-thân* (*geng-shen*), 1st day of the month. There was an eclipse of the Sun.

嘉隆十三年六月庚申朔, 日有食之. [ĐNTL-CB-I.48]

Oplzr.SE #7201, 5MCSE #09076. A partial eclipse (0.80) was observable in Huế.

(1-99) 16 May 1817

Gia Long reign period, 16th year, summer, 4th month, *giáp-tuất* (*jia-xu*), 1st day of the month. There was an eclipse of the Sun.

嘉隆十六年夏四月甲戌朔, 日有食之. [ĐNTL-CB-I.55]

Oplzr.SE #7207, 5MCSE #09082. A partial eclipse (0.93) was observable in Huế. It was almost annular at mid-eclipse. This eclipse is one of the two predicted by Nguyễn Hữu Thận in 1815: "Gia Long reign period, 14th year, 11th month (in December, 1815). [Nguyễn] Hữu Thận reported that his retainers' calculation of the movement of celestial bodies leads to the occurrence of a solar eclipse on 1st day of 4th month and of 10th month in the year *đinh-sửu* (*ding-chou*) (嘉隆十四年十一月, …[阮]有慎因奏曰, 臣推步天象至, 丁丑四月十月朔, 俱當有日食)". See Subsection 4.5.3 and #1-100.

(1-100) 9 November 1817

Gia Long reign period, 16th year, winter, 10th month, day *tân-mùi* (*xin-wei*), 1st day of the month. There was an eclipse of the Sun.

嘉隆十六年冬十月辛未朔, 日有食之. [ĐNTL-CB-I.56]

Oplzr.SE #7208, 5MCSE #09083. A partial eclipse (0.80) was observable in Huế. This is another eclipse of the two predicted by Nguyễn Hữu Thận in 1815. See Subsection 4.5.3 and #1-99.

(1-101) 4 March 1821

Minh Mệnh reign period, 2nd year, 2nd month, day *nhâm-ngọ* (*ren-wu*), 1st day of the month. There was an eclipse of the Sun.

明命二年二月壬午朔, 日有食之. [ĐNTL-CB-II.7]

Oplzr.SE #7217, 5MCSE #09092. A partial eclipse (0.73) was observable in Huế.

(1-102) 27 June 1824
Minh Mệnh reign period, 5th year, 6th month, day *quý-tị* (*gui-si*), 1st day of the month. There was an eclipse of the Sun.
明命五年六月癸巳朔, 日有食之. [ĐNTL-CB-II.27]
Oplzr.SE #7226, 5MCSE #09101. A partial eclipse (0.49 at sunrise) was observable in Huế. The Sun rose after mid-eclipse.

(1-103) 14 April 1828
Minh Mệnh reign period, 9th year, spring, 3rd month, day *canh-tý* (*geng-zi*), 1st day of the month. There was an eclipse of the Sun.
明命九年春三月庚子朔, 日有食之. [ĐNTL-CB-II.51]
Oplzr.SE #7235, 5MCSE #09110. A partial eclipse (0.73 at sunset) was observable in Huế. The Sun set before mid-eclipse.

(1-104) 9 October 1828
Minh Mệnh reign period, 9th year, autumn, 9th month, day *mậu-tuất* (*wu-xu*), 1st day of the month. There was an eclipse of the Sun.
明命九年秋九月戊戌朔, 日有食之. [ĐNTL-CB-II.54]
Oplzr.SE #7236, 5MCSE #09111. A partial eclipse (0.51 at sunrise) was observable in Huế. The Sun rose after mid-eclipse.

(1-105) 4 March 1840
Minh Mệnh reign period, 21st year, spring, 2nd month, day *nhâm-tuất* (*ren-xu*), 1st day of the month. There was an eclipse of the Sun. Before that, the Astronomical Bureau reported that, on the first day of the month, there would be an eclipse of the Sun in the hour of *tị* (*si*, 9:00 – 11:00).
明命二十一年春二月壬戌朔, 日有食之.先是, 欽天監奏, 是月朔巳刻, 日當食. [ĐNTL-CB-II.210]
Oplzr.SE #7263, 5MCSE #09138. A partial eclipse (0.66) was observable in Huế. This record is followed by saying: "…in the hour of *tị* (*si*), there were dark clouds with rain. (the eclipse) was not seen… (……巳刻, 陰雲帯雨, 望之不見……)". Thus, this is a record of an eclipse prediction. The eclipse started at 9:08 and ended at 11:57, reaching its maximum at 10:31. Thus, the predicted time is consistent with that obtained with eclipse computation. The prediction was made four months before: "The Astronomical Bureau reported that the calculation of the movement of the Sun and Moon leads to the occurrence of a solar eclipse on 1st day of 2nd month and of 10th month in the following year. (欽天監奏言, 推算日月行度, 開年二月初一日, 日當食)".

(1-106) 8 July 1842
Thiệu Trị reign period, 2nd year, summer, 6th month, day *mậu-dần* (*wu-yin*), 1st day of the month. There was an eclipse of the Sun.
紹治二年夏六月戊寅朔, 日有食之. [ĐNTL-CB-III.9]
Oplzr.SE #7270, 5MCSE #09145. A partial eclipse (0.51) was observable in Huế.

(1-107) 21 December 1843
Thiệu Trị reign period, 3rd year, 11th month, day *kỷ-tị* (*ji-si*), 1st day of the month. There was an eclipse of the Sun.

紹治三年十一月己巳朔, 日有食之. [ĐNTL-CB-III.34]
Oplzr.SE #7273, 5MCSE #09148. A partial eclipse (0.83) was observable in Huế.

(1-108) 9 October 1847
Thiệu Trị reign period, 7th year, autumn, 9th month, day *đinh-sửu* (*ding-chou*), 1st day of the month. There was an eclipse of the Sun.
紹治七年秋九月丁丑朔, 日有食之. [ĐNTL-CB-III.72]
Oplzr.SE #7282, 5MCSE #09157. A partial eclipse (0.84 at sunset) was observable in Huế. The Sun set before mid-eclipse.

(1-109) 23 February 1849
Tự Đức reign period, 2nd year, 2nd month, day *canh-tý* (*geng-zi*), 1st day of the month There was an eclipse of the Sun.
嗣德二年二月庚子朔, 日有食之. [ĐNTL-CB-IV.4]
Oplzr.SE #7287, 5MCSE #09162. A partial eclipse (0.65) was observable in Huế. The Sun rose after the eclipse started. The mid-eclipse occurred after sunrise. This eclipse was predicted three months before: "The Astronomical Bureau reported that there would be an eclipse of the Sun on the 1st day of the 2nd month of the following year (欽天監奏言, 開年二月朔, 日食)".

(1-110) 12 February 1850
Tự Đức reign period, 3rd year, spring, 1st month, day *giáp-ngọ* (*jia-wu*), 1st day of the month. There was an eclipse of the Sun.
嗣德三年春正月甲午朔, 日有食之. [ĐNTL-CB-IV.5]
Oplzr.SE #7289, 5MCSE #09164. A partial eclipse (0.59) was observable in Huế. This eclipse was also predicted two months before: "The Astronomical Bureau reported that there would be an eclipse of the Sun on the 1st day of the 1st month of the following year (欽天監奏言, 開年正月朔, 日食)".

(1-111) 11 December 1852
Tự Đức reign period, 5th year, 11th month, day *đinh-mùi* (*ding-wei*), 1st day of the month. There was an eclipse of the Sun.
嗣德五年, 十一月丁未朔, 日有食之. [ĐNTL-CB-IV.8]
Oplzr.SE #7295, 5MCSE #09170. A partial eclipse (0.33) was observable in Huế. This record is followed by saying: "The officials of the Astronomical Bureau had not reported any prediction of the eclipse before. Then they were demoted (欽天監臣不先奏, 坐降)".

(1-112) 18 September 1857
Tự Đức reign period, 10th year, 8th month, 1st day of the month, day *kỷ-dậu* (*ji-you*). There was an eclipse of the Sun.
嗣德十年八月朔己酉, 日食. [ĐNTL-CB-IV.17]
Oplzr.SE #7305, 5MCSE #09180. A partial eclipse (0.72) was observable in Huế. This eclipse was predicted one month before: The *ĐNTL-CB* says: "10th year in the Tự Đức reign period, 7th month (in August – September, 1857), the Astronomical Bureau reported that there would be an eclipse of

the Sun on the 1st day of next month (嗣德十年七月, 欽天監奏, 來月朔日當食)”.

(1-113) 8 July 1861
Tự Đức reign period, 14th year, 6th month, day *mậu-ngọ* (*wu-wu*), 1st day of the month. There was an eclipse of the Sun.
嗣德十四年六月戊午朔, 日食. [ĐNTL-CB-IV.24]
Oplzr.SE #7315, 5MCSE #09190. A partial eclipse (0.74) was observable in Huế. This record is followed by saying: “The officials of the Astronomical Bureau had not reported any prediction of the eclipse before. Then they were punished (監臣以不先推奏, 得罰)”.

(1-114) 21 December 1862
Tự Đức reign period, 15th year, 11th month, day *kỷ-dậu* (*ji-you*), 1st day of the month. There was an eclipse of the Sun.
嗣德十五年十一月己酉朔, 日食. [ĐNTL-CB-IV.27]
Oplzr.SE #7319, 5MCSE #09194. A slightly partial eclipse (0.005) was observable in Huế.

(1-115) 8 March 1864
Tự Đức reign period, 17th year, 2nd month, day *nhâm-thân* (*ren-shen*), 1st day of the month. There was an eclipse of the Sun.
嗣德十七年二月壬申朔, 日食. [ĐNTL-CB-IV.29]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(1-116) 6 May 1864
Tự Đức reign period, 17th year, summer, 4th month, day *tân-mùi* (*xin-wei*), 1st day of the month. There was an eclipse of the Sun.
嗣德十七年夏四月辛未朔, 日食. [ĐNTL-CB-IV.29]
Oplzr.SE #7322, 5MCSE #09197. A partial eclipse (0.64) was observable in Huế. The Sun rose after the eclipse started. The mid-eclipse occurred after sunrise.

(1-117) 18 August 1868
Tự Đức reign period, 21st year, autumn, 7th month, day *bính-tý* (*bing-zi*), 1st day of the month. There was an eclipse of the Sun.
嗣德二十一年秋七月丙子朔, 日食. [ĐNTL-CB-IV.39]
Oplzr.SE #7332, 5MCSE #09207. A partial eclipse (0.78) was observable in Huế.

(1-118) 12 December 1871
Tự Đức reign period, 24th year, 11th month, day *đinh-hợi* (*ding-hai*), 1st day of the month. There was an eclipse of the Sun.
嗣德二十四年十一月丁亥朔, 日食. [ĐNTL-CB-IV.45]
Oplzr.SE #7340, 5MCSE #09215. A partial eclipse (0.36) was observable in Huế.

(1-119) 6 April 1875
Tự Đức reign period, 28th year, 3rd month, day *mậu-tuất* (*wu-xu*). There was an eclipse of the Sun.
嗣德二十八年三月戊戌, 日食. [ĐNTL-CB-IV.53]

Oplzr.SE #7347, 5MCSE #09222. A total eclipse (1.01) was observable in Huế. The total eclipse lasted 3 min 02 sec.

(1-120) 12 January 1880
Tự Đức reign period, 32nd year, 12th month, day *canh-tý* (*geng-zi*). There was an eclipse of the Sun.
嗣德三十二年十二月庚子, 日食. [ĐNTL-CB-IV.62]
Oplzr.SE #7358, 5MCSE #09233. The eclipse was not observable in Huế.

(1-121) 19 March 1882
Tự Đức reign period, 35th year, 2nd month, day *đinh-tị* (*ding-si*). There was an eclipse of the Sun.
嗣德三十五年二月丁巳, 日食. [ĐNTL-CB-IV.67]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(1-122) 17 May 1882
Tự Đức reign period, 35th year, summer, 4th month, day *bính-thìn* (*bing-chen*). There was an eclipse of the Sun.
嗣德三十五年夏四月丙辰朔, 日食. [ĐNTL-CB-IV.67]
Oplzr.SE (#7364), 5MCSE (#09239). A partial eclipse (0.44) was observable in Huế.

(1-123) 6 March 1886
Đồng Khánh reign period, 1st year, 2nd month, day *ất-sửu* (*yi-chou*), 1st day of the month. There was an eclipse of the Sun.
同慶元年二月朔乙丑, 日有食之. [ĐNTL-CB-VI.3]
Oplzr.SE #7373, 5MCSE #09248. The eclipse was not observable in Huế.

(1-124) 19 August 1887
Đồng Khánh reign period, 2nd year, 7th month, day *bính-thìn* (*bing-chen*), 1st day of the month. There was an eclipse of the Sun.
同慶二年七月丙辰朔, 日有食之. [ĐNTL-CB-VI.7]
Oplzr.SE #7376, 5MCSE #09251. A partial eclipse (0.09) was observable in Huế.

Appendix 4.2

Solar Eclipse Records in the *ĐNTL-TB*

We provide the original texts in classical Chinese and their English translation of the solar eclipse records collected from the *Đại Nam Thực Lục Tiền Biên* (*ĐNTL-TB*) in the same format as used in Appendix 4.1. Since the Nguyễn Lords did not have their reign name to indicate years, we use the temple name of the ruling king of the time in parenthesis. The palace of the Nguyễn Lords was located in Huế. See Tables 4.A1 and 4.A2 in Appendix 4.1 for the historical source abbreviations used here and the geographical coordinate of Huế, respectively.

(2-1) 2 October 1587
(Thái tổ) 30th year, autumn, 9th month, 1st day of the month. There was an eclipse of the Sun.

(太祖)三十年秋九月朔, 日有食之. [ĐNTL-TB-1]
Oplzr.SE #6632, 5MCSE #08512. A partial eclipse (0.06) was observable in Huế. The eclipse was also recorded in TT (#1-62).

(2-2) 31 July 1590
(Thái tổ) 33rd year, autumn, 7th month, 1st day of the month. There was an eclipse of the Sun.
(太祖)三十三年秋七月朔, 日有食之. [ĐNTL-TB-1]
Oplzr.SE #6638, 5MCSE #08518. A partial eclipse (0.95) was observable in Huế. The eclipse was also recorded in TT (#1-63).

(2-3) 11 May 1603
(Thái tổ) 46th year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.
(太祖)四十六年夏四月朔, 日有食之. [ĐNTL-TB-1]
Oplzr.SE #6669, 5MCSE #08548. A partial eclipse (0.48) was observable in Huế. The eclipse was also recorded in TT (#1-66).

(2-4) 29 March 1615
(Huy Tông) 2nd year, spring, 3rd month, 1st day of the month. There was an eclipse of the Sun.
(熙宗)二年春三月朔, 日有食之. [ĐNTL-TB-2]
Oplzr.SE #6696, 5MCSE #08575. A partial eclipse (0.45) was observable in Huế. The eclipse was also recorded in TT (#1-67).

(2-5) 21 July 1667
(Thái Tông) 19th year, 6th month, 1st day of the month. There was an eclipse of the Sun.
(太宗)十九年六月朔, 日有食之. [ĐNTL-TB-5]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-6) 5 August 1671
(Thái Tông) 23rd year, autumn, 7th month, 1st day of the month. There was an eclipse of the Sun.
(太宗)二十三年秋七月朔, 日有食之. [ĐNTL-TB-5]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-7) 27 April 1672
(Thái Tông) 24th year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.
(太宗)二十四年夏四月朔, 日有食之. [ĐNTL-TB-5]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-8) 28 November 1674
(Thái Tông) 26th year, 11th month, 1st day of the month. There was an eclipse of the Sun.
(太宗)二十六年十一月朔, 日有食之. [ĐNTL-TB-5]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-9) 13 April 1676
(Thái Tông) 28th year, 3rd month, 1st day of the month. There was an eclipse of the Sun.

(太宗)二十八年三月朔, 日有食之. [ĐNTL-TB-5]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-10) 31 May 1677
(Thái Tông) 29th year, summer, 5th month, 1st day of the month. There was an eclipse of the Sun.
(太宗)二十九年夏五月朔, 日有食之. [ĐNTL-TB-5]
Oplzr.SE #6852, 5MCSE #08730. The eclipse was not observable in Huế.

(2-11) 21 May 1678
(Thái Tông) 30th year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.
(太宗)三十年夏四月朔, 日有食之. [ĐNTL-TB-5]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-12) 1 November 1690
(Anh Tông) 3rd year, winter, 10th month, 1st day of the month. There was an eclipse of the Sun.
(英宗)三年冬十月朔, 日有食之. [ĐNTL-TB-6]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-13) 16 May 1692
(Hiển Tông) 1st year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)元年夏四月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-14) 22 July 1694
(Hiển Tông) 3rd year, summer, 6th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)三年夏六月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-15) 13 April 1695
(Hiển Tông) 4th year, 3rd month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)四年三月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-16) 8 October 1695
(Hiển Tông) 4th year, 9th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)四年九月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-17) 4 March 1696
(Hiển Tông) 5th year, spring, 2nd month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)五年春二月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-18) 27 May 1702
(Hiển Tông) 11th year, summer, 5th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)十一年夏五月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-19) 16 May 1703
(Hiển Tông) 12th year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)十二年夏四月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-20) 7 October 1706
(Hiển Tông) 15th year, autumn, 9th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)十五年秋九月朔, 日有食之. [ĐNTL-TB-7]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-21) 2 May,1707
(Hiển Tông) 16th year, summer, 4th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)十六年夏四月朔, 日有食之. [ĐNTL-TB-8]
Oplzr.SE #6927, 5MCSE #08805. The eclipse was not observable in Huế.

(2-22) 14 September 1708
(Hiển Tông) 17th year, 8th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)十七年八月朔, 日有食之. [ĐNTL-TB-8]
Oplzr.SE #6931, 5MCSE #08809. A partial eclipse (0.95 at sunset) was observable in Huế. The Sun set before mid-eclipse.

(2-23) 19 January 1711
(Hiển Tông) 19th year, 12th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)十九年十二月朔, 日有食之. [ĐNTL-TB-8]
Oplzr.SE #6936, 5MCSE #08814. The eclipse was not observable in Huế.

(2-24) 24 May 1713
(Hiển Tông) 22nd year, 5th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)二十二年五月朔, 日有食之. [ĐNTL-TB-8]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-25) 4 April 1715
(Hiển Tông) 24th year, 3th month, 1st day of the month. There was an eclipse of the Sun.
(顯宗)二十四年三月朔, 日有食之. [ĐNTL-TB-8]
Oplzr.SE —, 5MCSE —. No eclipse occurred anywhere on the Earth.

(2-26) 15 July 1730
(Túc Tông) 5th year, summer, 6th month, 1st day of the month. There was an eclipse of the Sun.
(肅宗)五年夏六月朔, 日有食之. [ĐNTL-TB-9]

Oplzr.SE #6987, 5MCSE #08864. A partial eclipse (0.13) was observable in Huế. The eclipse was also recorded in TB (#1-83).

(2-27) 4 July 1731
(Túc Tông) 6th year, 6th month, 1st day of the month. There was an eclipse of the Sun.
(肅宗)六年六月朔, 日有食之. [ĐNTL-TB-9]
Oplzr.SE #6989, 5MCSE #08866. A partial eclipse (0.41) was observable in Huế. The eclipse was also recorded in TB (#1-84).

(2-28) 16 October 1735
(Túc Tông) 10th year, autumn, 9th month, 1st day of the month. There was an eclipse of the Sun.
(肅宗)十年秋九月朔, 日有食之. [ĐNTL-TB-9]
Oplzr.SE #6999, 5MCSE #08876. A partial eclipse (0.06) was observable in Huế. The eclipse was also recorded in TB (#1-86).

(2-29) 6 September 1774
(Duệ Tông) 9th year, 8th month, 1st day of the month. There was an eclipse of the Sun.
(睿宗)九年八月朔, 日有食之. [ĐNTL-TB-11]
Oplzr.SE #7099, 5MCSE #08975. A partial eclipse (0.86) was observable in Huế. The eclipse was also recorded in TB (#1-93).

Appendix 4.3

Lumar Eclipse Records in the *TT&TB* and *ĐNTL-CB*

We provide the original texts in classical Chinese and their English translation of the lunar eclipse records collected from the *Đại Việt Sử Ký Toan Thư* (*TT*) supplemented by the *Đại Việt Sử Ký Tục Biên* (*TB*), and the *Đại Nam Thực Lục Chính Biên* (*ĐNTL-CB*) in a format similar to that used in Appendices 4.1 and 4.2. (For the lunar eclipse records in the *TT&TB*, see also Okazaki (2014).

In comparison with Appendices 4.1 and 4.2, we replace the catalog/list numbers of Oplzr.SE, 5MCSE, and Ho #iv by those of Oppolzer's (1887) *Canon of Lunar Eclipses* (Oplzr.LE), Espenak and Meeus's (n.d.-b) *Five Millennium Catalog of Lunar Eclipses: -1999 to +3000* (5MKLE) and Ho's (1964) list number (Ho #vii) of lunar eclipse records, respectively. For lunar eclipse computations, we used *JavaScript Lunar Eclipse Explorer* developed by Espenak and O'Byrne (n.d.-b) and also *Lmap* developed by Takesako (n.d.) in some cases.

In some of the lunar eclipse records, an eclipse date was indicated by using the word "望 (vọng) or Full Moon day (of the month)," which only tells us that an eclipse date is someday around 15th day of the month. In this case, we present its converted date in italics prefixed by a tilde (~), which is tentatively obtained by putting 15th day for the Full Moon day. In the other lunar eclipse records, an eclipse date was specified by day number (of the month) or by the Chinese sexagenary cycle. However, such an eclipse date, even in reliable records, is not necessarily equal to its corresponding computed eclipse date because of *the same day/the following day* issue (see Subsection 4.5.5). In these circumstances, we added a computed eclipse date in brackets immediately after a converted date in all the (reliable) lunar eclipse records. An eclipse timing is expressed in true solar time in the capital of the Dynasty in those days. It is noted that, in this Appendix, a computed eclipse date after midnight remains unchanged (i.e., *the same day* is used throughout the night) because we employ a clock of more than 24 hours to avoid possible confusion caused by the date change at midnight.

(3-1) *~13 April 1169* [—]
Chính Long Bảo Ứng reign period, 7th year, spring, 3rd month, Full Moon day of the month, there was an eclipse of the Moon.
政隆寶應七年春三月望, 月蝕. [TT (BK)-4]
Oplzr.LE —, 5MKLE —, Ho #vii-01. No eclipse occurred anywhere on the Earth, though a partial eclipse (0.60) was observable in Thăng Long one month before. This one-month discrepancy may be explained by a difference in positioning an intercalary month in the year between Vietnamese and Chinese calendars. However, we have no other information supporting the interpretation as found in the case of #1-35. See Sub-subsection *4.5.1.3*.

(3-2) 22 October 1306 [22 October 1306]
Hưng Long reign period, 14th year, autumn, 9th month, 15th day of the month, there was an eclipse of the Moon in the hour of *tuất* (*xu*, 19:00 – 21:00).
興隆十四年秋九月十五日, 戌時, 月蝕. [TT (BK)-6]
Oplzr.LE #3895, 5MKLE #07989, Ho #vii-02. A total eclipse (1.05) was observable in Thăng Long. The eclipse started at 19:07 and ended at 22:26, and the totality started at 20:30 and ended at 21:03. Thus, we may say that the eclipse timing given by the record is in good agreement with that obtained with an eclipse computation.

(3-3) *~13 November 1388* [14 November 1388]
Xương Phù reign period, 12th year, winter, 10th month, Full Moon day of the month, there was a total eclipse of the Moon.
昌符十二年冬十月望, 月食, 既. [TT (BK)-8]
Oplzr.LE #4017, 5MKLE #08180, Ho #vii-03. A total eclipse (1.32) was observable in Thăng Long.

(3-4) 20 April 1437 [20 April 1437]
Thiệu Bình reign period, 4th year, 3rd month… day *ất-tị* (*yi-si*), there was an eclipse of the Moon.
紹平四年三月乙巳, 月有食. [TT (BK)-11]
Oplzr.LE #4091, 5MKLE #08291, Ho #vii-04. Day *ất-tị* (*yi-si*) is the fifteenth day of the month. A partial eclipse (0.14) was observable in Đông Kinh. This record is followed by saying: "The Astrologer Bùi Thì Hanh confidentially reported that (the eclipse) should be hidden and not be saved. (太史裴時亨密奏, 隱之不救.)".

(3-5) *~24 August 1439* [24 August 1439]
Thiệu Bình reign period, 6th year, autumn, 7th month, Full Moon day of the month, there was an eclipse of the Moon.
紹平六年秋七月望, 月有食之. [TT (BK)-11]
Oplzr.LE #4094, 5MKLE #08296, Ho #vii-05. A total eclipse (1.35) was observable in Đông Kinh.

(3-6) *~12 June 1443* [12 June 1443]
Thái Hòa reign period, 1st year, 5th month, Full Moon day of the month, there was an eclipse of the Moon.
太和元年五*月望, 月有食之. [TT (BK)-11]
Oplzr.LE #4100, 5MKLE #08305, Ho #vii-06. A total eclipse (1.81) was observable in Đông Kinh.
* The conflated version of the *TT* by Chen (1984-86) gave "四月 (4th month)". Other versions of the *TT*, however, yield "五月 (5th month)". We adopted here "5th month".

(3-7) *~24 November 1444* [25 November 1444]
Thái Hòa reign period, 2nd year, winter, 10th month …, there was an eclipse of the Moon.
太和二年冬十月……月食. [TT (BK)-11]
Oplzr.LE —, 5MCSE #08308, Ho #vii-07. Since the record gives the eclipse month only, we assumed the eclipse occurred on the Full Moon day of the month. A penumbral eclipse, which is almost unobservable, occurred in Đông Kinh.

(3-8) 13 September 1448 [12 September 1448]
Thái Hòa reign period, 6th year, 8th month…, (The Astrologer) Thì Hanh gave an absurd report (to the Emperor) that there would be an eclipse of the Moon in the hour of *mẹo* (*mao*, 29:00 – 31:00) on 16th day of the month. …The eclipse was not seen.
太和六年八月……時亨妄奏, 是月十六日, 卯時, 月食.……不見食. [TT (BK)-11]
Oplzr.LE #4107, 5MKLE #08317, Ho —. This is a record of an eclipse prediction. Although the record mentions that the eclipse of the Moon was not seen, a partial eclipse (0.09) actually occurred in Đông Kinh at low altitude (14° – 0°) during 28:55–29:58, as predicted almost exactly by (Bùi) Thì Hanh. However, he was falsely charged with a crime of this 'absurd' prediction report.

(3-9) 11 April 1465 [11 April 1465]
Quang Thuận reign period, 6th year, 3rd month, 16th day of the month, there was a total eclipse of the Moon.
光順六年三月十六日, 月食, 既. [TT (BK)-12]
Oplzr.LE #4131, 5MKLE #08355, Ho #vii-08. A total eclipse (1.25) was observable in Đông Kinh.

(3-10) 11 March 1476 [10 March 1476]
Hồng Đức reign period, 7th year, spring, 2nd month, 16th day of the month, there was a total eclipse of the Moon.

洪德七年春二月十六日, 月食, 既. [TT (BK)-13]
Oplzr.LE #4148, 5MKLE #08379, Ho #vii-09. A total eclipse (1.11) was observable in Đông Kinh.

(3-11) 3 September 1476 [3 September 1476]
Hồng Đức reign period, 7th year, 8th month, 16th day of the month, there was a full eclipse of the Moon at initial mark of the 5th night watch (approximately 27:10 – 27:25).
洪德七年八月十六日, 夜五更初刻, 月蝕, 全分. [TT (BK)-13]
Oplzr.LE #4149, 5MKLE #08380, Ho —. A total eclipse (1.28) was observable in Đông Kinh. This is the only record that expresses time in the night watch system. "初刻 (initial mark)" is an unusual expression for the night watch system. We assumed here that it would be equivalent to "一点 (1st point)" which was widely used in the night watch system in those days. The eclipse started at 27:58 and the totality started at 29:03. The Moon set at 29:54 before the eclipse ended. Thus the eclipse timing mentioned in the record is not in good agreement with that obtained by an eclipse computation.

(3-12) 18 January 1478 [18 January 1478]
Hồng Đức reign period, 8th year, 12th month, 15th day of the month, there was a total eclipse of the Moon.
洪德八年十二月十五日, 月食, 既. [TT (BK)-13]
Oplzr.LE #4150, 5MKLE #08383, Ho #vii-10. A slightly partial eclipse (0.03) was observable in Đông Kinh.

(3-13) 8 January 1479 [8 January 1479]
Hồng Đức reign period, 9th year, 12th month, 16th day of the month, there was an eclipse of the Moon.
洪德九年十二月十六日, 月有食之. [TT (BK)-13]
Oplzr.LE #4152, 5MKLE #08385, Ho #vii-11. A penumbral eclipse, which is almost unobservable, occurred in Đông Kinh; the Moon rose after the last contact with the umbra and before the last contact with the penumbra.

(3-14) 26 October 1482 [26 October 1482]
Hồng Đức reign period, 13th year 9th month, 15th day of the month, there was an eclipse of the Moon in the hour of *tuất* (*xu*, 19:00 – 21:00).
洪德十三年九月十五日, 戌時, 月蝕. [TT (BK)-13]
Oplzr.LE #4157, 5MKLE #08394, Ho #vii-12. A partial eclipse (0.89) was observable in Đông Kinh. The eclipse started at 22:23 and ended at 25:39. Thus the eclipse timing given in the record is not in good agreement with that obtained with an eclipse computation.

(3-15) 5 July 1525 [4 July 1525]
Thống Nguyên reign period, 4th year, summer, 6th month, 15th day of the month, there was an eclipse of the Moon.
統元四年, 夏六月十五日, 月食. [TT (BK)-15]
Oplzr.LE #4220, 5MKLE #08489, Ho #vii-13. A partial eclipse (0.21) was observable in Đông Kinh. The Moon set before the eclipse ended.

(3-16) 30 December 1525 [29 December 1525]
Thống Nguyên reign period, 4th year, 12th month, 17th day of the month, there was an eclipse of the Moon.
統元四年, 十二月十七日, 月食. [TT (BK)-15]
Oplzr.LE #4221, 5MKLE #08490, Ho #vii-14. A total eclipse (1.10) was observable in Đông Kinh.

(3-17) 26 April 1526 [—]
Thống Nguyên reign period, 5th year, 3rd month, 15th day of the month, there was an eclipse of the Moon.
統元五年三月十五日, 月食. [TT (BK)-15]
Oplzr.LE —, 5MKLE —, Ho #vii-15. No eclipse occurred anywhere on the earth.

(3-18) 17 September 1587 [16 September 1587]
Quang Hưng reign period, 10th year, 8th month, day *nhâm-thân* (*ren-shen*), Full Moon day of the month, there was an eclipse of the Moon on the night.
光興十年八月壬申望夜, 月食. [TT (BK)-17]
Oplzr.LE #4315, 5MKLE #08636, Ho #vii-16. Day *nhâm-thân* is the fifteenth day of the month. A partial eclipse (0.76) was observable in Vạn Lại.

(3-19) 26 August 1589 [25 August 1589]
Quang Hưng reign period, 12th year, 7th month …, 16th day of the month, there was an eclipse of the Moon in the hour of *sửu* (*chou*, 25:00 – 27:00) in the north. The Moon, eclipsed more than half, restored to fullness.
光興十二年七月十六日, 丑時, 月食, 在北方, 過半復圓. [TT (BK)-17]
Oplzr.LE #4318, 5MKLE #08640, Ho #vii-17. A partial eclipse (0.24) was observable in the southwest in Vạn Lại. The eclipse started at 24:48 and ended at 26:31. Thus, we may say that the eclipse timing given in the record is in good agreement with that obtained with an eclipse computation.

(3-20) *~5 July 1591* [6 July 1591]
Quang Hưng reign period, 14th year, 5th month, Full Moon day of the month, day *bính-tuất* (*bing-xu*), there was an almost exhausted eclipse (an almost total) of the Moon in the southeast. The Moon restored to fullness after one double-hour.
光興十四年五月望丙戌, 月食, 巽方, 殆盡, 一箇時復圓. [TT (BK)-17]
Oplzr.LE #4321, 5MKLE #08644, Ho #vii-18. Day *bính-tuất* is 22nd day of the month, which is inconsistent with the Full Moon day. We consider that, in this case, the day in the Chinese sexagenary cycle is incorrect. A total eclipse (1.53), lasting for 1h36m, was observable in the southwest through south in Vạn Lại in roughly the same way as described in the record.

(3-21) *~4 May 1594* [4 May 1594]
Quang Hưng reign period, 17th year, 3rd month, Full Moon day of the month, there was an eclipse of the Moon. But it was very rainy.
光興十七年三月望, 月食, 天大雨. [TT (BK)-17]
Oplzr.LE #4325, 5MKLE #08652, Ho #vii-19. A partial eclipse (0.67) was observable in Vạn Lại.

(3-22) *~11 May 1596* [—]
Quang Hưng reign period, 19th year, summer, 4th month, Full Moon day of the month, there was an eclipse of the Moon.
光興十九年夏四月望, 月食. [TT (BK)-17]
Oplzr.LE —, 5MKLE —, Ho —. No eclipse occurred anywhere on the Earth.

(3-23) 6 August 1599 [6 August1599]
Quang Hưng reign period, 22nd year, 6th month, 16th day of the month, there was an eclipse of the Moon on the night in the hour of *dậu* (*you*, 17:00 – 19:00).
光興二十二年六月十六日, 酉時, 月食. [TT (BK)-17]
Oplzr.LE #4334, 5MKLE #08664, Ho —. A total eclipse (1.28) was observable in Đông Kinh. The Moon rose at 18:26 after the totality started. The totality ended at 19:15 and the eclipse ended at 20:19. Thus, we may say that the eclipse timing given in the record is in good agreement with that obtained with an eclipse computation.

(3-24) *~4 June 1602* [4 June 1602]
Hoằng Định reign period, 3rd year, summer, 4th month…, Full Moon day of the month, there was an eclipse of the Moon.
弘定三年夏四月, ……是月望, 月有食. [TT (BK)-18]
Oplzr.LE #4338, 5MKLE #08671, Ho #vii-20. A total eclipse (1.66) was observable in Đông Kinh.

(3-25) *~2 July 1613* [—]
Hoằng Định reign period, 14th year, 5th month…, Full Moon day of the month, there was an eclipse of the Moon.
弘定十四年五月望, 月有食之. [TT (BK)-18]
Oplzr.LE —, 5MKLE —, Ho #vii-21. No eclipse occurred anywhere on the Earth.

(3-26) *~30 August 1613* [—]
Hoằng Định reign period, 14th year, autumn, 7th month, Full Moon day of the month, there was an eclipse of the Moon.
弘定十四年秋七月望, 月有食之. [TT (BK)-18]
Oplzr.LE —, 5MKLE —, Ho #vii-22. No eclipse occurred anywhere on the Earth.

(3-27) 3 March 1616 [3 March 1616]
Hoằng Định reign period, 17th year, spring, 1st month, 26th day of the month, there was an eclipse of the Moon.
弘定十七年春正月二十六日, 月有食之. [TT (BK)-18]
Oplzr.LE #4359, 5MKLE #08706, Ho #vii-23. “26th day of the month” is obviously an inappropriate day for a lunar eclipse. This contradiction can be resolved if we assume that one character “二 (two)” was added erroneously so that “26th day (二十六日)” should be read “16th day (十六日)”. Ho (1964) also remarked that “26th day” must be a misprint for “16th day.” Then, we adopt “16th day” for the date of the eclipse. A partial eclipse (0.93) was observable in Đông Kinh.

(3-28) *~20 February 1617* [20 February 1617]
Hoằng Định reign period, 18th year, spring, 1st month, Full Moon day of the month, there was an eclipse of the Moon.
弘定十八年春正月望, 月有食之. [TT (BK)-18]
Oplzr.LE #4361, 5MKLE #08708, Ho #vii-24. A total eclipse (1.41) was observable in Đông Kinh.

(3-29) 16 August 1617 [16 August 1617]
Hoằng Định reign period, 18th year, autumn, 7th month, 16th day of the month, there was an eclipse of the Moon. 弘定十八年秋七月十六日, 月有食之. [TT (BK)-18]
Oplzr.LE #4362, 5MKLE #08709, Ho #vii-25. A total eclipse (1.40) was observable in Đông Kinh.

(3-30) *~9 February 1618* [9 February 1618]
Hoằng Định reign period, 19th year, spring, 1st month, Full Moon day of the month, there was an eclipse of the Moon.
弘定十九年春正月望, 月有食之. [TT (BK)-18]
Oplzr.LE #4363, 5MKLE #08710, Ho #vii-26. A partial eclipse (0.17) was observable in Đông Kinh.

(3-31) 20 November 1630 [19 November 1630]
Đức Long reign period, 2nd year, winter, 10th month, 17th day of the month, day *nhâm-tuất* (*ren-xu*), there was an eclipse of the Moon.
德隆二年冬十月十七日壬戌, 月有食之. [TT (BK)-18]
Oplzr.LE #4382, 5MKLE #08741, Ho #vii-27. A partial eclipse (0.70) was observable in Đông Kinh. The Moon set before the eclipse ended.

(3-32) 16 May 1631 [15 May 1631]
Đức Long reign period, 3rd year, summer, 4th month, 16th day of the month, day *kỷ-mùi* (*ji-wei*), there was an eclipse of the Moon. But it was windy, rainy and dark by chance. (The eclipse was) Not seen.
德隆三年夏四月十六日己未, 月食, 適風雨晦冥, 不見. [TT (BK)-18]
Oplzr.LE #4383, 5MKLE #08742, Ho #vii-28. A total eclipse (1.87) was observable in Đông Kinh.

(3-33) *~8 November 1631* [8 November 1631]
Đức Long reign period, 3rd year, 10th month, Full Moon day of the month, there was an eclipse of the Moon.
德隆三年十月望, 月有食之. [TT (BK)-18]
Oplzr.LE #4384, 5MKLE #08743, Ho #vii-29. A total eclipse (1.66) was observable in Đông Kinh. The Moon set before the eclipse ended.

(3-34) 4 May 1632 [4 May 1632]
Đức Long reign period, 4th year, 3rd month, 16th day of the month, there was an eclipse of the Moon in the hour of *dậu* (*xu*, 17:00 – 19:00).
德隆四年三月十六日, 酉時, 月食. [TT (BK)-18]
Oplzr.LE #4385, 5MKLE #08744, Ho #vii-30. A partial eclipse (0.56) was observable in Đông Kinh. The Moon rose at 18:23 after the eclipse started. The eclipse ended at 20:36. Thus, we may say that the eclipse time given in

the record is in good agreement with that obtained with an eclipse computation.

(3-35) *~28 October 1632* [27 October 1632]
Đức Long reign period, 4th year, autumn, 9th month, Full Moon day of the month, there was an eclipse of the Sun in the hour of *mẹo* (*mao*, 29:00 – 31:00).
德隆四年秋九月望, 卯時, 日食. [TT (BK)-18]
Oplzr.LE #4386, 5MKLE #08745, Ho #vii-31. The character "日 (the Sun)" in this text should read "月 (the Moon)", because the eclipse occurred on the Full Moon day. A partial eclipse (0.41) was observable in Đông Kinh. The eclipse started at 29:06. The Moon set at 30:19 before the eclipse ended. Thus, we may say that the eclipse timing given in the record is in good agreement with that obtained with an eclipse computation.

(3-36) *~14 March 1634* [14 March 1634]
Đức Long reign period, 6th year, spring, 2nd month, Full Moon day of the month, there was an eclipse of the Moon.
德隆六年春二月望, 月食. [TT (BK)-18]
Oplzr.LE #4387, 5MKLE #08750, Ho #vii-32. A partial eclipse (0.87) was observable in Đông Kinh.

(3-37) 16 June 1666 [16 June 1666]
Cảnh Trị reign period, 4th year, 5th month, day *giáp-ngọ* (*jia-wu*), Full Moon day of the month, there was an eclipse of the Moon.
景治四年五月甲午望, 月有食之. [TT (BK)-19]
Oplzr.LE #4437, 5MKLE #08829, Ho #vii-33. Day *giáp-ngọ* (*jia-wu*) is the fourteenth day of the month. A partial eclipse (0.17) was observable in Đông Kinh. Ho (1964) gave the converted date which is one day earlier than the correct date.

(3-38) 30 November 1667 [30 Novembe 1667]
Cảnh Trị reign period, 5th year, winter, 10th month, day *bính-tuất* (*bing-xu*), Full Moon day of the month, there was an eclipse of the Moon.
景治五年冬十月丙戌望, 月有食之. [TT (BK)-19]
Oplzr.LE #4440, 5MKLE #08832, Ho #vii-34. Day *bính-tuất* (*bing-xu*) is the fifteenth day of the month. A total eclipse (1.72) was observable in Đông Kinh.

(3-39) 11 October 1707 [11 October 1707]
Vĩnh Thịnh reign period, 3rd year, autumn, 9th month, day *ất-sửu* (*yi-chou*), there was an eclipse of the Moon.
永盛三年秋九月乙丑, 月有食之. [TB-2]
Oplzr.LE #4504, 5MKLE #08934. Day *ất-sửu* (*yi-chou*) is the sixteenth day of the month. A total eclipse (1.70) was observable in Đông Kinh. The Moon rose before the totality ended.

(3-40) 29 July 1730 [29 July 1730]
Vĩnh Trị reign period, 2nd year, 6th month, day *nhâm-tý* (*ren-zi*), there was an eclipse of the Sun.
永慶二年六月壬子, 日食. [TB-2]

Oplzr.LE #4541, 5MKLE #08993. The character "日 (the Sun)" in this text should be read "月 (the Moon)", because day *nhâm-tý* (*ren-zi*) is the fifteenth day of the month, on which a lunar eclipse occurred. A partial eclipse (0.30) was observable in Đông Kinh.

(3-41) 13 December 1731 [13 December 1731]
Vĩnh Khánh reign period, 3rd year, 11th month, day *giáp-tuất* (*jia-xu*), Full Moon day of the month, there was an eclipse of the Moon.
永慶三年十一月甲戌望, 月食. [TB-2]
Oplzr.LE #4543, 5MKLE #08997. Day *giáp-tuất* (*jia-xu*) is the fifteenth day of the month. A partial eclipse (0.41) was observable in Đông Kinh.

(3-42) *~7 June 1732* [8 June 1732]
Vĩnh Khánh reign period, 4th year, intercalary 4th month, Full Moon day of the month, there was an eclipse of the Moon.
永慶四年閏四月望, 月食. [TB-2]
Oplzr.LE #4544, 5MKLE #08998. A total eclipse (1.51) was observable in Đông Kinh.

(3-43) *~3 October 1732* [—]
Vĩnh Khánh reign period, 4th year, autumn, 8th month, Full Moon day of the month, there was an eclipse of the Moon.
永慶四年秋八月望, 月食. [TB-2]
Oplzr.LE —, 5MKLE —. No eclipse occurred anywhere on the Earth.

(3-44) 1 December 1732 [1 December 1732]
Long Đức reign period, 1st year, winter, 10th month, day *mậu-thìn* (*wu-chen*), Full Moon day of the month, there was an eclipse of the Moon.
龍徳元年冬十月戊辰望, 月食. [TB-2]
Oplzr.LE #4545, 5MKLE #08999. Day *mậu-thìn* (*wu-chen*) is the fourteenth day of the month. A total eclipse (1.77) was observable in Đông Kinh.

(3-45) 16 March 1737 [16 March 1737]
Vĩnh Hựu reign period, 3rd year, spring, 2nd month, day *giáp-tuất* (*jia-xu*), there was an eclipse of the Moon.
永祐三年春二月甲戌, 月食. [TB-3]
Oplzr.LE #4552, 5MKLE #09010. Day *giáp-tuất* (*jia-xu*) is the fourteenth day of the month. A partial eclipse (0.55) was observable in Đông Kinh.

(3-46) 25 July 1738 [—]
Vĩnh Hựu reign period, 4th year, 6th month, day *canh-dần* (*geng-yin*), there was an eclipse of the Moon.
永祐四年六月庚寅, 月食. [TB-3]
Oplzr.LE —, 5MKLE —. Day *canh-dần* (*geng-yin*) corresponds to the ninth day of the month, on which neither lunar nor solar eclipses should occur anywhere on the Earth.

(3-47) *~17 February 1753* [—]
Cảnh Hưng reign period, 14th year, spring, 1st month, Full Moon day of the month, there was an eclipse of the Moon.
景興十四年春正月望, 月有食之. [TB-4]

Oplzr.LE —, 5MKLE —. No eclipse occurred anywhere on the Earth.

(3-48) *~31 October 1762* [1 November 1762]
Cảnh Hưng reign period, 23rd year, 9th month, Full Moon day of the month, there was an eclipse of the Moon.
景興二十三年九月望, 月食. [TB-4]
Oplzr.LE #4593, 5MKLE #09076. A partial eclipse (0.59) was observable in Đông Kinh.

(3-49) 7 March 1765 [7 March 1765]
Cảnh Hưng reign period, 26th year, 1st month, day *nhâm-thìn* (*ren-chen*), Full Moon day of the month, there was an eclipse of the Moon.
景興二十六年春正月壬辰望, 月食. [TB-5]
Oplzr.LE #4596, 5MKLE #09083. Day *nhâm-thìn* (*ren-chen*) is the sixteenth day of the month. A total eclipse (1.73) was observable in Đông Kinh.

(3-50) 24 February 1766 [24 February 1766]
Cảnh Hưng reign period, 27th year, spring, 1st month, day *bính-tuất* (*bing-xu*), there was an eclipse of the Moon.
景興二十七年春正月丙戌, 月食. [TB-5]
Oplzr.LE #4598, 5MKLE #09085. Day *bính-tuất* (*bing-xu*) is the sixteenth day of the month. A partial eclipse (0.33) was observable in Đông Kinh.

(3-51) *~23 December 1768* [23 December 1768]
Cảnh Hưng reign period, 29th year, 11th month, Full Moon day of the month, there was an eclipse of the Moon.
景興二十九年十一月望, 月食. [TB-5]
Oplzr.LE #4602, 5MKLE #09093. A total eclipse (1.75) was observable in Đông Kinh.

(3-52) 23 October 1771 [23 October 1771]
Cảnh Hưng reign period, 32nd year, 9th month, day *quý-sửu* (*gui-chou*), there was an eclipse of the Moon.
景興三十二年九月癸丑, 月食. [TB-5]
Oplzr.LE #4606, 5MKLE #09100. Day *quý-sửu* (*gui-chou*) is the fourteenth day of the month. A partial eclipse (0.37) was observable in Đông Kinh.

(3-53) 18 March 1772 [—]
Cảnh Hưng reign period, 33rd year, 2nd month, day *canh-thìn* (*geng-chen*), there was an eclipse of the Moon.
景興三十三年二月庚辰*, 月食. [TB-5]
Oplzr.LE —, 5MKLE —. No eclipse occurred anywhere on the Earth.
* This record might be an erroneous duplicate of the next record (#3-54) happening in the transcription process because sentence expression in the two records is very similar one to another with only two character (二/三 and 辰/戌) differences.

(3-54) 17 April 1772 [17 April 1772]
Cảnh Hưng reign period, 33rd year, 3rd month, day *canh-tuất* (*geng-xu*), there was an eclipse of the Moon.
景興三十三年三月庚戌, 月食. [TB-5]

Oplzr.LE #4607, 5MKLE #09101. Day *canh-tuất* (*geng-xu*) is the fifteenth day of the month. A total eclipse (1.77) was observable in Đông Kinh.

(3-55) 11 October 1772 [11 October 1772]
Cảnh Hưng reign period, 33rd year, 9th month, day *đinh-mùi* (*ding-wei*), there was an eclipse of the Sun.景興三十三年九月丁未, 日食. [TB-5]
Oplzr.LE #4608, 5MKLE #09102. The character "日 (the Sun)" in this text should be read "月 (the Moon)", because day *đinh-mùi* (*ding-wei*) is the fifteenth day of the month, on which a lunar eclipse occurred. A total eclipse (1.64) was observable in Đông Kinh.

(3-56) 7 December 1843 [6 December 1843]
Thiệu Trị reign period, 3rd year, 9th month,… a circular from the Ministry of Rites of the Qing Dynasty mentioned that there would be a brief eclipse of the Moon on the 16th day of 10th month, this year ... (Being questioned by the Emperor's Cabinet why the Astronomical Bureau reported no prediction of this eclipse, officials in charge said,) "In our country, according to the calculation of the Sun's altitude at *mao zheng* 2 *ke* 6 *fen* (30:36*) when the eclipse of the Moon occurs, the Sun will already have risen before the eclipse. Then, it will be within the daytime eclipse. It will not be an eclipse (that deserved to be reported) …"紹治三年九月……清國禮部移文, 是年十月十六日月食分秒.……, 本國太陽高度推算, 月食當在, 卯正二刻六分, 則日既先出, 已屬晝分當食, 而不食, …. [ĐNTL-CB-III.33]
Oplzr.LE #4720, 5MKLE #09282. This is a record of an eclipse prediction. In Beijing, the eclipse started about 10 min before the Moon set: It was a brief eclipse, as predicted by the circular from the Qing Dynasty. On the other hand, in Huế, the eclipse started at 30:37 or about 11 min after the Moon set. At that time, the Sun was at an altitude of 2°. Thus, the eclipse prediction made by the Astronomical Bureau is in excellent agreement with that obtained with a modern eclipse computation. This implies that, in their calendar calculation with the *Hiệp Kỷ* method (equivalent to *Shixian*), they had taken account of the difference in geographical coordinates between Beijing and Huế. Since this record is clearly reliable, it is counted as 'observable' in Fig. 4.2 and Table 4.2, although the eclipse was actually not observable.
* Under the *Shixian* calendar, which is equivalent to the *Hiệp Kỷ* calendar used in Period D, 1 day = 12 double hours = 96 *ke* (not 100 *ke*) so that 1 *ke* =15 min and 1 *fen* = 1 min (Saito, 1995).

(3-57) 17 January 1851 [17 January 1851]
Tự Đức reign period, 3rd year, 12th month…, an official of the Astronomical Bureau reported that on 16th day (of this month), there would be an eclipse of the Moon.
嗣德三年十二月, ……辰監臣奏, 十六日, 有月食…. [ĐNTL-CB-IV.5]
Oplzr.LE #4731, 5MKLE #09301. This is a record of an eclipse prediction. A partial eclipse (0.37) was observable in Huế.

(3-58) 14 October 1856 [13 October 1856]
Tự Đức reign period, 9th year, 10th month, ... this month, Full Moon day of the month, day *canh-ngọ* (*geng-wu*), there was an eclipse of the Moon. The Astronomical Bureau had not reported its prediction before …
嗣德九年十月, ……是月庚午望, 有月食. 欽天監無有預奏, ….
[ĐNTL-CB-IV.15]
Oplzr.LE #4742, 5MKLE #09313. This is a record of an eclipse observation. Day *canh-ngọ* (*geng-wu*) is not in the 10th month but in the 9th month, corresponding to "9th month, 16th day", on which a lunar eclipse occurred in Huế. Then we regard that this record have been wrongly placed in the compilation process, and adopt "9th month, 16th day".

(3-59) 13 August 1859 [13 August 1859]
Tự Đức reign period, 12th year, 7th month, … this month, Full Moon day of the month, day *quý-mùi* (*gui-wei*), there was an eclipse of the Moon. The Astronomical Bureau had not reported its prediction before …
嗣德十二年七月, ……是月癸未望, 有月食.欽天監無有預奏, ….
[ĐNTL-CB-IV.21]
Oplzr.LE #4746, 5MKLE #09320. This is a record of an eclipse observation. Day *quý-mùi* (*gui-wei*) is the fifteenth day of the month. A total eclipse (1.82) was observable in Huế.

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Chapter 5
Father Antoine Thomas and the Birth of ‘Modern Astronomy’ in Thailand

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5.1 Introduction

This chapter deals with the introduction and subsequent development of modern astronomy in Siam (which is now known as Thailand). By ‘modern astronomy’ we refer to Western astronomy, as practised by trained astronomers in Europe during the seventeenth to twentieth centuries, and the emergence of solar physics and

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astrophysics in Thailand and other Asian nations in the nineteenth and twentieth centuries (see Nakamura and Orchiston, 2017).

An underlying theme throughout this paper is the significance of Royal patronage, which was pivotal in the birth of Western astronomy in Siam, and continued during the nineteenth and twentieth centuries, culminating in the founding of the National Astronomical Research Institute of Thailand, or NARIT (see Orchiston et al., 2019). The first of these Royal patrons was King Narai.

5.1.1 'King Narai The Great'

One of the most revered of Thailand's historic rulers was 'King Narai the Great' (Fig. 5.1; see Orchiston et al., 2016). He was born in 1633 and died prematurely on 11 July 1688. Narai was the fourth king to rule during the Prasat Thong Dynasty, which was the fourth of the five dynasties of the Ayutthaya Kingdom (see Table 5.1). He was just 23 years of age when he became the King of Ayutthaya, in 1656, and he ruled until his death.

In 1686, two years before his death, King Narai was described by a visiting Westerner as "… about 55 years old, handsome, lovely, dark, has good behaviour, and is brave. He is also intelligent, a good ruler … [and is] kindhearted …" (Chaumont, 1686). The previous year another Western visitor described him as "… a very thin man, of low stature, and no beard …" (see Smithies, 1996: 53), which does not quite tally with the likeness shown in Fig. 5.1! We suspect that the preparation of this portrait involved a degree of artistic licence, triggered in no small part by the fact that not long before these Western accounts of 1685–1686 King Narai had entertained a Persian delegation, and he liked their attire so much that he decided to adopt it for his own court appearances (Smithies and Bressan, 2001).

When he became king, Narai

> ... inherited a large and powerful kingdom in the centre of mainland South-East Asia. His realm reached south to the kingdoms of Pattani, Ligor, Phattalung and Songkhla; in the east Cambodia had acknowledged Ayutthaya's suzerainty, and in the west the port of Tenasserim on the Bay of Bengal was under Thai control. (Hodges, 1999: 36).

For Thai localities mentioned in this paper see Figure 5.2.

King Narai was very active in international affairs. He saw exposure to Eastern and Western civilisations as a way of developing Siam, and during his reign he signed treaties with England, France, Holland and Persia and expanded trade between Siam and India, Indonesia, China and Japan. These initiatives led to a proliferation of international trade, and cemented "... Ayutthaya's reputation as an 'emporium of the East' ..." at this time, which rested largely "... upon her role as a focus for the trans-shipment of goods between Europe/India and China/Japan ..." (Sternstein, 1965: 108). Ayutthaya was located on an island on the flood plain of the Chao Phraya, Lop Buri and Pa Sak Rivers, 110 km from the sea.

Fig. 5.1 King Narai (https://en.wikipedia.org/wiki/Narai#/media/File:French_depiction_of_King_Narai.jpg).

We might regard King Narai as

> ... a strange but also positive anachronism—or precursor—for the Siam of the time. Not only [because of] his wide spirit of religious tolerance but also his positive interest in far-away lands, their customs, religions and peoples ... (Sioris, 1992: 60).

Because of King Narai's enlightened policy of promoting increasing contact with Eastern and Western nations, both Lop Buri and Ayutthaya quickly acquired a cosmopolitan flavour, with Armenian, Chinese, Dutch, English, French, Indian, Japanese, Javanese, Malay, Persian, Portuguese and Turkish communities. Many of these people worked for the state or had their own businesses, but there was always a transient population of visiting Europeans, Arabs, Indians and Asians. Because of this, there is a wealth of published material on seventeenth century Siam, as book

Table 5.1 Thai kingdoms and dynasties. King Narai ruled during the Prasat Thong Dynasty (after Chumsriphan, 1990: 22–23).

Kingdom	Duration (years CE)	Dynasty
Sukhothai	1238–1438	
Ayutthaya	1350–1767	Uthong
		Suphannaphum
		Maha Thammaracha
		Prasat Thong
		Ban Phlu Luang
Thonburi	1767–1782	
Rattanakosin/ Thailand	1782–	

after book appeared describing—and often singing the praises of—Ayutthaya and Lop Buri.

It must be remembered that by international standards both were large cosmopolitan cities. Thus, in 1689 Gervaise described Lop Buri as "… a town which is, so to speak, in the Kingdom of Siam what Versailles is in France." Because King Narai preferred to spend most of the year there, he "... had caused to be carried out many works in his desire to improve and embellish the town." (Giblin, 1904: 9). Thus, he repaired the ruined Buddhist temples, built a new palace and other buildings, and surrounded them with attractive gardens, ornamental fountains and water features (e.g. see Chaumont, 1686; Gervaise, 1689; Smith, 1880). Ayutthaya was no different, and some indication of the affluence of that city is provided by Figure 5.3, which was published in 1680.

One of King Narai's personal interests was astronomy. In keeping with his royal pedigree, as a prince he received a sound Buddhist temple education from the monks, but he also was taught non-religious subjects such as astrology and astronomy by lay teachers. Then as a young king his

> … contact with foreigners also contributed to his education. His reign coincided with European advances in the sciences associated with navigation, astronomy and horology. He lived in an age when humans were first beginning to grasp the nature and extent of the cosmos ... (Hodges, 1999: 36).

Thus, King Narai learnt about telescopes and other scientific instruments, the newly constructed Paris Observatory and Jesuit astronomical activities in Peking from Jesuits and others who were on their way to Peking or returning home to Europe and stopped off in Siam along the way. Furthermore, sometimes he was able to influence the types of gifts he received from visiting dignitaries, which went far beyond the typical "... cloth, spices and jewellery of his predecessors ..." to include telescopes, clocks and military equipment (ibid.).

Fig. 5.2 A map showing Thailand localities mentioned in the text (map: Wayne Orchiston).

It was against this politico-religious backdrop that Father Antoine Thomas (1644–1709), a Belgian Jesuit missionary, arrived in Ayutthaya in 1681, and as far as we know he was the first European to carry out astronomical observations there and expose Siam to Western astronomy (see Hennequin, 2004).

Fig. 5.3 A section of a painting showing buildings on the outskirts of Ayutthaya in 1680 (photograph: Darunee Lingling Orchiston, Royal Palace, Ayutthaya).

5.2 Father Antoine Thomas: Siam's First Western Astronomer

5.2.1 Introduction

Among the Europeans who settled in Ayutthaya during King Narai's reign were French missionaries from the Société des Missions Étrangères de Paris. The Société was formed to "... bypass the old privileges of the Portuguese and Spanish missions that depended entirely on the kings of Portugal and Spain, and to launch a new missionary instrument at the Pope's beck and call." (Cruysse, 1992: 64). Their missionaries first arrived in Siam in 1662 (see Love, 1999), but they found that other Catholic missionaries were already living in the city, and thus began an intriguing and complicated power-play involving different factions of Catholics and different nationalities. To explain this situation we need to understand that there were different orders of the Roman Catholic faith (e.g. Jesuits, Dominicans, Franciscans, etc.) and at the time there was competition between the Pope (the international leader of the Catholic Church, based in the Vatican) and the Kings of Spain and Portugal (working collectively) for control of Catholic missionaries world-wide. Until the second half of the seventeenth century “All the Catholic missions in the East [i.e. in Asia] were under Portuguese protection and the *personnel* were composed mainly of Portuguese and Spaniards.” (Hutchinson, 1933: 6; his italics). Then, from the 1660s,

> ... two rival Catholic missionary circuits shared the Asian scene ... They engaged in a fierce struggle where all kinds of dirty tricks were allowed. It will surprise nobody that the Siamese were sick and tired of the never-ending quarrels, and that very few among them felt the urge to join the Church which preached peace and brotherly love, but whose representatives were at each other’s throats. (Cruysse, 1992: 64–65).

Of all the Catholic faiths, the Jesuits had a special passion for science, and especially mathematics and astronomy (Udias, 2003, 2015), and during the sixteenth century the Spaniard Jesuit, Francis Xavier, founded missions in Asia. Then during the early years of the seventeenth century

> ... his followers spread over the Indo-Chinese Peninsula, and, when P’ra Narai came to the throne of Siam [in 1656] there were Jesuits as well as Dominicans [already] established in the Portuguese colony at Ayŭt’ĭa. (Hutchinson, 1933: 6).

Although there had been Jesuit visitors to Ayutthaya from March 1607 (see Chumsriphan, 1990: 76), the first Jesuit known to have settled there long-term was the talented Sicilian architect and engineer Father Tommaso Valguarnera (1608–1677; Gnolfo, 1974), who arrived in 1655 from Macau and stayed in Siam for 15 years. He was then appointed Visitator of the Japanese and Chinese Province and left in 1670, but he returned to Ayutthaya in 1675 and died there just two years later.

It was Father Valguarnera who built the San Paolo Church and a Jesuit residence within the Portuguese settlement. He also constructed the ‘Collegio San Salvador’, and on King Narai’s request he rebuilt the city walls of Ayutthaya. Then,

> Besides the construction of new forts in different towns, king Narai also ordered him to build the new Royal residence at Lopburi. Valguarnera so pleased the king that when the Jesuit church was burnt by the fire-accident in 1658, King Narai gave him the new church which was better than the old one. (Chumsriphan, 1990: 80).

Just four years after Father Valguarnera died Father Antoine Thomas arrived in Ayutthaya. By this time there were about 4000 people living in the Portuguese settlement (see Tachard, 1688). So who was Antoine Thomas?

5.2.2 Antoine Thomas: The Early Years

Antoine Thomas was born on 25 January 1644 in Namur, in what is now Belgium (Lefebvre, 1930). From 1652 to 1660 he attended the Jesuit College in Namur, studying grammar and humanities (ibid.). He joined the Society of Jesuit in Tournai on 24 September 1660, and by 1678 had been ordained a priest. While training for the priesthood he led a peripatetic existence (Golvers, 2017: 120n; Hermans and

Parmentier, 2017), between 1660 and 1675 studying in Tournai (1660–1662), Douai (1662–1664), Lille (1664–1665), Namur (1666–1667), Huy (1668–1670), back in Tournai (1670–1671), and once again in Douai (1671–1675). He then taught at schools in Armentières, Huy and Tournai, and served as a Professor of Philosophy at the Collège d'Anchin in Douai. Armentières, Douai and Lille are in present-day France, while Huy, Namur and Tournai are in Belgium (for these and other European localities see Fig. 5.4).

In the course of his training, Father Thomas developed a passion for mathematics and astronomy, and between March 1678 and January 1680 he taught mathematics at the College of Arts in Coimbra, Portugal, while living in the adjacent Jesuit College (Golvers, 2007). At the time, Coimbra was a noted centre for mathematical studies (see Baldini, 2004; Casalini, 2016). The Jesuit College was established in 1542 at the request of Portugal's King John III by a Portuguese co-founder of the Society of Jesus, Simão Rodrigues (1510–1579), making it the oldest Jesuit college in the world, and when Father Antoine Thomas arrived in March 1678 it already was an impressive facility. But the College continued to grow, and as Fig. 5.5 illustrates, by 1732 it featured a truly impressive main building. Father Thomas held his classes in the adjoining Royal College of the Arts, which also was run by the Jesuits. This

Fig. 5.4 Map of part of Europe showing localities mentioned in the text (base map: www.free-worldmaps.net; map modifications: Wayne Orchiston).

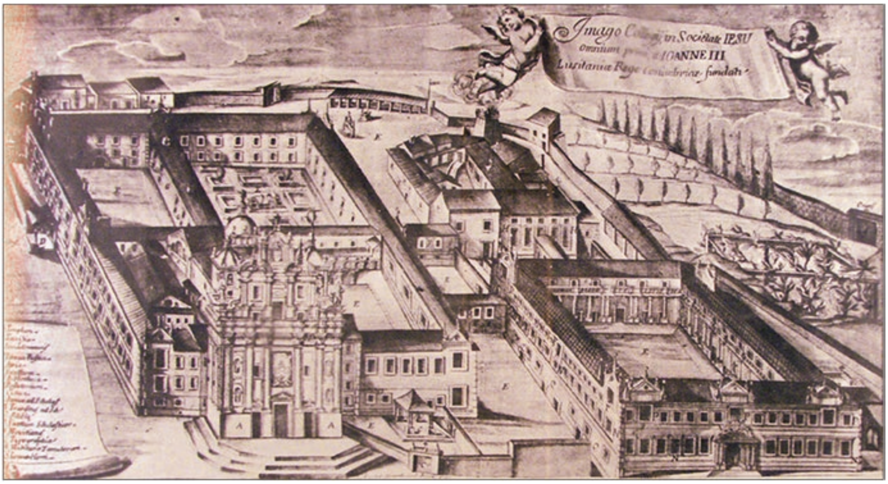

Fig. 5.5 The Jesuit College (left) and Royal College of Arts (right) in Coimbra in 1732 (after Leitão and Gessner, 2014: 2).

somewhat smaller facility was founded by King John III in 1548, but the building that Father Thomas used—which was constructed in 1568—is in the right foreground in Fig. 5.5.

While he was in Coimbra Father Thomas made a range of astronomical observations. On 29 October 1678 he observed a lunar eclipse, publishing a short account in the *Journal des Sçavans* (Thomas, 1679), the earliest European academic journal, which included obituaries of notable people, church history, legal notes and, of course, astronomy. This was to be the first of Antoine Thomas’ many scientific publications (see Bosmans, 1924–1926).

Another indication of Father Thomas’ passion for astronomy was the monumental book *Synopsis Mathematica* … (Thomas, 1685), which he wrote while teaching mathematics in Coimbra (Golvers, 2007). This was published in Douai in 1685,

> … and was explicitly written for the use of Jesuit candidates for the China mission, and describes in detail the minimum level of mathematical, *and especially astronomical, knowledge and skills* that were expected of them. (Golvers, 2017: 120; our italics).

This 2-volume book, written in Latin and designed specifically for ‘beginners’ in mathematics, contains 15 ‘Treatises’ that span nearly 1000 pages, and was used at Jesuit colleges from 1685 until at least 1756. *Synopsis Mathematica*

> … was conceived as a step-by-step preparation for Treatise 15, devoted to astronomy, *the last and most important of all mathematical sciences* … Not only is the Treatise on Astronomy the final treatise and the ‘end’ of the entire work, but it is also by far the most voluminous, its 255 pages constituting a small monograph on its own … As such, all the other sciences are reduced to auxiliary sciences, or preliminary stages leading to the study of astronomy; this affinity with astronomy is particularly emphasized in chapters 11 to 14, which deal respectively with sundials, spherical trigonometry, astrolabes and the calendar. (Golvers, 2017: 134–135; our italics).

Chapters 11 to 14, all in Volume II, span pages 150 to 338. One other chapter with clear astronomical associations is 9 (Optics, Vol. II, pp. 1–66). Thus, astronomy-related chapters total 510 pages, or 52% of the whole book, a clear indication of Father Thomas' commitment to astronomy, but only in so far as this reflected 'the official Catholic view.' Thus, he was obliged to reject Copernicanism.

Upon discussing astronomical observations that Antoine Thomas made while in Coimbra, Golvers (2017: 140) reflects on "… the central place of personal observation in Thomas's conception of 'Science'."

5.2.3 *Siam and Beyond*

On 3 April 1680 Antoine Thomas left Lisbon, bound for Goa in India. His goal was to carry out missionary work in Japan, which ultimately would prove to be impossible, and while trying to arrange this he was forced to spend nearly a year in Siam. He arrived in Ayutthaya on 1 September 1681 (Thomas, 1682), and was living there on 22 February 1682 when there was a lunar eclipse.

After finally realising that his dream of carrying out missionary work in Japan was not to be, Father Thomas acceded to a request from the aging Father Ferdinand Verbiest (1623–1688) and went to China instead, arriving in Macau on 4 July 1682. He would spend the rest of his life living in China, where he enjoyed a distinguished career in astronomy and mathematics (Bosmans, 1924–1926; Han, 2003; Jami, 2007; Witek, 2003; but cf. Golvers, 2017: 120) using the adopted Chinese name Ngan To P'Ing-Che (安多). Antoine Thomas died in Peking on 28 July 1709 at the comparatively young age of 65 (Collani, n.d.).

5.3 Father Thomas' Astronomical Observations While in Siam

5.3.1 *Solar Observations and the Latitude of Ayutthaya*

During his sojourn in Ayutthaya, from 1 September 1681, Father Thomas lived in the Portuguese sector of the city, where the Jesuit settlement was. As we have seen, prior to coming to the Far East he spent several years at Coimbra in Portugal; he came to Siam via Goa, the Portuguese colony on the west coast of India; and when trying to arrange to conduct missionary work in Japan it was Portuguese supporters who lobbied (unsuccessfully, as it turned out) on his behalf (see Collani, n.d.). All of his associations were with the Portuguese, and we should note that "... Portuguese [which he spoke] was the *lingua franca* for communication with Europeans in Ayutthaya in the seventeenth century ..." (Smithies, 1989: 60).

Soon after he arrived in Ayutthaya Father Thomas realised that up to that time no-one had determined its geographical position, so first he decided to obtain the latitude of the city. Having no quadrant to measure the angular distance of the Sun from the zenith, he proceeded to make a wooden one himself that had small 'pinnules' (pins) for sighting, and could be read to one minute of arc. For time-keeping he devised a simple pendulum (not a pendulum clock) comprising an iron wire with a lead ball (Thomas, 1729).

On 14 October 1681, one and a half months after his arrival in Ayutthaya, Father Thomas made his first solar observations, but according to the following account he did not use his home-made quadrant but instead relied on the principle of using a gnomon:

> I used, to take the meridian height of the sun, a gnomon of about forty Roman feet [about 11.84 metres]: I did it, advancing a pierced wooden board on the top of the wall of our Chapel; and placing on this board an iron plate parallel to the plane of the horizon, pierced in the middle by a little round hole, through which passed the ray of the sun, which would fall on another board which had been placed at the foot of the wall parallel to the plane of the horizon by means of a channel full of water; so that the meridian line drawn on this board made a right angle with a wire which fell perpendicularly in the middle of the small hole through where passed the ray which formed the image of the sun on this board. (Thomas, 1729: 653–654; our English translation).

His solar observations are listed in Table 5.2, but it is interesting that in his account he states the observations were made "… at the House of the Society of Jesus in the suburbs …" (Thomas, 1729: 654; our English translation). However, the word 'House' is ambiguous: it can refer to the Jesuit house residence where Antoine Thomas was staying or to the whole Jesuit complex of house and church. We suspect that by mentioning 'House' rather than 'house' Antoine Thomas was referring to the whole complex. Elsewhere Thomas (1729: 656) mentions that the Jesuit complex was located within the Portuguese settlement, "… which is a bit more than half a league [2.5 km] to the south of the city."

On 30 December 1681 Father Thomas carried out further solar observations (see Table 5.3). After allowing for refraction and parallax and applying other corrections, Father Goüye derived a mean figure of 14° 19′ 20″ N for the latitude of

Table 5.2 Observations of the Sun from Ayutthaya at mid-day on 14 October 1681 (after Thomas, 1721: 654).

Parameter	Value °	 ′	 ″
Distance from the Sun to the zenith	22	39	15
True position of the Sun	21	23	00
Declination of the Sun	–08	21	30
Latitude of Ayutthaya	14	17	45

Table 5.3 Observations of the Sun from Ayutthaya at midday on 30 December 1681 (after Thomas, 1721: 654).

Parameter	Value °	 ′	 ″
Distance from the Sun to the zenith	37	29	20
True position of the Sun	09	13	33
Declination of the Sun	–23	10	53
Latitude of Ayutthaya	14	18	27

Ayutthaya on the basis of Father Thomas' combined observations. Note that this latter value is remarkably close to the currently-accepted figure of 14° 21′ 12″ N (based on the WGS84 datum, which is used throughout this chapter).

With the latitude issue solved it was now a matter of determining Ayutthaya's longitude, and for this Antoine Thomas would take advantage of an up-coming lunar eclipse. But while waiting for this event there was time to make some observations of selected stars.

5.3.2 *Stellar Observations made by Father Thomas from Ayutthaya*

On 19 December 1681, even before he made his second set of solar latitude observations, Father Thomas began observing the first magnitude star Achernar (*Alpha Eridani*), and he made further observations of this star on 6 February 1682, then on 18 January 1682 he observed Canopus (*Alpha Carinae*) and stars in Centaurus in January and February 1682 (see Thomas, 1692: 658–684). His primary aim was to determine the right ascensions and declinations of these stars, and compare them with the results obtained by the French astronomer Jean Richer (1630–1696) in Cayenne (French Guiana) between 1671 and 1673 (Richer, 1679) and Britain's Edmond Halley (1656–1742) from the Atlantic island of St Helena in 1677–1678 (Halley, 1679). Golvers (2014: 313) believes that Father Thomas took these publications with him when he left Lisbon, and that if "… these books were really part of his "Personal" luggage … this reflects a careful selection of sources before he left Europe as a determined missionary and a well prepared astronomical observer …"

Unfortunately, we cannot compare Thomas' right ascension and declination values with those published by Halley and Richer, because of uncertainties surrounding their published results and because of the corrections that Goüye applied to Father Thomas' values.

Table 5.4 Details of the lunar eclipse of 22 February 1682.

	Local Apparent Time		Moon		Sun	
Eclipse	h	m	Altitude	Azimuth	Altitude	Azimuth
Start of partial eclipse	03	55	+31°	274°	–33°	93°
Start of total eclipse	04	54.5	+17°	276°	–19°	96°

Table 5.5 Antoine Thomas' timing (in local apparent time) of the immersion of different lunar features during the eclipse of 22 February 1682 (after Goüye, 1729: 692).

	Thomas' time		Modern calculation		Difference
Event	h	m	h	m	m
Start of the partial eclipse	03	53.8	03	55.0	–1.2
Total immersion of Aristarchus	04	02.5	04	04.0	–1.5
Commencement of immersion of Copernicus	04	09.5	04	12.6	–3.1
Total immersion of Timocharis	04	16.3	04	17.7	–1.4
Commencement of immersion of S. Cyrille	04	31.2	04	33.5	–2.3
Commencement of immersion of S. Theophile	04	31.7	04	34.6	–2.9
Commencement of immersion of Francastor	04	34.7	04	37.2	–2.5
Commencement of immersion of Palus Meotid	04	43.3	04	43.4	–0.1
Start of totality	04	52.7	04	54.5	–1.8

5.3.3 The Lunar Eclipse of 22 February 1682, and the Longitude of Ayutthaya

In Table 5.4 we list the start and end times of the first partial phase of the lunar eclipse in local apparent time, along with the positions of the Moon and Sun, as observed from Ayutthaya. In deriving the times listed in this table we corrected the figures calculated using Herald's OCCULT v3.6 and the NASA Catalog by –18 minutes to allow for the time difference between the 7 hour meridian (105° E) and the meridian of Ayutthaya (100.65° E). Additionally, we allowed a correction of –14 minutes for the equation of time to get apparent solar time. As Table 5.4 illustrates, this eclipse was visible in the morning just before the beginning of astronomical twilight, and the Moon was low in the western sky. Sunrise occurred at 06h 06m local apparent time, before the eclipse had ended, so only the very early parts of totality were visible in a completely dark sky. Mid-totality occurred just before the beginning of civil twilight. By this time, the sky would have had an obvious blue hue, with only the brighter stars still visible.

Once again Father Thomas (1729) used a simple pendulum for time-keeping, having tested it extensively prior to the eclipse. His timing of the eclipse in local apparent time (based on true solar time) and the immersion of different lunar features is shown in Table 5.5, while the locations of most of these features are shown in Fig. 5.6. 'S. Cyrille' was identified as the crater Cyrillus and 'S. Theophile' as the crater Theophilus. 'Palus Meotid' is not so straight forward. Although the term Palus Mæotis was used by selenographers during the eighteenth century, the term has no lunar connection today—the modern Palus Mæotis relates to the Mæotian

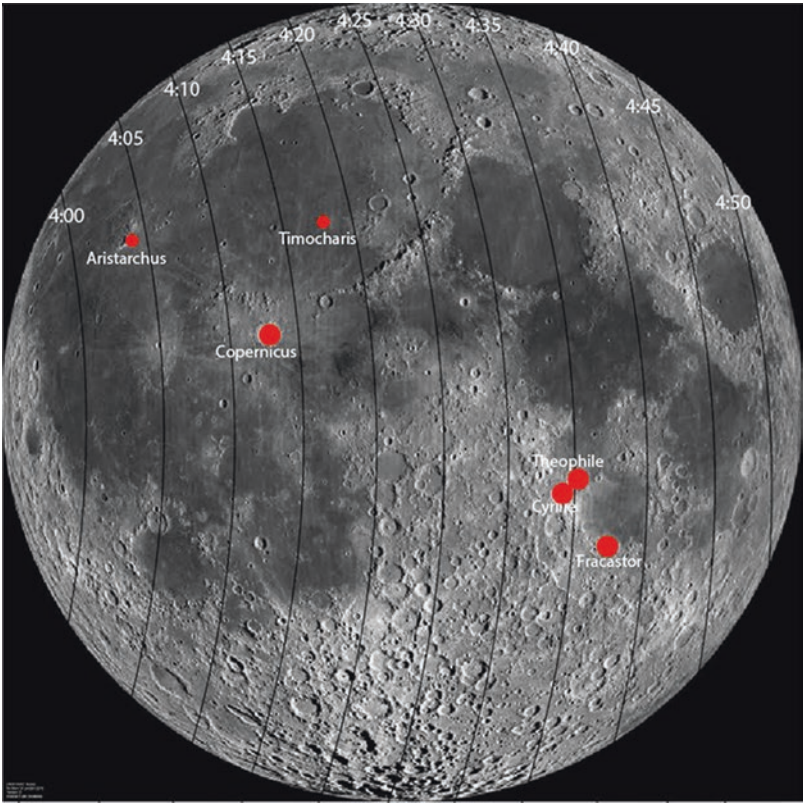

Fig. 5.6 Locations of the lunar features timed by Antoine Thomas during the 22 February 1682 eclipse (map: Lars Gislén).

Swamp at the mouth of the Don River in Russia. However, there are three small lunar *maria* incorporating the name 'Palus':

(1) Palus Epidemiarum (Marsh of Epidemics), a small *mare* in Mare Imbrium with dimensions of about 300 × 120 km on the southwestern part of the Moon, southwest of Mare Nubrium and southeast of Mare Humorum, with selenographic coordinates of 32.0° S and 28.2° W;
(2) Palus Putredinis (Marsh of Decay), between the Apennine Mountains and the craters Archimedes and Autolycus, has a diameter of 180 km and selenographic coordinates of 27.4° N and 00.0° E; and
(3) Palus Somni (Marsh of Sleep), on the northeastern edge of Mare Tranquillitatis and the Sinus Concordiae, has a diameter of 163 km and selenographic coordinates of 14.1° N and 45.9° E.

From the sequence of Thomas' eclipse timings we can tentatively identify 'Palus Meotid' as Palus Somni.

The 'modern' times listed in Table 5.5 were derived using planetarium software, and the differences between Thomas' times and the 'modern times' are shown in the right-hand column. One problem with Thomas' timings is that he sometimes used the commencement of immersion and at other times total immersion. All of the modern times that we calculated were for immersion of the centre of the crater. For Aristarchus and Timocharis 'total immersion' would push up the modern times by up to a minute. For the other craters it would decrease the modern time by about a minute. The beginning and mid-eclipse times are a little early, and it would seem that Thomas had a rather consistent difference of about –2 minutes in his timings. The most obvious reason for this is that he had a slightly different criterion for immersion than that implemented in the Meeus algorithm. Having said that, we should note the extreme difficulty that even experienced modern lunar eclipse observers encounter in timing these events, given the nebulous nature of the edge of the Earth's shadow, and this must be borne in mind when evaluating the differences listed in the fourth column.

From his observations of the eclipse Thomas (1729: 693) derived a longitude for the city of Ayutthaya of 120° 40′ 30″ East of El Hierro. El Hierro (or Ferro) is the westernmost of the Canary Islands, and during the seventeenth century was referred to as the 'Meridian Island'. The El Hierro meridian was used as the prime meridian (or zero meridian) on many old European maps (with the notable exception of British maps) at this time. El Hierro was thought to be exactly 20° west of the Paris meridian (although the actual value was 20° 23′ 9″ west of Paris). Later it was found that the El Hierro meridian was 17° 39′ 46.02″ west of the Greenwich meridian (Ferro Meridian, n.d.). If we deduct the El Hierro-Greenwich difference from the longitude Thomas determined for his location, we get 103° 0′ 44″. The current longitude of the region where the Portuguese Jesuit church was situated in Ayutthaya is 100° 34′ 21″. Therefore, Thomas' longitude calculation was in error by 2° 26′ 23″.

5.3.4 Thomas Goüye's Editorial Involvement

The Jesuit Thomas Goüye (1650–1725) was Professor of Mathematics at the Collège Louis-le-Grand in Paris, and one of his tasks was to prepare astronomical and other scientific observations made by Jesuits for publication, especially by the Académie des Sciences (of which he became a member in 1699). Thus, Goüye

> … carefully emended the materials sent by his *confrères* from all over Asia, refined them in light of academicians' interests and research, and solicited academicians' responses to appear alongside the Jesuits' work. This editorial labor resulted in texts which, even in the late 1720s, were viewed as academic works. (Hsia, 1999: 321).

We know that Goüye certainly made these types of changes to reports in his 1688, 1692 and 1729 books, but without finding Father Thomas' original manuscripts and comparing them with the published versions, it is difficult to know how much of the foregoing account of his lunar eclipse observations reflects his own records and how much was contributed by Goüye.

In this context, we should note that Goüye's editorial involvement has generated some confusion in the literature. Thus, Bhumadhon (2000) was under the impression that the February 1682 eclipse was observed from Ayutthaya by Father Thomas *and* Father Goüye, but the original French account (Goüye, 1692: 693) clearly identifies Father Thomas as the sole observer. This confusion appears to have arisen because even though Goüye was tasked with publishing the astronomical observations of the Jesuit missionary-astronomers who were based in Siam, as we have already noted, he also liked to add his own comments and corrections. Goüye's biography (see Thomas Goüye, n.d.) clearly indicates that he spent his whole life in France and never visited Siam.

It is interesting to compare Father Thomas' Ayutthaya longitude value with figures derived from later observations. For example, in discussing French Jesuit observations of the lunar eclipse observed from Lop Buri on 11 December 1685, Tachard (1686) notes that

> By the observations of the Eclipse of the Moon on the 21st of February, 1682, the longitude of Ayutia was found to be 121°, which agrees perfectly with … [our] observations. It is an astonishing thing that … the great Chart of the Observatory, made before all these observations, gives it at 122°, only one degree different from these observations.

Finally, in reviewing Father Thomas' Siamese astronomical observations it is interesting to note that all of them were made with the naked eye, or the wooden quadrant that he constructed, not with telescopes. Yet in his *Synopsis Mathematica*, written before he went to Siam and China, Thomas (1785(II): 348–349) refers to his own telescopic observations of the Sun and "… I also observed the moon here [at the Jesuit College in Douai] with *my Belgian telescopes* …" (Golvers, 2017: 138–139n; our italics). Note that the reference here is to 'my Belgian telescopes', in the plural. Clearly, he owned more than one telescope, so it is puzzling that he did not take any of his telescopes to the Far East, or if he did take them that he decided not to make use of them for the various astronomical observations that he carried out whilst in Ayutthaya.

5.3.5 Pin-pointing Antoine Thomas' Observing Site

Father Thomas indicates that his observations were made from "… the House of the Society of Jesus in the suburbs [of Ayutthaya]." (Thomas, 1729; our English translation), as already noted. There are no published descriptions of the Jesuit residence where Father Thomas was based or of the nearby Jesuit church, but from La Loubère's (1693) account we can anticipate that the house was built of brick and was only one storey high:

> The Europeans ... build with brick, every one according to his Genius ... At the side of their Houses, to keep off the Sun and not hinder the Air, some do add Penthouses, which are

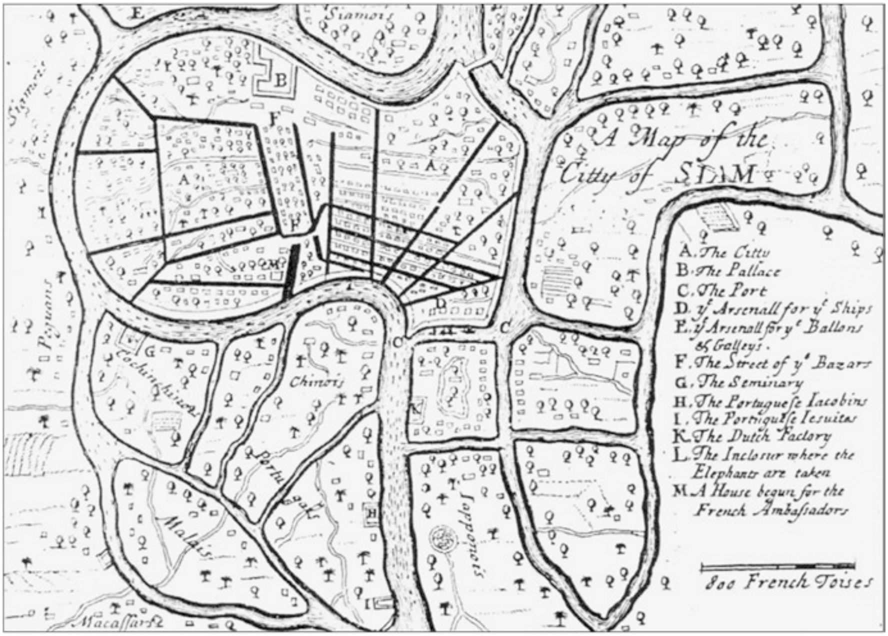

Fig. 5.7 A map of Ayutthaya in the 1680s showing the location of the Portuguese residential precinct (marked ‘Portugals’ to the south of the river on the left, and above the Malayan precinct). The location of the Portuguese Jesuit church is shown at the bottom centre of the map, on the western bank of the Chao Phraya River, and marked by the ‘I’ (after La Loubère, 1693).

> sometimes supported by Pillars ... The Chambers [in the main house] are large and full of windows, to be the more fresh and airy ... (cited in Sternstein, 1965: 100).

We know that the Jesuit complex where Antoine Thomas carried out his lunar eclipse observations was in the Portuguese residential sector of Ayutthaya, which in Fig. 5.7 is marked by the ‘I’ at the centre bottom of the map, beside the western bank of the river. This location is confirmed by a second—albeit somewhat cruder—map of Ayutthaya, which was published in 1686, and is reproduced here in Fig. 5.8. As we have seen, the datum point for Father Thomas’ latitude observations was a wooden board that was mounted high on one of the walls of the church, and contained an indented metal plate that was aligned parallel to the horizon.

Unfortunately, there is no record of the *precise* location of the Jesuit residence near the church, and even the actual location of the church itself cannot be pinpointed on the ground at the present time, given the wholesale destruction that occurred when the Burmese attacked Ayutthaya (including the Portuguese sector) in the 1760s and occupied the city (for details, see Cushman, 2000).

By the 1980s scholars thought that the ruins of the Jesuit San Paolo Church were located at latitude 14° 19′ 39.32″ and longitude 100° 34′ 17.25″, but when the site was excavated in 2008 to everyone’s surprise all that turned up were Buddhist relics. This was not the site of San Paolo. The second author of this chapter then carried out

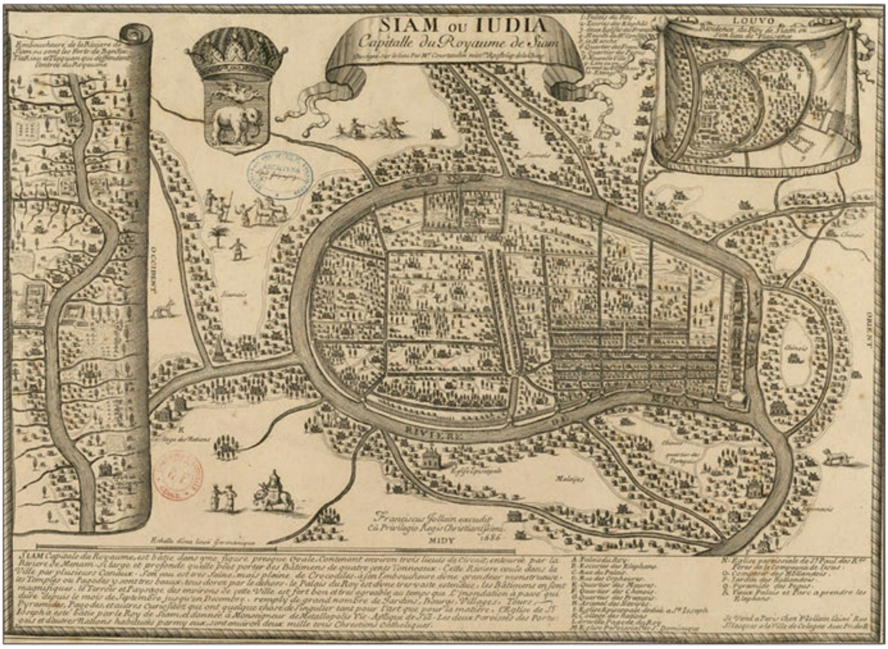

Fig. 5.8 A map of Ayutthaya by Jean de Courtaulin de Maguellon (1686) confirms the location of the Jesuit church in the southern sector of the Portuguese residential precinct. The inset map at top right shows Lop Buri (http://www.esnips.com/web/NDMI-Oldmap).

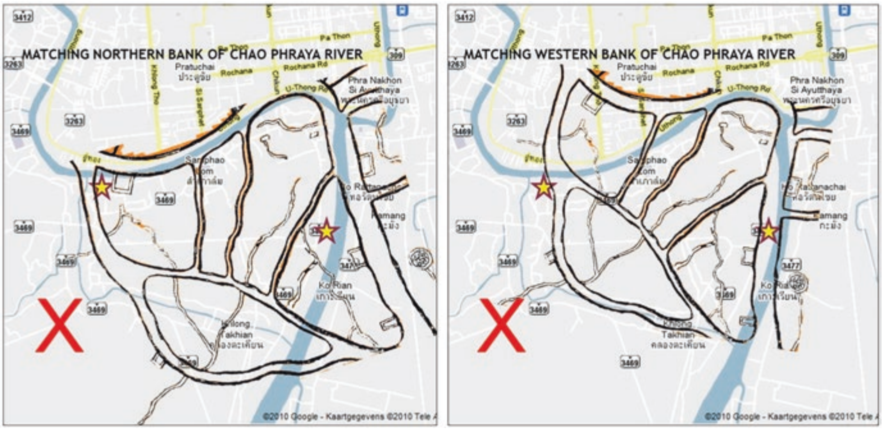

Fig. 5.9 Two comparisons of La Loubère's 1693 map with the current channels of the Chao Phraya River. The yellow stars are the reference points for the comparisons, and the red crosses indicate that neither comparison is a match (maps: Patrick Dumon).

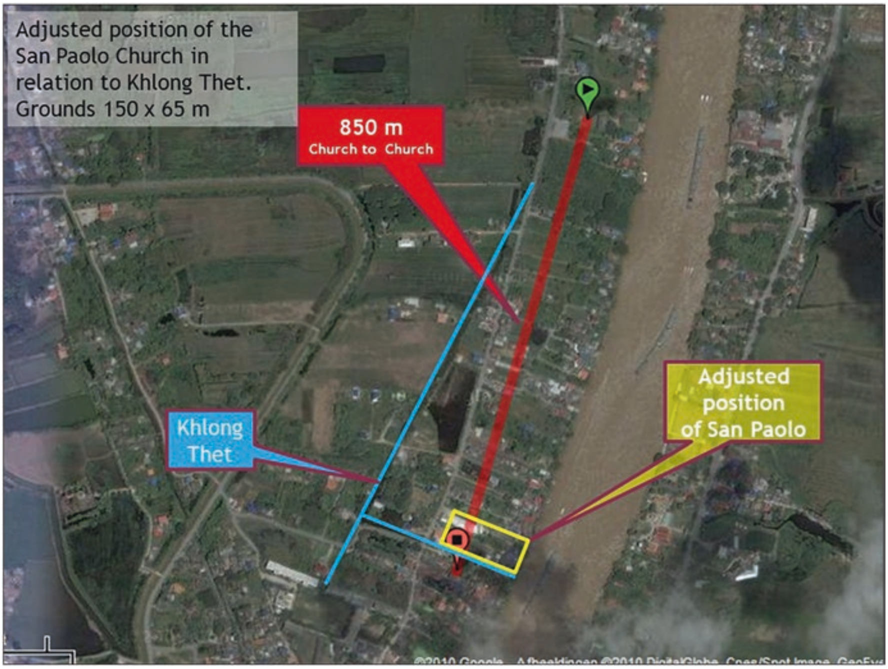

Fig. 5.10 The relative positions of the San Pedro Dominican Church and the San Paolo Jesuit Church in the Portuguese residential sector, based on La Loubère’s 1693 map (map modifications: Patrick Dumon).

his own investigation. First, he tried to correlate the Chao Phraya River shown in Fig. 5.7 above with the present-day configuration of the River, but the old map was not based on a proper survey, was not to scale, and contained distortion (e.g. see Fig. 5.9). Unfortunately, the same result was obtained when he tried to overlay only the south-western section of the Fig. 5.7 map on a present-day map of the River, although the general area where San Paolo was located could be identified. He then analysed the relative positions of this Church and the Dominican’s San Pedro Church further to the north. The site of the latter Church is well known, and according to the scale of La Loubère’s 1693 map San Paolo would be 850 metres to the south, near the bank of the Chao Phraya River (see Fig. 5.10). The area in question is now built on, but when Dumon examined 1944 aerial photographs these showed a temple site, associated moats, and a vacant area of land that looked promising (Fig. 5.11). He was able to identify a large error box and within this a smaller rectangular area where the church probably was located (see Fig. 5.12). But this is no more than a probable match, and there is no guarantee, given the passage of time and the amount of construction (and destruction) in this area, that an archaeological excavation will automatically produce evidence of the Jesuit church.

The fact that we cannot pinpoint the location where Antoine Thomas carried out the first Western astronomical observations made in Siam is disappointing. It would

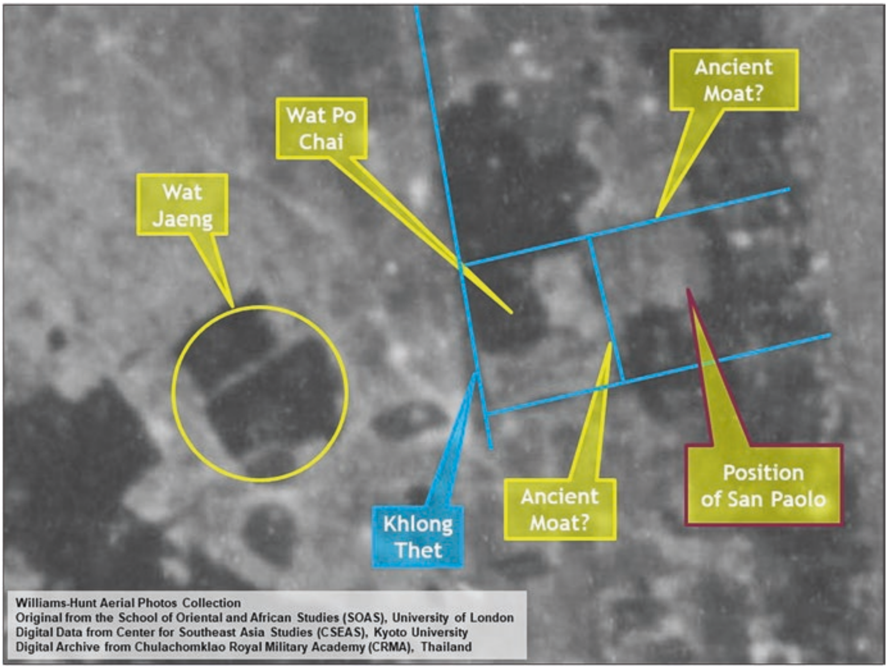

Fig. 5.11 An 1944 aerial photograph from the Williams Hunt Collection showing Wat Pho Chai, associated moats, and the possible site of the San Paolo Church (map: Patrick Dumon).

have been nice to install a commemorative plaque or signage—like those found at Lop Buri, for example (e.g., see Fig. 5.13)—to mark the position and celebrate these pioneering scientific endeavours.

5.3.6 *The Two Contingents of French Jesuit Missionary-Astronomers*

In June 1682, Father Thomas left Ayutthaya for China, but he was soon replaced not by one, but by a contingent of six French Jesuit missionary-astronomers, specifically sent to Siam by King Louis XIV at King Narai's request (see Orchiston et al., 2016). They joined King Narai in observing a lunar eclipse on 11 December 1685 (Gislén et al., 2018), and he was so impressed that he authorised the construction of a large tower observatory in Lop Buri (see Fig. 5.14)—ruins of which still exist (Fig. 5.15)—and arranged for a second contingent of French Jesuit astronomers to come to Siam and remain there once most of those in the first group left and went to China (Orchiston et al., 2016).

The all-too-short period from December 1685 to June 1688 was Siam's first 'Golden Age of Scientific Astronomy', as the French Jesuit visitors carried out a

Fig. 5.12 Error boxes showing the likely site of the San Paolo Church (map: Patrick Dumon).

range of different types of astronomical observations from Lop Buri and Ayutthaya, including three further lunar eclipses and one partial solar eclipse (see Gislén et al., 2021; Orchiston et al., 2019). In discussing the observations that some of the first French contingent made once they reached China, Florence Hsia (1999: 305) wrote: "In the late seventeenth century, French Jesuit missionaries in China transplanted a distinctively French and distinctively academic brand of scientific work from Paris to Beijing." This description applies equally to Siam, if we replace 'China' with 'Siam' and 'Beijing' with 'Lop Buri' in this quotation.

However, Siam's first astronomical 'Golden Age' ended abruptly in July 1688 when King Narai died. This was disastrous for 'Western astronomy' because

> Pra Phetracha then installed himself as the King of Ayutthaya, and upon reversing King Narai's progressive policies closed Siam's borders to the West and expelled most of the foreigners living there ... Wat San Paulo was closed, and all but one of the Jesuit astronomers quickly moved to the French fort in Bangkok before sailing to India ... This brought a sudden and totally unexpected end to an all-too-short, yet extremely productive, period of scientific astronomical activity in Siam. (Orchiston et al., 2021).

The one French Jesuit missionary astronomer who initially remained in Siam was Charles de La Breuille (ca 1653–1724; Besse, 1918), who joined a group of Portuguese Jesuit missionaries in Ayutthaya. There is no evidence that he continued to conduct astronomical observations, and by 1695 he was living in India. Instead, it was Jean Richaud (1633–1693), one of the French Jesuits who had escaped to

Fig. 5.13 One of the commemorate plaques erected in Lop Buri to celebrate important seventeenth century Jesuit astronomical observations carried out there (photograph: Darunee Lingling Orchiston).

India in 1688, who returned to Siam in 1690 and determined the latitude of Ayutthaya as 14° 18′ 00″ (Richaud, 1692: 11). This was in close accord with the values obtained earlier by Antoine Thomas and published by Goüye in 1688.

5.4 Discussion

Nearly two centuries then elapsed before the total solar eclipse of 18 August 1868 brought Western astronomy to Siam once more and ushered in Siam's second Golden Age of astronomy. Once again, this was a direct result of Royal Patronage. Siam's own 'Sun King', King Rama IV (Soonthornthum and Orchiston, 2021), carried out his own calculations and subsequent observations of the 1868 eclipse (Soonthornthum and Euarchukiati, 2022). He also invited local and overseas dignitaries (e.g. see

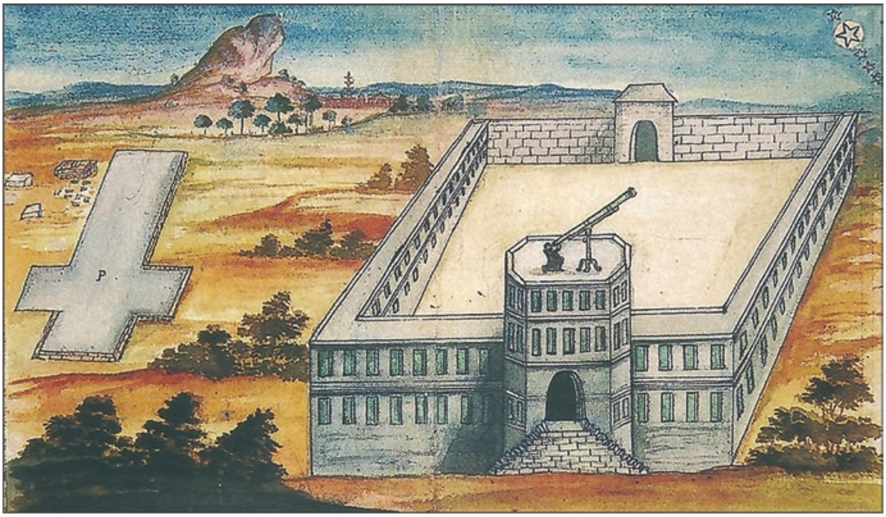

Fig. 5.14 A contemporary painting of Wat San Paulo, with its distinctive 4-storey observatory (https://upload.wikimedia.org/wikipedia/commons/5/57/Wat_San_Paolo_Plan.jpg).

Orchiston and Orchiston, 2022) and a contingent of French astronomers to Wah-koa[1] in southern Siam (see Fig. 5.2) to observe this eclipse (Orchiston and Orchiston, 2017), which would turn out to be a watershed event in the history of solar physics (Nath, 2013; Orchiston, 2022). Regrettably, King Rama IV paid the ultimate price for his passion for astronomy: during the 1868 eclipse expedition he caught malaria, and on 1 October 1868 he died. He was just three weeks short of his 64th birthday.

King Rama IV's son also caught malaria at Wah-koa but fortunately for Siam and for Western astronomy he survived. He assumed the throne as King Rama V, and also brought an interest in astronomy inherited from his father. Just seven years later he was able to action this when Siam would witness another total solar eclipse. On this occasion British astronomers went to Chulai Point[2] near Petchaburi (see Fig. 5.2) to view the 6 April 1875 eclipse (Euarchukiati, 2021b), while King Rama V, members of the Royal Family and invited dignitaries observed it from the Grand Palace in Bangkok. An interesting innovation on this occasion was the 'eclipse drawing contest' organised by the King (see Euarchukiati, 2021a).

The next total solar eclipse to grace Siamese skies occurred on 9 May 1929, and King Rama VII invited teams of British and German astronomers to make observations from near Pattani in far southern Thailand (Soonthornthum et al., 2021). Unfortunately, on this occasion cloudy skies severely limited the range of observations that could be made. But one positive outcome of this eclipse was the launch of

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[1] 'Wah-koa' was the spelling used in the nineteenth century. The present spelling is 'Ban Wako', at 11° 42′ 58.6″ N and 99° 45′ 16.4″ E.

[2] 'Chulai Point' was also the spelling used in the nineteenth century. The present name is 'Laem Phak', at 13° 03′ 31.4″ N and 100° 06′ 16.1″ E.

Fig. 5.15 Ruins of the San Paolo tower observatory at Lop Buri (photographs: Patrick Dumon).

undergraduate astronomy lectures at Chulalongkorn University during the 1930s. This marked the start of academic astronomy in Thailand, which culminated in 2009 with the founding of the National Astronomical Research Institute of Thailand (see Orchiston, et al., 2019; Soonthornthum, 2017). Royal patronage, through the late King Rama IX and his daughter HRH Princess Maha Chakri Sirindhorn, played a key role in this important development.

5.5 Concluding Remarks

The Belgian scholar Noël Glovers (2014: 304) has described Antoine Thomas as “… a multi-faceted character with rich competences, a very good observer and reporter …” who made an important contribution to astronomy in China. But he did more than this. *En route* to China he pioneered scientific astronomy in Siam, providing latitude and longitude co-ordinates for the capital city of Ayutthaya, using the first scientific observations of a lunar eclipse made from Siam to derive the longitude value.

We know that Antoine Thomas carried out some of his astronomical observations from the Jesuit church in Ayutthaya and other observations from the nearby House of the Society of Jesus. Although the location of the church is shown on two maps dating from the late seventeenth century, unfortunately the wholesale destruction of Ayutthaya by Burmese invaders during the eighteenth century means that we can no longer identify the precise site of the Jesuit church. Thus, we cannot erect a monument to celebrate Siam’s entry into the realm of scientific astronomy.

Father Thomas’ stay in Ayutthaya was all-too-brief, and we can only imagine what he may have been able to achieve for Siam had he stayed longer and had access to the latest Western astronomical instruments. Yet his sojourn was the springboard that would launch a full-scale French Jesuit assault on Siamese astronomy between 1685 and 1688, and the construction of a major observatory at Lop Buri.

Acknowledgements We are grateful to Mr Visanu Euarchukiati (Bangkok, Thailand) and Professor Noël Golvers (Katholieke Universiteit Leuven, Belgium) for their assistance; to staff at the Jesuit Archives in Paris for access to biographical material about Father Thomas; and to staff at the Paris Observatory Library for providing access to Siamese archival records.

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Chapter 6
King Rama IV: Astronomer and 'The Father of Thai Science'

Boonrucksar Soonthornthum and Wayne Orchiston

6.1 Introduction: A Biographical Sketch of King Rama IV

King Rama IV or Phra Bat Somdet Phra Chom Klao Chao Yu Hau (Fig. 6.1) was the fourth King of the Chakri Dynasty (Bhumadhon, 2012; Moffat, 1961; Saibejra, 2006). His former name was 'King Mongkut Sommutti Deva Wong', or 'King Mongkut' for short. He was born on 18 October 1804, the son of Phra Bat Somdet Phra Buddha Loetla Nabhalai (King Rama II; Fig. 6.2) and Queen Sri Suriyendra. Before he became King he was known as Prince Mongkut. The Prince had a younger brother, 'Somdet Chao Fa Juthamani Krom Khun Issares Rangsan', and once Prince Mongkut assumed the throne and became King Rama IV he had his brother appointed as the second King, 'Phra Pin Khao Chao Yu Hau'.

When Prince Mongkut was 14 years old, he became a Buddhist novice for 7 months, according to Royal tradition. Then in 1824, when he was 20 years old, he became a Buddhist monk. After he was in the monkhood for only 15 days, his father King Rama II passed away (Wachirayannawarorot, 1997: 14). King Rama III or 'Nangklao' (Fig. 6.3), who was a son of one of the concubines of King Rama II and was older and with more experience in governance, was appointed as the third King of the Chakri Dynasty. Therefore, Prince Mongkut decided to stay in the monkhood, and he served as a Buddhist monk and scholar for a total of 27 years.

King Rama III passed away in 1851, and on 3 April 1851 Prince Mongkut assumed the throne, becoming King Rama IV; he was 47 years of age. He then ruled Siam successfully and safely for 17 years, until his death on 1 October 1868 from

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Fig. 6.1 King Rama IV (https://www.google.com/search?q=king+rama+iv&client=firefox-b-d&sxsrf=ALeKk02Fcwey7PsR909TNbId0olPLsMpHg:1588986995393&source=lnms&tbm=isch&sa=X&ved=2ahUKEwjj06brzaXpAhUXU30KHYFdAQ8Q_AUoAXoECBoQAw&biw=1177&bih=650#imgrc=1DzFBbH8KdeIEM).

Fig. 6.2 King Rama II, the father of King Ramas III and IV (https://upload.wikimedia.org/wikipedia/commons/f/f9/Buddha_Loetla_Nabhalai_portrait.jpg).

malaria after visiting Wah-koa[1] village in Prachuap Kiri Khan Province, where he had observed the total solar eclipse of 18 August 1868 (see Bhumadhon, 2012).

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[1] There are various Anglicised spellings of this name in the literature. Throughout this chapter we have chosen to use ‘Wah-koa’, which was the spelling in use at the time of the 18 August 1868 total solar eclipse.

Fig. 6.3 A postage stamp showing King Rama III (Siamstamp.com).

During his 27 years as a monk Prince Mongkut took time to benefit from studying various subjects, both religious and worldly—and especially science and mathematics. He established a new branch of Buddhism, Dhammayut, which had a stricter practice. He made pilgrimages to several cities in Northern Thailand, including Pitsanulok, Sawankhalok and Sukhothai, where he had the opportunity to learn about the lives of his people before he became King. He also discovered many valuable historical documents, and visited archeological sites in Siam.

6.2 Science and Technology in the Rattanakosin Period

A big change on a global scale occurred in the eighteenth century with the advent of the ‘Industrial Revolution’. The industrial revolution marked a period of development that transformed agricultural and rural societies in Europe and America into urban and industrialized societies. The industrial revolution began in Britain and spread to the rest of the world. By the end of the reign of King Rama II, economically Siam was strong. There was no war, and agriculture, the main national occupa-

Fig. 6.4 Bishop Jean-Baptiste Pallegoix (https://en.wikipedia.org/wiki/Jean-Baptiste_Pallegoix#/media/File:Jean-Baptiste_Pallegoix.jpg).

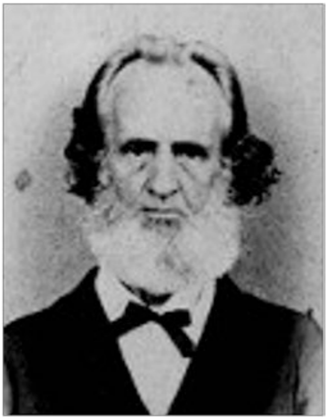


Fig. 6.5 Dr Dan Beach Bradley in about 1865 (https://en.wikipedia.org/wiki/Dan_Beach_Bradley#/media/File:Dan_Beach_Bradley.jpg).

tion, had growth significantly. The King promoted good relations with foreign countries, for example trading with China and with Western countries.

During the reign of King Rama III, several notable foreign missionaries and professionals came to live in Siam. For example, French-born Catholic priest Bishop Jean-Baptiste Pallegoix (1805–1862; Fig. 6.4; 1977) arrived in Bangkok in 1829, and the American medical missionaries Dr Dan Beach Bradley (1804–1873; Fig. 6.5; Lord, 1969), Reverend Dr Jesse Caswell (1809–1848; Fig. 6.6; Bradley, 1966) and Dr Samuel Reynolds House (1817–1899; Fig. 6.7) in 1835, 1845 and 1847 respectively.

Fig. 6.6 Dr Jesse Caswell (courtesy: National Archives, Bangkok).

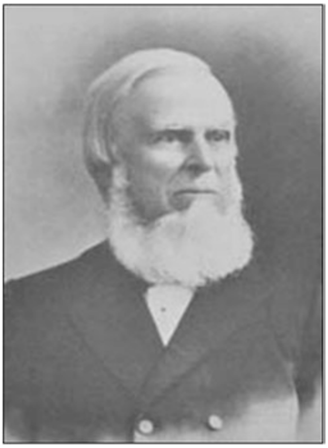


Fig. 6.7 Dr Samuel Reynolds House (courtesy: National Archives, Bangkok).

In 18 April 1855, during the reign of King Rama IV, the 'Bowring Treaty' was signed between the United Kingdom and the Kingdom of Siam (Jumsai, 1970; Taylor, 2018), which liberalized foreign trade in Siam. An image of King Rama IV published by Sir John Bowring (1857) is reproduced here as Fig. 6.8.

During the mid-nineteenth century, there were opium wars between the British Government and China resulting in a concession of some of China's territory to Great Britain. King Rama IV was well aware that there was no point in trying to compete with Western powers—Siam had to be responsible for its own development in science and technology and negotiate wisely with the Western powers to prevent a war.

As a result, King Rama IV started to learn foreign languages, and about science and technology, both by reading up himself and learning from foreign missionaries and professionals who lived in Bangkok at that time. Thus, awareness of Western science and technology was disseminated among Siamese Royalty, and the ruling classes.

Fig. 6.8 A chromolithograph of King Rama IV published by Sir John Bowring. The signature by the King below his portrait is in Latin, and translates as "Somdet Phra Poramenthra Maha Mongkut, King of the Siamese" (after Bowring, 1857, Volume 1: frontispiece facing the title page).

6.3 King Rama IV: Astronomer

6.3.1 Attitude to Education

After he became King, King Rama IV was still interested in studying many subjects, including the arts and social sciences, science and astronomy. He was inspired and yearned to gain knowledge through self-education (e.g. his proficiency and fluency in the Pali (Ma-kot) language and the contents of the Tipitaka (Buddhist text)).

Meanwhile, he studied astronomy, chemistry, geography, French and Latin with Bishop Pallegoix, who was his first Western teacher. In reviewing the context of 'Siam Astronomy', Bishop Pallegoix (1977: 319) was surprised that

> … the Siamese have several astronomical texts translated from Pali language about the motions of the sun, moon and planets around the zodiac for astrological purposes. But, these knowledges have been distributed only among some Brahmins who are appointed as the 'Royal Astrologers'. They have never used any telescope or astronomical instrument for observations, but rather based on some unclear criteria in their calculations using the old Siam astronomical texts.

The medical missionary Dr Dan Beach Bradley arrived in Siam in July 1835, but spent 1848–1850 back in the USA before returning to Siam, where he remained until his death in 1873. In 1839, when he was a monk at Wat Samor Rai (temple) in Bangkok, Prince Mongkut first studied English with Dr Bradley. Dr Bradley brought the first printing press to Siam and in 1839 he published leaflets banning opium in Siam. During 1844–1845, at King Rama III's request, he published Siam's first

๏หนังสือจดหมายเหตุ

THE BANGKOK RECORDER.

Vol. I เล่ม ๑ บางกอก เดือน หก ขึ้น เจ็ดค่ำ จุลศักราช ๑๒๒๗ March 1st 1865. ครีศศักราช ๑๘๖๕ ใบ ๑ No. 1.

หนังสือ หลวง

Fig. 6.9 The title page of the second series of The *Bangkok Recorder* newspaper, dated 1 March 1865 (https://en.wikipedia.org/wiki/Dan_Beach_Bradley#/media/File:Bangkok_Recorder.png).

newspaper, *The Bangkok Recorder*, and later, after his return from the USA, it appeared monthly from 1865 to 1868 (see Fig. 6.9). From 1845 to 1851, Prince Mongkut, along with several monks and Siamese officers, studied English at Wat Bowonniwet Vihara with another American medical missionary, the Reverend Dr Jesse Caswell (Phra Bat Somdet …, 2004).

Prince Mongkut also joined several scientific discussions sessions with Dr Caswell (e.g. about evidence that the Earth was spherical), and he also attended scientific and medical lectures and demonstrations organized by Dr Samuel Reynolds House (e.g., see Fig. 6.10).

6.3.2 Astronomy Education

According to Dr Édouard Stephan (1837–1923; 1869: 549), the leader of the 1868 French solar eclipse expedition at Wah-koa (see Orchiston and Orchiston, 2017) in the Gulf of Thailand, in order to learn astronomy King Rama IV studied traditional Siam astronomical and astrological texts that were based on the Indian astronomical *Surya Siddhanta* texts (e.g. see Fig. 6.11) and on the Mon astronomical Saros text called the *Saramph Mon* (Wirabutra, n.d.). Fig. 6.12 shows calculations in the *Saramph Mon*.

From the *Saramph Mon*, Prince Mongkut developed the method of calculating the 'precise lunar month' by counting the day of the Full Moon and the day of the New Moon using a Pkakanana Board (see Fig. 6.13). These Boards have a rectangular shape, and are used in making precise 'fortnight movements' in order to deter-

Fig. 6.10 Prince Mongkut sometimes attended Dr House's scientific or medical demonstrations in Bangkok (courtesy: National Archives, Bangkok).

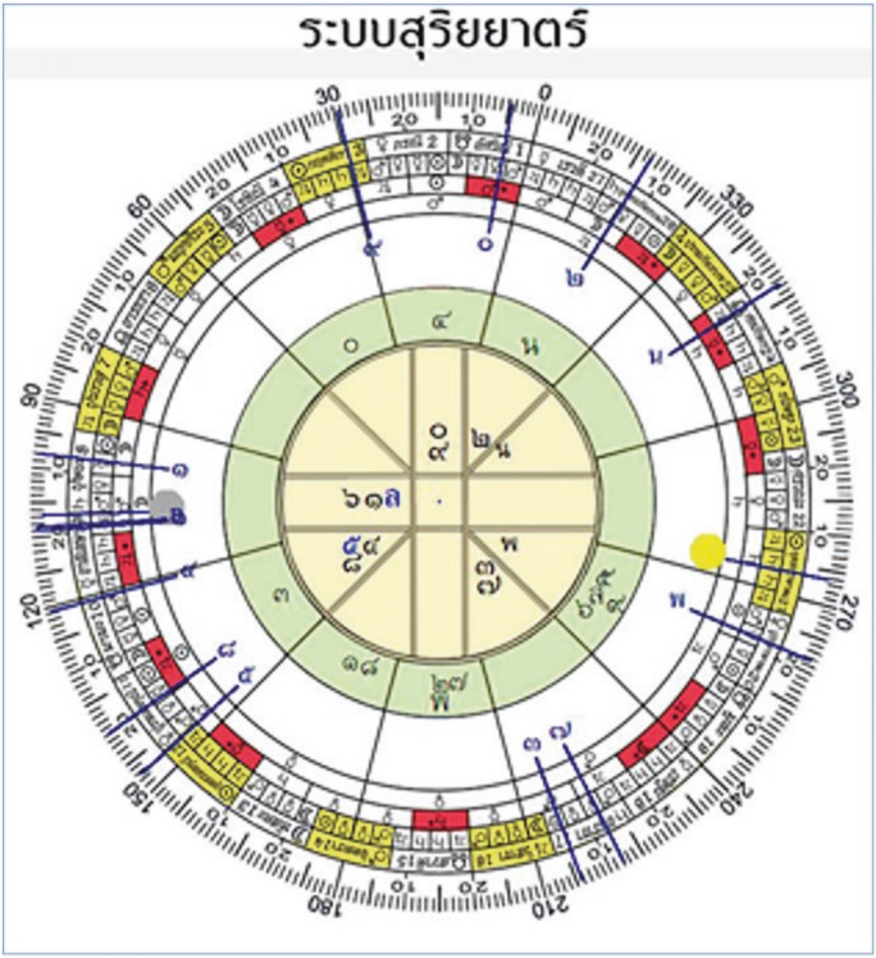


Fig. 6.11 A modern Thai version of the *Surya Siddhanta* (courtesy: National Archives, Bangkok).

mine specific ‘Buddhist Days’. Pkakanana Boards are still used today but only in *Dharmmayuttika Nikaya*, an order of Theravada Buddhism that was founded by Rama IV (Phra Bat Somdet …, 2004: 474).

King Rama IV also studied Western astronomy, using many English-language astronomy textbooks. The afore-mentioned 4th British Governor of Hong Kong, Sir John Bowring (1792–1872; Fig. 6.14) may have been controversial, but he had a special place reserved in his heart for Siam, as shown in his book *The Kingdom and People of Siam: With a Narrative of the Mission to that Country in 1855* (Bowring, 1857). During his visit to Bangkok in 1855, Sir John (Bowring, 2004: 265) specifically mentioned seeing the following books in King Rama IV’s collection:

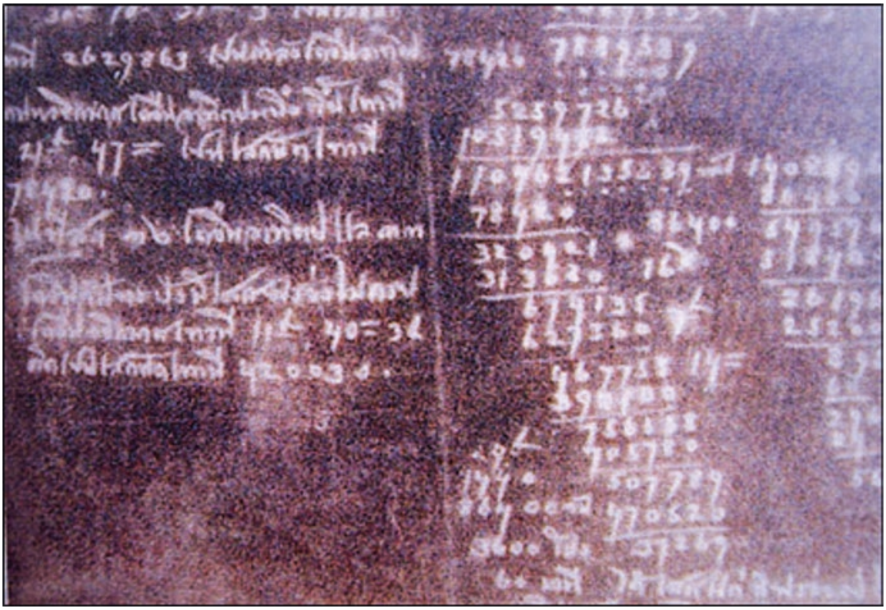


Fig. 6.12 Examples of calculations in the *Saramph Mon* (courtesy: National Archives, Bangkok).

Fig. 6.13 On the left is an example of a modern digital Pkakanana Board (Instagram: ThailandNSTFair).

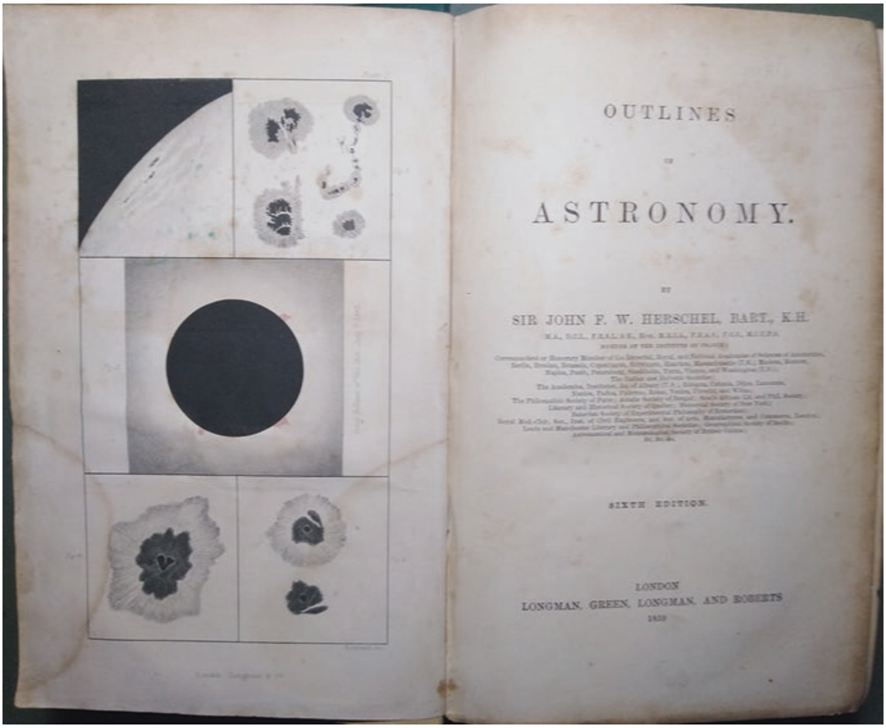
Fig. 6.14 Sir John Bowring in about 1857 (adapted from Bowring, 1857, Volume 2: frontispiece facing the title page).

- Anonymous, 1861. *Guide to the Stars, in Eight Planispheres, Showing the Aspect of the Heavens for Every Night in the Year with an Explanatory Introduction. New Edition*. London, Walton and Mabery.
- Lardner, D.C.L., 1853–1856. *Handbook of Astronomy. Volume II*. London, Walton and Mabery (872 pp.)
- Herschel, Sir John F.W., 1859. *Outlines of Astronomy. Sixth Edition*. London, Longman, Green, Longman and Roberts (714 pp.)
- Ward, Mrs, 1859. *Telescope Teachings*. London, Groombridge and Sons (219 pp.)

Without doubt, the most authoritative, and hence useful, of these is *Outlines of Astronomy*, written by the famous British astronomer, Sir John Herschel (1792–1871)—who, like Sir John Bowring, also was born in 1792, but he died just one year earlier, in 1871. Herschel's weighty tome was first published in 1849, and by the time King Rama IV acquired the Sixth Edition it had grown to 714 pages plus xxix Front Pages, and eight unnumbered End Pages with illustrations and advertisements. The second author of this chapter just happens to have a (poor-quality water-stained) copy of this edition of Herschel's book in his own library, and Fig. 6.15 shows the title page and facing frontispiece. As we shall see, King Rama IV had a special interest in comets and solar eclipses (see Sections 6.7 and 6.8, below), so he would have enjoyed reading Herschel's 40-page Chapter XI on comets, but in the 1850s solar physics was in its infancy (Meadows, 1970), so there is no chapter on solar eclipses in this edition of Herschel's tome.

The only other reference to specific astronomical books owned by Rama IV dates to when he was still Prince Mongkut and living at Wat Bowonniwet Vihara. The American medical missionary Dr Samuel House was granted an audience with him, and when he looked around the room he "… saw the Bible and Webster's Dictionary and also the astronomical and nautical almanac on his table. On the other desk, I saw a map of the next predicted eclipses written with pencil …" (Feltus, 1936: 22).

Although King Rama IV is reputed to have had access to a range of astronomical instruments, as yet no one has investigated this aspect of his astronomical interests.



OUTLINES

OF

ASTRONOMY.

BY

SIR JOHN F. W. HERSCHEL, BART., K.H.

SIXTH EDITION.

LONDON
LONGMAN, GREEN, LONGMAN, AND ROBERTS
1859

Fig. 6.15 The title page and frontispiece of the Sixth Edition of Herschel's *Outlines of Astronomy* (Orchiston Collection).

What we can reveal, though, is that there is a small refracting telescope on display in a museum at the King Mongkut Science Park at Wah-koa (the site of the 1868 solar eclipse—see Subsection 6.8.2 below), which is reputed to have belonged to King Rama IV. This is shown in Fig. 6.16. It has a clear aperture of about 2.5 inches (we were not able to measure it), contains a small finder, and features an altazimuth mounting with slow-motion controls.

6.4 King Rama IV and 'Modern Astronomy'

King Rama IV was very interested in learning 'Modern Astronomy', and about new discoveries made around the world. On 6 April 1855 when Sir John Bowring was granted an audience with his Majesty Bowring noted that King Rama IV "… mentioned about the discovery of a planet, 'Neptune'. Due to his enthusiasm in this new discovery, his majesty bestowed the name 'Neptune' on his 'Private Cargo Ship …" that sailed regularly between Bangkok and Hong Kong (Phra Thep Mongkon Suthi, 2004: 305).

Fig. 6.16 A small altazimuth-mounted refracting telescope reputed owned by King Rama IV, and on display at the King Mongkut Science Park at Wah-koa, south Thailand (courtesy: siamrat.blog).

King Rama IV also made regular astronomical observations (Phra Bat Somdet …, 2004: 109–110), including using a sextant to observe the Sun and selected stars in order to determine the latitude and longitude of different locations in Siam. He also liked to observe rarer astronomical events, such as the 18 September 1857 solar eclipse, the lunar eclipse of 13 August 1859, a transit of Mercury on 12 November 1861, and the impressive naked eye comets of 1853 and 1861. We will return to this latter comet in Section 6.7. But now, let us look at his other observations in turn.

The 18 September 1857 eclipse was an annular event, with the path of totality conveniently crossing Siam close to Bangkok (see Fig. 6.17). For King Rama IV, this served as an ideal introduction to solar eclipses, an interest he would take up in a more substantial way in August 1868. More on this in Section 6.8, below.

Bangkok, and indeed all of Siam, were ideally situated to enjoy the whole of the lunar eclipse of 13 August 1859, when a

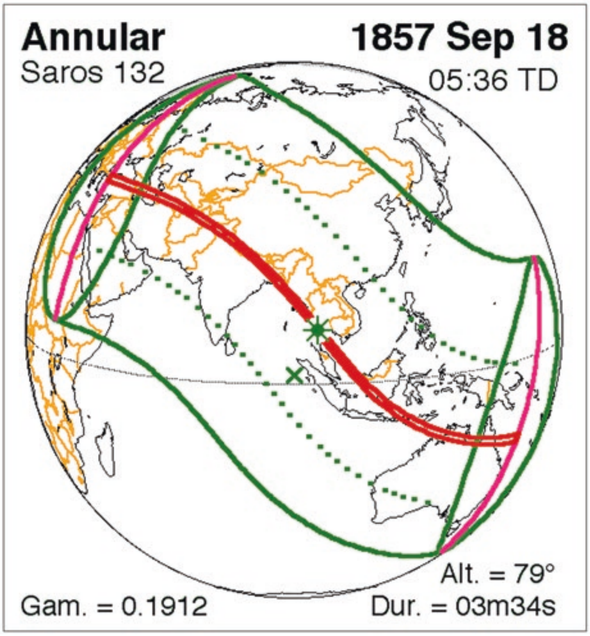


Fig. 6.17 Map showing the path of totality of the annual solar eclipse of 18 September 1857 (after Espenak and Meeus, 2006).

> … dramatic total eclipse lasting 1 hour and 47 minutes plunged the full Moon into deep darkness, as it passed right through the centre of the Earth's umbral shadow. While the visual effect of a total eclipse is variable, the Moon may have been stained a deep orange or red colour at maximum eclipse. This was a great spectacle for everyone who saw it. The partial eclipse lasted for 3 hours and 56 minutes in total … During this eclipse the Moon was just a day past apogee, making it very small. At maximum eclipse it was 0.498° in apparent diameter, which is 6.2% smaller than average. (Smith, 2015).

Espenak (n.d.) mentions that the Moon was in the constellation of Capricorn at the time, and that with a duration of 1 hour 47 minutes (to be precise, 106.5 minutes), this "… qualifies the eclipse as a member of a select class of exceptionally long total eclipses with durations exceeding 100 minutes."

A little over two years later, on 12 December 1861 King Rama IV used a telescope to observe a transit of Mercury, when the planet could be seen as a very small black disc traversing the face of the Sun. Compared to the rare and scientifically invaluable 1874 and 1882 transits of Venus (see Cottam and Orchiston, 2015; Sheehan and Westfall, 2004), transits of Mercury were "Somewhat less spectacular in appearance and of lesser importance …" (Orchiston 2017a: 27), although through their observation astronomers could look for evidence of an atmosphere around Mercury and any indication of a satellite (or satellites). Transits of Mercury were more common that their Venus counterparts, typically with 13 or 14 per century, and during King Rama IV's lifetime there were seven of them. However, one of them occurred in 1815 when he was still a child and had yet to be seduced by astronomy, and of the other six (in 1822, 1832, 1835, 1845, 1848 and 1861), for one reason or another not all of them would have been visible from Siam. As far as we know, Prince Mongkut observed none of them and King Rama IV just one, in 1861. Because the 1861 transit occurred in November, Mercury would have appeared just 10 arc seconds in diameter, a small black spot just 1/194 the diameter of the Sun (Young, 2011)! According to the Australian astronomer John Tebbutt (1859–63), sunspots were present at the time, so King Rama IV should also have seen these, even with the small telescopes at his disposal.

While still a monk, Prince Mongkut was able to indulge his knowledge of and interest in Solar System astronomy in 1834 when at the age of 30 he authorized the construction of a new Buddhist temple, Wat Borommaniwat, in Bangkok. However, construction was deferred, and the temple was only finished after Prince Mongkut became King. During the construction phase the temple was known as Wat Nok, and it only received its current name upon completion.

The unique feature of this temple is described clearly in the following *Bangkok Post* tourism web site:

> Stepping into the ordination hall (ubosot) of Wat Borommaniwat in Bangkok’s Pathumwan district, visitors will be bewildered by the unorthodox mural paintings lining the walls. Wat Borommaniwat is home to Thailand’s first scientific painting of the universe. Combining Thai and Western art, these murals depict the solar system, Saturn and other planets …

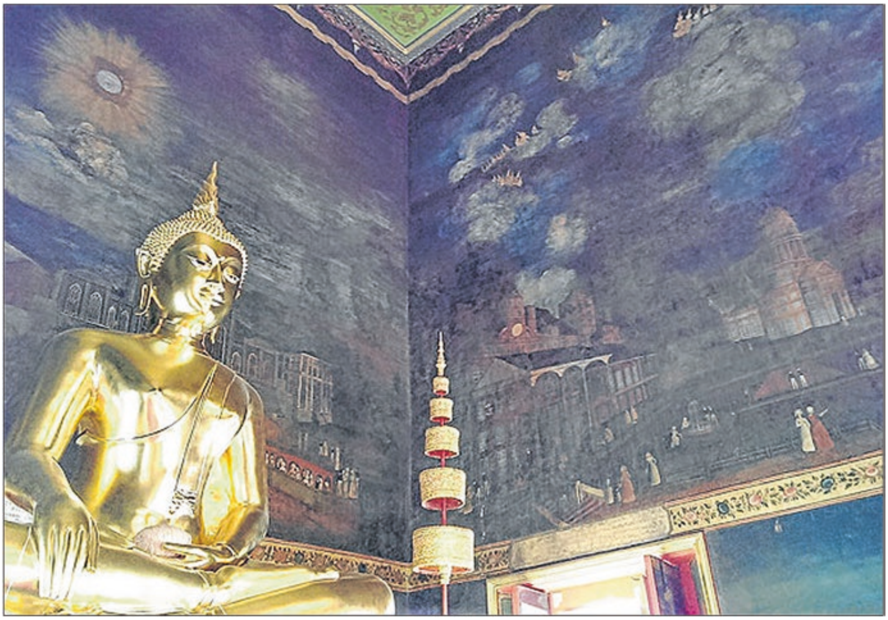


Fig. 6.18 Phra Thossapollayan, the principle Buddha statue, in the ordination hall of Wat Borommaniwat, with the mural painting on the wall behind the statue depicting the Sun in place of Mount Meru (Wat Borommaniwat, n.d.).

> In the ubosot, above the blue- and green-toned paintings of European architecture and Western people are murals of traditional Thai devas (guardian spirits). If you look at some of these murals carefully, you will see several scientifically correct constellations painted in the sky. The Sun is visible on the interior wall behind Phra Thossapollayan, the principle [*sic*] Buddha statue in post-Sukhothai art style. In the upper part of the wall on the right side of the statue, Saturn with its two brightest rings shines in the dark sky. A little below Saturn is a group of devas flying behind white clouds. On the left side of the statue is a large planet believed to be Jupiter, as it contains horizontal stripes of clouds and is surrounded by the four Galilean moons. (Wat Borommaniwat, n.d.).

Fig. 6.18, below, shows the principal Buddha and the walls with the astronomical murals, while Fig. 6.19 has close-ups of the Sun, Jupiter and Saturn. Actually, the *Bangkok Post* web site web site (ibid.) states that there are eight planets depicted in the murals, but it is hard to identify all of them, even if eight Solar System planets were known to astronomers in the 1850s when the temple was completed. Positive identifications of Mercury, Venus, Earth, Mars, Uranus and Neptune have yet to be made.

We also learn from the *Bangkok Post* tourism web site (ibid.) that this was the first temple built by Prince Mongkut, and that the murals were painted by the monk artist Khrua In Khong who was famous during the 1850s and 1860 (Khrua In Khong, n.d.). Khong was born in Phetchaburi during the reign of King Rama III and spent his whole life as a monk. He and Prince Mongkut knew each other as monks, and a friendship developed that blossomed once the Prince became King. Rama IV often would commission Khong to paint murals in new temples, and in those undergoing restoration. Initially Khong's mural paintings were in the traditional Buddhist style, but through King Rama IV's influence he started to incorporate Western people, buildings, ships and even historical events in his temple murals, and some of his murals are now important historical records of political events and social conditions during the reigns of Kings Rama III and IV. In this way, Khong produced a unique portfolio of mixed Buddhist-Western images. Yet he never visited the West, "... relying on western commercial prints, observations of westerners in Bangkok and his imagination." (ibid.). It has also been suggested that Khong's mural paintings helped with King Rama IV's desire to modernize and Westernize Siam, partly in order to block the colonial ambitions of England and France (Thongmitr, 1979).

When it came to a specialist area of science, we can assume that Khong's knowledge was limited to traditional Siamese astrology as taught in the temple, and that

Fig. 6.19 Close-ups showing the depictions of what appears to be a total solar eclipse (left), and the planets Jupiter, with its four Galilean satellites (centre) and Saturn with its rings (right)(photographs: Boonrucksar Soonthornthum).

he derived inspiration and guidance from King Rama IV when depicting Western astronomical motifs. Meanwhile, to help visitors interpret the astronomical murals "A sign under the mural painting behind the principle Buddha statue contains words about the Sun. In this painting, the Sun is positioned exactly where Mount Meru (Khao Phra Sumen) and heaven would traditionally be painted." (Wat Borommaniwat, n.d.). As we have already mentioned, the temple web site also indicates that "The names of several other planets seen in the paintings here remain unknown. Some of these planets were painted with a good understanding of science for having bright and dark sides, thanks to the direction of sunlight." (ibid.). These would appear to relate to images of Mercury and Venus. Apparently, Khong died sometime during King Rama IV's reign. At a later date the temple was restored by King Rama V (Wat Borommaniwat, n.d.), who had inherited a passion for astronomy from his father.

Apart from being familiar with the telescopic appearance of the Sun and planets, Prince Mongkut developed the skill to calculate eclipses before he assumed the throne (in 1851). When Sir John Bowring visited Bangkok in 1855 he reported: "… I have an interesting document, 20 pages, published in Bangkok in 1850 A.D. and some "Royal Writings" of King Rama IV (when he was still Prince Mongkut) sent to "Bangkok Recorder Newspaper" written about "The Annual Calculations of Eclipses" and His Majesty declared that the publications were made to let his foreign alliances understood that His Majesty could make his own calculations of Solar and Lunar Eclipses." (Bowring, 2004: 308).

Fig. 6.20 A view of Chatchawan Wiang Chai Hall at Kao Wang showing the recently-restored lighthouse (https://www.thailandtourismdirectory.go.th/en/info/attraction/detail/itemid/4383).

6.5 King Rama IV's 'Astronomical Observatory'

On 10 May 1860 King Rama IV built a structure at Kao Wang (Wang Mountain Palace) at Petchaburi that was named Chatchawan Wiang Chai Hall (Fig. 6.20). Local people refer to this as 'Krajome Kaew' (the Glass Dome). Contrary to popular belief, this was not an astronomical observatory. Rather it was a light house that was used to guide fishermen to Taboon Bay at night.

6.6 Time Reckoning and Time-Keeping in Nineteenth Century Siam

King Rama IV realized that he and the visiting French astronomers would need to accurately record the times of the different phases of the 18 August 1868 total solar eclipse, so he had the foresight to establish 'Bangkok Standard Time' in Siam beforehand. Indeed, Siam was the first country in the world to introduce a national standardized time service, followed soon after, on 2 November 1868, by New Zealand (King, 1902). Siam and New Zealand were the pioneers, long before other countries around the world introduced national time services. The United Kingdom, for instance, only legally approved 'Greenwich Mean Time' in 1880, although a standardized 'Railway Time' had been adopted throughout the nation by 1841 (Bartky, 2007).

Having a national time service is one thing, but how to get time to the local population? In Bangkok, King Rama IV's solution was simple. In the Grand Palace he erected a conspicuous 5-storey clock tower with clock-faces visible from all four cardinal directions (see Fig. 6.21; Fig. 6.22 shows a close-up of the Royal Clock Tower). The clocks showed 'Bangkok Standard Time', using the Royal Observatory at Greenwich, England, as the 'Zero Meridian', with the longitude of the Grand Palace in Bangkok deemed to be 100° E of Greenwich. The Royal Clock Tower

Fig. 6.21 An 1872 photograph of the Grand Palace showing the Royal Clock Tower on the far right (1872-grand-palace-front-gate-from-sanam-luang-bkk-xbx).

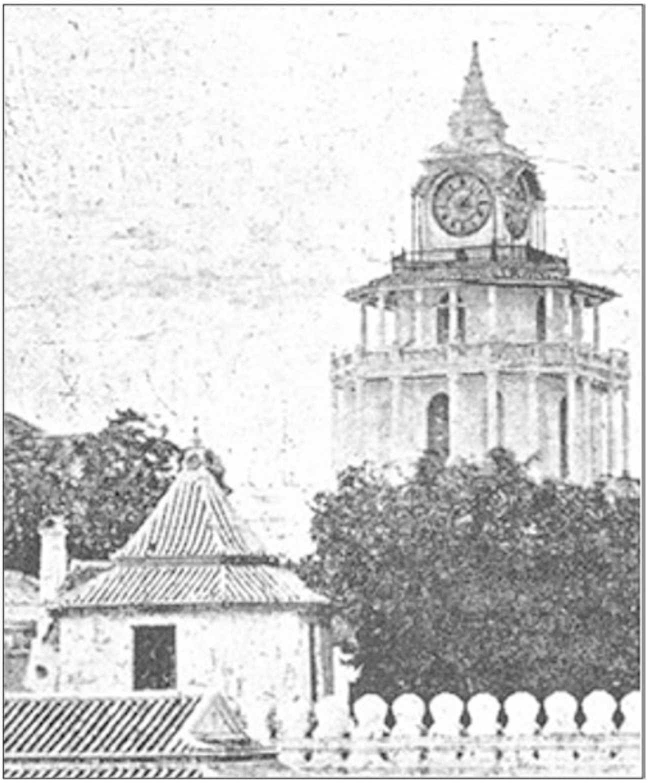


Fig. 6.22 A close-up of the Royal Clock Tower in Bangkok cropped from an 1879 photograph of the Grand Palace (1879-outside-grand-palace-sanam-lunah-grounds).

served as the prime meridian for Siam, and was 6.7 hours ahead of Greenwich. King Rama IV also appointed two Time-keeping Officers to observe sunrise and sunset daily, and he assigned an officer termed Pun Thiwathit to beat a gong at sunrise and another officer, Pun Pinith Chandra, to beat a drum at sunset. Siam only adopted Greenwich Mean Time in 1884, during the reign of King Rama V.

6.7 King Rama IV and Public Relations: Astronomy

King Rama IV made regular 'Royal Announcements' so that the Siamese people could understand how the country was governed and changes that would take place. These Royal Announcements also included mention of natural events and astronomical phenomena, in order to help eliminate belief in superstition and make people more scientifically aware so that they could prepare themselves for unexpected objects (like comets) or events (such as eclipses). Let us now examine two major naked eye comets that were visible from Siam, and King Rama IV response to each of them.

6.7.1 King Rama IV and Spectacular Naked Eye Comets

6.7.1.1 Introduction

In fact, the first major comet to appear during King Rama IV's lifetime was the Great Comet of 1811 (C/1811 F1 Flaugergues), which was visible to the naked eye for around 260 days. It had become a conspicuous object by September 1811, and on 6 October had a 25° tail (Fig. 6.23). It reached maximum brightness in October, at $m_v = 0$. We know that as a 6-7 year old, Prince Mongkut regularly observed this comet.

6.7.1.2 Donati's Comet (C/1858 L1)

The first major comet to impress King Rama IV after he became King was C/1858 L1 (Donati), which was considered to be one of the most spectacular comets to appear in the sky. It was discovered by the Italian astronomer Giovanni Battista Donati on 2 June 1858 (Donati, 1858) and turned out to be the most brilliant comet after the Great Comet of 1811 (see Fig. 6.24). It remained a naked eye object for nine months, and was widely observed by astronomers in Europe, North America and India (e.g., see Kapoor, 2021; Kronk, 2003; Pettersen, 2015; Vsekhsvyatskii, 1964). It was the first comet that astronomers attempted to photograph (see Pasachoff et al., 1996), and it left its mark on art and society (Gasperini et al., 2011; Olson and Pasachoff, 1998: 227–244). It was visible from Siam for two months, in September and October 1858.

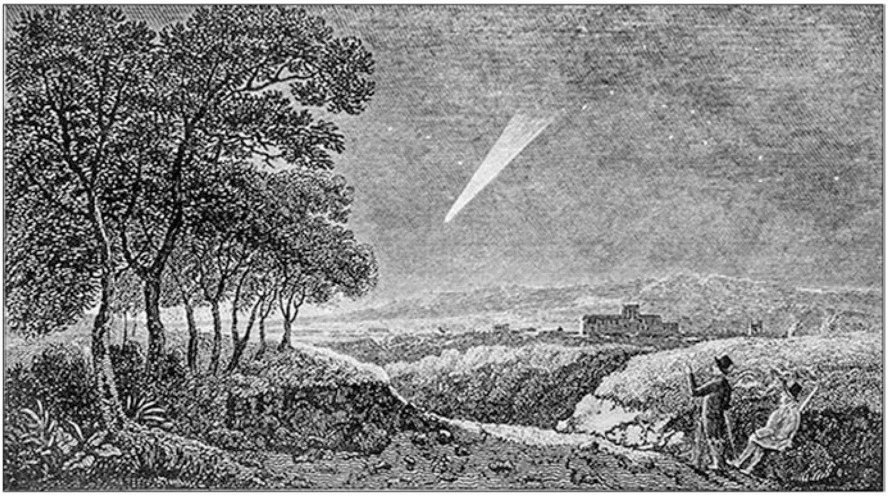


Fig. 6.23 A view of the Great Comet of 1811 from England (http://www.wordcraft.net/comets5.html).

Fig. 6.24 The appearance of Donati's Comet on 30 September 1858, when it was visible from Siam (http://www.wordcraft.net/comets5.html).

King Rama IV issued his first official Donati's Comet announcement for the public on Sunday in the 11th Month 12th Day of the Full Moon, Year of the Horse, Samritti Sok. It was titled "Dao-Hang Khun, Xya Witok (ดาวหางขึ้น อย่าวิตก)", which means "Do not panic with the appearance of the comet":

> On Saturday 10th Month 10th Day of the Waning Moon, the third king, H.M. Jhob Kochasilpa saw a comet and on Thursday 10th Month 15th Day of the Waning Moon, many masters and officers had also been watching this comet. King Rama IV mentioned that he also had observed this comet and remembered seeing a similar comet during the reign of King Rama II. So, the people of Siam should not panic.

Then on Sunday in the 10th Month, Year of the Horse, Samritti Sok on 2713 days in the present reign, he issued the following proclamation:

> The Europeans have observed this comet for several months and published drawings of it since the sixth month. The comet shows a long tail in the sky. Its appearance is different from planets seen in the sky. A comet is a celestial object that will move away from the Earth and return again in a number of years. So, the people of Siam should not panic and worry since the comet is visible not only in this and nearby cities, but is visible throughout many cities on the Earth.

Before leaving this comet let us see what Herschel (1859: 409) has to say about it:

> The third great comet of the present century (those of 1811 and 1843 being the other two) appeared from June 2, 1858, to January 1859. Its head was remarkably brilliant; and its tail, like a vast *aigrette* or gracefully-curved plume, extended, when longest, over a space of upwards of 30°. Its curvature was very marked, deflected towards the region quitted by the comet … The American observers speak of two long, narrow, perfectly straight rays of faint light, tangents to the limiting arcs of the aigrette at its quitting the head. The phenomena of the nucleus under high magnifying powers were very complex and remarkable.

King Rama IV would still have had a clear recollection of this remarkable comet when he first read Herschel's account of it. We have to wonder whether the above description resonated with him.

6.7.1.3 The Great Comet of 1861

The next major comet to be visible from Siam was Comet C/1861 J1 (Tebbutt) that was discovered by the Australian amateur astronomer John Tebbutt in May 1861 (Tebbutt, 1861). Tebbutt would go on to become Australia's foremost nineteenth century astronomer and an international figure (see Orchiston 2017a), while his comet would turn out to be a Great Comet, and one of the most spectacular comets of the century (Kronk, 2003; Main, 1861; Orchiston, 1998; 2017b: 139–171; Vsekhsvyatskii, 1964). At its best, it was brighter and had a longer tail than Donati's Comet. Fig. 6.25 shows the Great Comet on 30 June. Because the Earth was passing through the end of the tail at the time, for just two days it displayed this beautiful distorted appearance. The comet was visible from Siam during June and July 1861, and King Rama IV reported its appearance in advance and made a public announcement that people should not be scared and superstitious.

Fig. 6.25 Richard Proctor's drawing of the Great Comet of 1861 (after Weiss, 1888).

6.8 Eclipses

6.8.1 The 1856 Songkran Royal Proclamation about Eclipses

In 1856, during the Songkran Festival King Rama IV made a Royal announcement about two up-coming astronomical events: “In the middle of the 8th month of 1857, there will be a lunar eclipse observable from Siam and at the end of the 10th month, there also will be a solar eclipse visible from Siam.” (Phra Bat Somdet …, 2004: 120). This was the first Royal public announcement about the occurrence of eclipses.

6.8.2 King Rama IV and the Total Solar Eclipse of 18 August 1868

From 1866, King Rama IV carried out precise calculations of the orbital motions of the Sun and the Moon using local astronomical texts and modern Western books in order to predict the total solar eclipse of 1868. He announced that

> The total solar eclipse will be visible on Tuesday 18th August 1868 with the center line at Wha Kor district in Prachuap Kiri Khan province. The path of the total solar eclipse visible in Siam is 130 Lida × 140 Lida [1 Lida = 1 arcminute = about 111 km]. The total eclipse in Siam will be visible from Pranburi District, Prachuap Kirikhan province to Chumporn province [approximately 230 km. long].” (Division of Literature …, 1999: 283).

The modern map of Thailand and Myanmar in Fig. 6.26 shows the path of totality of this eclipse between the two blue lines, with the central path marked in red. The village of Wah-koa (as it was then known) is indicated by the red bull’s eye, and the area is now the ‘King Mongkut Science Park’, with a prominent monument to the King (Fig. 6.27), and an assortment of public museums and other scientific attractions (Figs. 6.28) fronting a long sandy beach (Fig. 6.29).

King Rama IV invited a team of French astronomers to Wah-koa, and arranged for a special eclipse camp and observing precinct to be prepared for them (see Orchiston and Orchiston, 2017). He also invited high-ranking Western and Siamese officials to join him at his specially-constructed Royal Eclipse Camp at Wah-koa village (99° 42 E′, 11° 39′ N), where he and his 14-year old son, H.R.H. Prince Chulalongkorn (1853–1910; Fig. 6.30) planned to observed the 18 August 1868 eclipse. Among these distinguished guests were Sir Harry Ord (1819–1885), the Singapore-based British Governor of the Straits Settlements, and his wife (see Orchiston and Orchiston, 2022), along with some diplomats from Bangkok (the French Consul and the Acting British Consul), and his old English teacher, the American medical missionary Dr Bradley (Division of Literature …, 1999: 290). The King and his distinguished guests are shown in Fig. 6.31 at the commodious eclipse camp at Wah-koa, which was sited about 1 mile north of the camp occupied by the French astronomers.

Fig. 6.26 A map of parts of Thailand, Myanmar and Cambodia showing the path of totality of the 18 August 1868 total solar eclipse, with the centre line in red. The red bulls-eye is at Wah-koa, where the observing camps of King Rama IV and the French expedition were located. For scale: the distance, as the crow flies, from central Bangkok to the red bull's eye is about 250 km. There is now a public 'science park' at Wah-koa (base map: Google Maps; map modifications: Wayne Orchiston).

Fig. 6.27 The prominent monument to King Rama IV at the King Mongkut Science Park, Wah-koa (photograph: Boonrucksar Soonthornthum).

Fig. 6.28 Different science attractions and sculptures at the King Mongkut Science Park at Wahkoa (photographs: Wayne Orchiston).

Fig. 6.29 The long sandy beach at Wah-koa (photograph: Wayne Orchiston).

Fig. 6.30 King Rama IV and Prince Chulalongkorn (courtesy: National Archives, Bangkok).

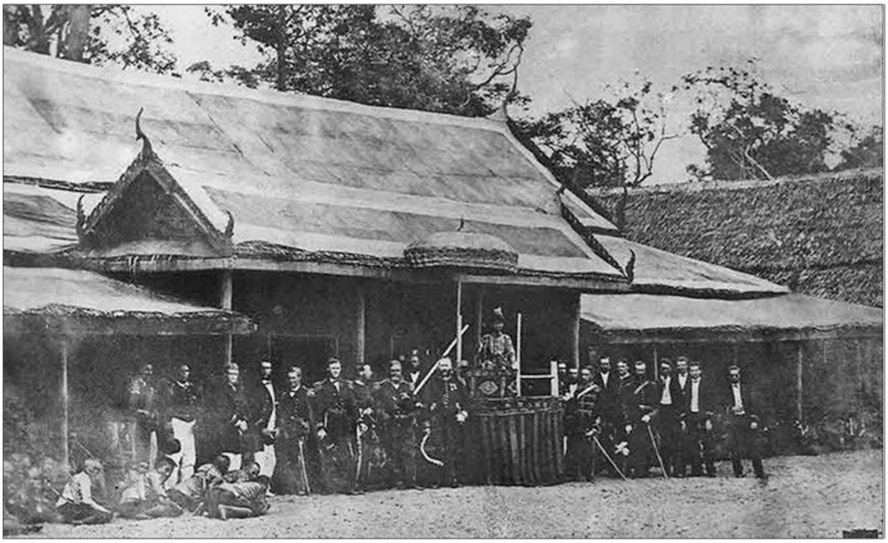


Fig. 6.31 King Rama IV and his distinguished Siamese and Western guests at the commodious eclipse camp erected at Wah-koa (courtesy: National Archives).

For King Rama IV this was special opportunity for him to pursue his passion for astronomy, so he arranged a 15-day excursion, from 7 to 21 August 1868, when he would be away from Bangkok. He went to Wah-koa on the Royal Yacht *Akaraj Woradech*, and was accompanied by Prince Chulalongkorn (Krom Khun Pinit Prachanath) and HRH Krom Khun Rajasihawikrom (Prince Pisdang Chumsai; 1851–1935).

By good fortune eclipse day, 18 August, was clear, and the King's official party were treated to the following rare astronomical spectacle which, subsequently, became known as 'The King of Siam's Eclipse' (e.g., see Lingberg, 1985):

> 10.06 am: This was first contact according to King Rama IV's calculation and prediction, but the sky was very cloudy and first contact could not be observed.
>
> 10.46 am: The clouds gradually dispersed. The Sun was visible, and a partial eclipse was seen. The King performed a Royal consecration rite.
>
> 11.25 am: The Sun's light became very 'soft', similar to the Full Moon at night.
>
> 11.30 am: The Moon blocked the Sun's light down to one-twelfth. Some stars were now visible in the sky. There was a big chatter from the crowd.
>
> 11.36 am: Totality was seen. A big prominence was visible on the east side of the eclipsed Sun.
>
> 11.43 am: A strip of a seesaw-like pattern was seen at the south-western edge of the Sun.

> 1.09 pm.: The fourth contact, the end of the total solar eclipse. Siam people called this moment 'Mokkhbrisuththi' (A Holy Time).(Division of Literature …, 1999: 309–315).

Details of the Royal expedition to Wah-koa and of the observations made there by King Rama IV and his guests are presented (in Thai) in a book written by Bhumadhon (2012).

A special feature of the Royal observing program was the successful photograph of totality shown in Fig. 6.32, where the inner corona is clearly visible. The photographer was Luang Akani Naruemitr (1830–1891; Fig. 6.33) who adopted the name Francis Chit when he converted to Christianity. Chit learnt photography from a French missionary and a British professional photographer who visited Siam, and he opened his own studio in Bangkok. Soon after the eclipse, King Rama V appointed him the official court photographer (Luang Akani Naruemitr, 2011).

Another to impress and be impressed was Sir Harry Ord. He was so taken with the eclipse and with the hospitality offered by his Siamese hosts that he later wrote a short book about his visit (for details, see Orchiston and Orchiston, 2022). Meanwhile, the French astronomers also carried out successful observations of the eclipse, as documented by Orchiston and Orchiston (2017) but, as this research paper indicates, the significance of their scientific findings was completed eclipsed by those of the French and British astronomers located in India. This eclipse would prove to be a watershed event in the development of solar physics, as discussed in the forthcoming book, *The Total Solar Eclipse of 18 August 1868 …* (Orchiston, 2022).

6.9 Concluding Remarks

King Rama IV was a progressive ruler who wanted to develop and modernize Siamese society. He used regular Royal announcements to educate the court and his own people about how the country was being governed and changes that would take place. He also had a personal passion for astronomy, and used astronomical events

Fig. 6.32 A photograph of the 18 August 1868 solar eclipse at totality taken by Francis Chit, with the inner corona clearly visible (courtesy: National Archives, Bangkok).

Fig. 6.33 A self-portrait of Francis Chit at about the time of the 1868 solar eclipse (after Luang Akani Naruemitr (Francis Chit), 2011).

(such as eclipses) and visitors (such as bright comets) to distinguish 'science fact' from 'science fiction' and try to stem the spread of mysticism and superstition.

In 1868 King Rama IV used modern science and technology to introduce a national time service based on the Greenwich meridian and Bangkok Standard Time. Siam was an international trend-setter in this regard, as the first country in the world to establish a national time service. King Rama IV then used this time service in August 1868 when he hosted a contingent of French professional astronomers who came to southern Siam to observe a total solar eclipse. He displayed his own mathematical skills by calculating the path of totality quite independently of the French, and he astutely used the eclipse as a political weapon to help defuse the colonial ambitions of Britain and France, which at the time threatened Siamese independence. The message was clear: Siam was an advanced Asian country and its nationals were capable of pursuing contemporary science and technology without overseas assistance (or domination). Meanwhile, the King's own astronomical knowledge and scientific diplomacy brought Siam local and international respect and recognition. The reign of King Rama IV could be considered the dawn of the scientific era in Siam.

Sadly, King Rama IVs passion for astronomy proved to be a 'two-edged sword'. During the 1868 eclipse expedition he and his son, Prince Chulalongkorn, both contracted malaria. While his son survived, sadly King Rama IV did not, and he died on 1 October 1868, just two and a half weeks shy of his 64th birthday. He had paid the ultimate price for his devotion to astronomy.

With this chapter we pay our respects and show our highest esteem to King Rama IV, Astronomer and 'The Father of Thai Science'.

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Chapter 7
J.A.C. Oudemans and Nineteenth Century Astronomy in the Dutch East Indies

Wayne Orchiston, Emanuel Sungging Mumpuni, and Wolfgang Steinicke

7.1 Introduction

Pyenson (1993) suggests that during the nineteenth and twentieth centuries, the physical sciences (e.g. astronomy, geophysics and physics) served the geopolitical interests of European colonial powers. In this way, practical imperatives often dominated a scientist's lifestyle and institution, just as imperialist policies or foreign customs did. However, a discussion of the socio-politic aspects of this era is beyond the scope of this review, and can be found elsewhere (e.g. see Pyenson, 1989; 1993).

Pyenson (1993) also argues that imperialist patterns of scientific activity during the nineteenth century followed three orthogonal axes: research, functionary and mercantile. What was important, however, was the extent to which the scientific contribution from the colony illustrated independence rather than being a mere reflection of its European counterpart. The independence of colonial scientific activities has been modeled by Basalla (1967), and one scientist who benefitted from the situation was Jean Abraham Chrétien Oudemans, a prominent astronomer from the Netherlands who served a term in the Dutch East Indies (present-day Indonesia)

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co-ordinating the trigonometrical survey of the colony, and in the process also was able to pursue his interest in research astronomy.

In this chapter, which draws in part on Mumpuni et al. (2017), we will provide a biographical sketch of Oudemans, and then review the range and importance of his astronomical activities during the 18 years he was based in the Dutch East Indies, including his observations of the total solar eclipses of 1868 and 1871.

7.2 J.A.C. Oudemans: Biographical Sketch

Jean Abraham Chrétien Oudemans (1827–1906; Fig. 7.1) was born in Amsterdam, where his father, Anthonie Cornelis Oudemans (1798–1874; Verwijs, 1875), was a poet, teacher and philologist and helped J.A.C. Oudemans and his two brothers find careers in science (Pyenson, 1989).

Young J.A.C. Oudemans and his brothers began school "… in Weltevreden, the suburb of Batavia, where between 1834 and 1840 their father was principal of an elementary school …" (Pyenson, 1989: 20). The family then returned to the Netherlands, where all three brothers completed their secondary schooling. It was probably at this time that Oudemans first inherited an interest in astronomy from his father, who just happened to be a personal friend of the British Astronomer Royal, George Biddell Airy (1801–1892).

When he was sixteen years of age Oudemans began as a student at the University of Leiden, where he studied under the noted astronomer Professor Frederik Kaiser (1808–1872; Fig. 7.2; Heijden, 2014). After graduating in 1846 he taught mathematics at a secondary school in Leiden, and for the next six years he also worked part-time on his doctoral dissertation, which was about the latitude of Leiden. He completed his doctorate in 1852 and the following year was appointed an Astronomer at the University Observatory,

Fig. 7.1 A painting of J.A.C. Oudemans in 1898 (Wikimedia commons).

Fig. 7.2 A painting of Frederik Kaiser in 1872, the year of his death (https://upload.wikimedia.org/wikipedia/commons/thumb/e/e2/Frederik-Kaiser-4.jpg/810px-Frederik-Kaiser-4.jpg).

> … and occupied himself mostly with observations and computations of planets, comets and variable stars, which are published chiefly in the *Astronomische Nachrichten*. His first astronomical publication, however, dates from 1846. (van de Sande Bakhuyzen 1907: 241).

In 1856 Oudemans was appointed a Professor of Astronomy at the University of Utrecht and Director of the University Observatory (van de Sande Bakhuyzen 1907). He was "… eager to make his mark as a research astronomer … [and] projected himself as a young man in a hurry." (Pyenson, 1989: 22). But in a letter to Airy, he commented on the limited instrumentation at the Observatory—which could only boast a 4-in Fraunhofer refractor—and the lack of even the basic astronomical journals in the University Library (Oudemans, 1865). He also criticized his predecessors. Pyenson (1989: 22) believes that Oudemans' letter "… conveyed impatience and irreverence at old-fashioned scientific norms. He belonged to the new generation of university researchers."

When Oudemans went and married Paulina Verdam, the daughter of a Professor of Mathematics at the University, his salary was not enough to keep the two of them in the manner he would have liked. So "… the young astronomer had prepared himself to bail out at the first opportunity." (Pyenson, 1989: 24), and

> … after just one year he resigned in order to accept the post of Head Engineer of the Geographical Service in the Dutch East Indies, with the primary task of conducting a geodetic survey of the colony. His old mentor, Kaiser, was the Holland-based supervisor of the Survey at that time (Heijden 2014) and he would have played a key role in arranging Oudemans' appointment. (Mumpuni et al., 2017: 358).

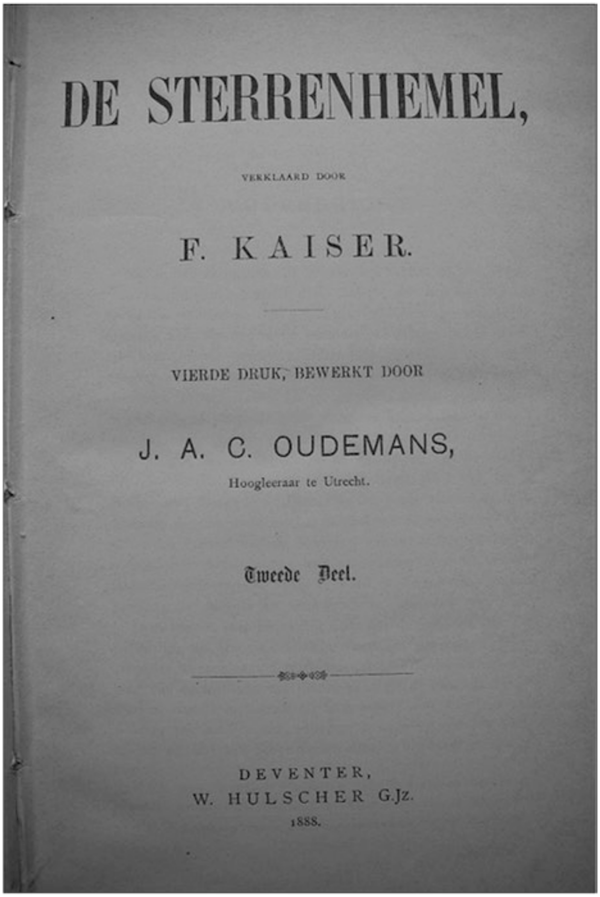
Pyenson (1989: 39) suggests that Oudemans' principal motive for deciding to accept the East Indies post was "… the high salary and the prospect of an annuity after twenty or so years." In fact, this tallies with his decision to return to the Netherlands in 1875, but instead of retiring and enjoying his pension he once again became Professor of Astronomy and Director of the Observatory at Utrecht University. A recent photograph of the Observatory—now a museum of astronomy and known as Sonnenborgh Observatory—is reproduced in Fig. 7.3.

Fig. 7.3 The University of Utrecht's original Sonnenborgh Observatory is now a popular astronomy museum (https://www.sonnenborgh.nl/bezoekersinformatie).

When he returned to Utrecht and the University Observatory, Oudemans was middle-aged, and must have anticipated that he would enjoy several decades of observational astronomy. But circumstances and the facilities at the aging Observatory would not allow this, and as Pyenson (1989: 39) poignantly points out, "The pensioned Indian [East Indies] civil servant could not anticipate that he would never again undertake any scientific work more significant than that relating to the topography of the Indies." Nonetheless, over the years he did manage some small-scale observing projects, and he published a number of (mainly) short papers in *Astronomische Nachrichten* and *Monthly Notices of the Royal Astronomical Society* on Saturn's rings (e.g. Oudemans, 1888; 1892) and the Great Red Spot on Jupiter (Oudemans, 1883a), amongst other topics.

Apart from these brief observational escapades, Oudemans was committed to populating astronomy in the same mould as his mentor Frederik Kaiser, whose "… popular *Starry Sky* (1844) proved immensely successful with the general public." (van Lunteren, 2011: 48) even though it lacked illustrations. So in 1884, more than a decade after Kaiser's death, Oudemans brought out a new edition of Kaiser's popular work, titled *De Sterrenhemel, verklaard door F. Kaiser* (Oudemans, 1884). A slightly later version is shown in Fig. 7.4.

Oudemans also followed up on his colonial astronomical interests, writing a short paper about the Javanese calendar (Oudemans, 1882). This was his sole excursion into Indonesian ethnoastronomy, a field that is now immensely popular with Indonesian and Malaysian scholars (e.g., see the chapters by Emas et al., 2021; Fatima et al., 2021; Jaafar and Khairuddin, 2021a, 2021b; Khairuddin and Jaafar, 2021; and Rasyid et al., 2021, that appear later in this book).



DE STERRENHEMEL,

VERKLAARD DOOR

F. KAISER.

VIERDE DRUK, BEWERKT DOOR

J. A. C. OUDEMANS,
Hoogleeraar te Utrecht.

Tweede Deel.

DEVENTER,
W. HULSCHER G.Jz.
1888.

Fig. 7.4 Oudemans' 1888 re-publication of Kaiser's popular *Starry Sky* book (https://www.catawiki.nl/l/478511-astronomie-f-kaiser-j-a-c-oudemans-de-sterrenhemel-2-delen-1888).

We can ascertain Oudemans' appearance at about this time thanks to the postcard that is reproduced here as Fig 7.5. An inscription on the reverse of the postcard is dated 31 December 1884.

Oudemans hoped to dedicate his retirement years to astronomy, but this was not to be. To paraphrase an old SE Asian saying: "You can take the man out of the East Indies, but you can't take the East Indies out of the man", so it was perhaps no surprise that in 1881 the Colonial Minister, Willem Baron van Goltstein, instructed Oudemans to synthesize and write up the geodetic survey data from Java and train up two naval officers who would then carry out a comparable survey of Sumatra. Despite his on-going Utrecht University commitments Oudemans tried unsuccessfully to take advantage of the Minister's directive and "… set himself up at the head of a veritable empire." (Pyenson, 1989: 42), but instead, "Calculating the triangulation of Java became a vortex that sucked at Oudemans's energies. He managed a

Fig. 7.5 J.A.C. Oudemans in about 1884, nearly ten years after he returned to the Netherlands (https://gallica.bnf.fr/ark:/12148/btv1b84529376/f1.item).

Fig. 7.6 Hendricus Gerardus van de Sande Bakhuyzen (https://en.wikipedia.org/wiki/H._G._van_de_Sande_Bakhuyzen#/media/File:H_G_v_d_Sande-Bakhuyzen.jpg).

team of permanent and casual calculators, and he supervised printing of the topographical maps once the data had been reduced." (Pyenson, 1989: 43).

Even after he retired from his University posts in 1898 'The Survey' continued to draw on his time and his energies. Following an initial volume that was published in the East Indes in 1875, Oudemans published the first of four large new volumes on the results of his triangulation of Java in 1891, but it was 1900 before the final volume came off the press (Oudemans et al., 1875–1900). Then in 1905 he published a further volume containing the results of the observations of latitude and azimuth made at thirteen stations, together with a study of the instruments employed and of their different errors. Just one year later he was dead.

From the obituary published in 1907 by his long-time friend and colleague, Hendricus Gerardus van de Sande Bakhuyzen (1838–1923; Fig. 7.6), we learn that Oudemans was elected an Associate of the Royal Astronomical Society in 1883 and a Correspondent of the French Academy in 1901, and that he was

> … indefatigably busy with astronomical work to the end of his life … He was a painstaking astronomer, with a vast knowledge, who in all his work strove his utmost to attain the highest accuracy and completeness. He had a noble and open character, and was much esteemed and beloved by all who knew him. (van de Sande Bakhuyzen, 1907: 242).

7.3 Oudemans' Triangulation of the Dutch East Indies

Through his childhood in Batavia, Oudemans knew what to expect when he and Paulina arrived in the Dutch East Indies. Pyenson notes (1989: 25) that through his contact with the Colonial Ministry, Oudemans

> … started at *ƒ*7200 per year. The salary would increase by *ƒ*600 annually until he attained the astonishing income of *ƒ*14,400. The salary, enormous by Dutch standards, would erode quickly in the tropics. As Oudemans explained in a letter to Kaiser, "one needs at least 500 guilders per month here to live decently when married and without children," and this sum did not take account of capital expenses necessary for setting up a household. Furthermore, Oudemans had to spend some *ƒ*1000 for his transport to Batavia.

Nonetheless, his starting salary of *ƒ*7200 was surely a princely sum after his modest salary of *ƒ*1600 at the University of Utrecht.

As indicated in Section 7.2., above, Oudemans' primary role in the Dutch East Indies was to co-ordinate a geodetic survey of the colony, assisted by staff some of whom had university training. In fact there were two components to this:

(1) To produce maps by topographical triangulation, with towns at the apexes of triangles, and

(2) To verify the positions of the apexes with astronomical observations.

Initially the focus would be Java (van de Sande Bakhuyzen 1907: 241), and later on other islands in the archipelago (referred to as the 'Outer Possessions'). However, from the start Oudemans encountered problems: "The military and agricultural authorities wanted good maps of the Indies … [but] The navy, however, remained cool towards the need for detailed longitude and latitude measurements …" (Pyenson, 1989: 25). Part of this problem, Oudemans (1858a) explained to Kaiser, lay with the cumbersome bureaucracy in the 'Indies', with tier-upon-tier of administrators, and the inevitable delay in getting any request approved. Oudemans also stressed the problems in logistics involved in trying to conduct survey work: "Except for Java, no big roads or horses are to be found, the coasts in various places are unapproachable and the inlands do not offer anything but marshes …" (Oudemans (1858b), and not to mention the problem of the monsoons. Consequently, to access survey locations Oudemans tended to use naval gunboats when they were not involved in policing activities (Pyenson, 1989). Money also was a problem, and to obtain any supplementary funding for the survey work Oudemans "… had to resort to intense politicking to negotiate between the governor general's' office, which would authorize supplementary funds, and the colonial ministry …" (Pyenson, 1989: 28).

Despite these initial setbacks, Oudemans did successfully carry out the trigonometrical survey of the 'East Indies', and by April 1868 could boast that "I shall have a new war steamer at my disposal. Except for the islands east of Java, I have been almost everywhere in our archipelago." (Oudemans, 1869b). Given the all too numerous islands in the East Indies that lay east of Java—see Fig. 7.7—his statement shows a degree of complacency.

By the end of the 1860s "… with the end of the triangulation of Java in sight …" (Pyenson, 1989: 32), the laying of submarine cables in the Asian region made Oudemans' task in determining longitudes so much easier—or so he anticipated. In order to link his survey of Java to the international network in 1871 Oudemans came to an arrangement with Norman Pogson (1829–1981), Director of the Madras Observatory in India, for them to exchange time signals between Madras and Singapore. Although Oudemans published the longitude difference between Batavia and Singapore in 1874 (i.e. Oudemans, 1874a), Pogson simply sat on his data and refused to co-operate until 1875 when he was forced to do so following a formal diplomatic complaint between the 'East Indies' and India. However, even then, publication of the final results would take many years (see Oudemans, 1883b).

7.4 Oudemans' Non-Meridian Astronomical Work While in the Dutch East Indies

Despite the demands that the trigonometrical survey placed on him, "… Oudemans's commitment to [non-meridian] astronomy remained strong … [and he] never lost an occasion to publish a scientific result in Europe." (Pyenson, 1989: 31). In this context, "Oudemans never ceased to see himself as a professional astronomer, who, for a time, had come to be employed as a topographical engineer." (Pyenson, 1989: 29). He merely saw the Dutch East Indies trigonometrical survey as a diversion, a distraction that dragged him away from his true calling, astronomy. It is ironic,

Fig. 7.7 The Dutch East Indies in red, showing the multitude of islands in the Lesser Sunda group to the east of Java. West Papua (now Irian Jaya), shown in orange, only later became Indonesian territory (theindoproject.org).

therefore, that he should now best be remembered for this survey, which was a colossal achievement, especially in light of the bureaucratic, climatic and environmental challenges that Oudemans and his survey teams encountered. But we digress …

7.4.1 A Comet, a Variable Star, Lunar Occultations, a Transit of Mercury and a Lunar Eclipse

Soon after settling in Batavia Oudemans began making non-meridian astronomical observations when the opportunity occurred. For example, between 9 and 19 October 1858 he observed Donati's Comet (C/1858 L1 Donati), recording its right ascension and declination, and he published a short report in *Astronomische Nachrichten* (Oudemans, 1859). This was the most magnificent comet to grace East Indies skies since the Great Comet of 1843 (C/1843 D1).

The 12 November 1861 transit of Mercury also attracted Oudemans' attention, and subsequently he published a short paper about it in *Astronomische Nachrichren* (Oudemans, 1862).

Then in April 1867 he observed the variable star δ Librae, and found that his magnitude estimates, especially of the minima, did not tally with those listed by the German astronomer, Eduard Schönfeld (1828–1891), the Director of the Mannheim Observatory (Oudemans, 1867). Oudemans made further observations on 9 May 1867, and these supported his earlier findings. He reported his new observations in a second paper (Oudemans, 1868), which was also published in *Astronomische Nachrichten*. Delta Librae is now known to be an Algol-type eclipsing binary that varies between apparent magnitude 4.91^{m} and 5.9^{m} (Samus et al., 2017), and with a period of 2.3274 days (Tomkin, 1978).

Not wishing to be restricted solely to solar eclipses (see Sub-section 7.3.2 below), in 1873 Oudemans observed the lunar eclipse of 4 November when three ninth magnitude stars were occulted during totality, and he published a short report in *Astronomische Nachrichten* (Oudemans, 1874b).

These observations, and others (see Sub-sections 7.4.2 and 7.4.3 below), plus his correspondence with European professional astronomers, show that Oudemans still wished to be thought of as an active observational astronomer, not just a geodesist, and that he was up-to-date with international trends and developments in astronomy (but not in the emerging field of astrophysics). Oudemans' self-promotional strategy would bear fruit when the time came for him to quit the East Indies and return to the Netherlands.

7.4.2 *Solar Eclipses*

This Subsection draws heavily on Mumpuni et al. (2017). Based on his experience in geodetic work and his knowledge of the archipelago, Oudemans contributed detailed calculations for the sites where the total solar eclipses of 1868 and 1871 could be observed, not only by his own expeditions, but also by other teams that planned to come to the Dutch East Indies to observe these phenomena.

7.4.2.1 The 18 August 1868 Total Solar Eclipse

The 18 August 1868 eclipse turned out to be a major event in the history of solar physics (Cottam and Orchiston, 2015; Orchiston, 2022). This was the first eclipse when prominences, the chromosphere and the corona were subjected to spectroscopic and polariscopic scrutiny, which revealed all were primarily composed of hydrogen. Astronomers also noted an anomalous spectral emission line which they associated with a new element that was named helium but was only discovered in the laboratory more than two decades later, in 1894 (Nath, 2013).

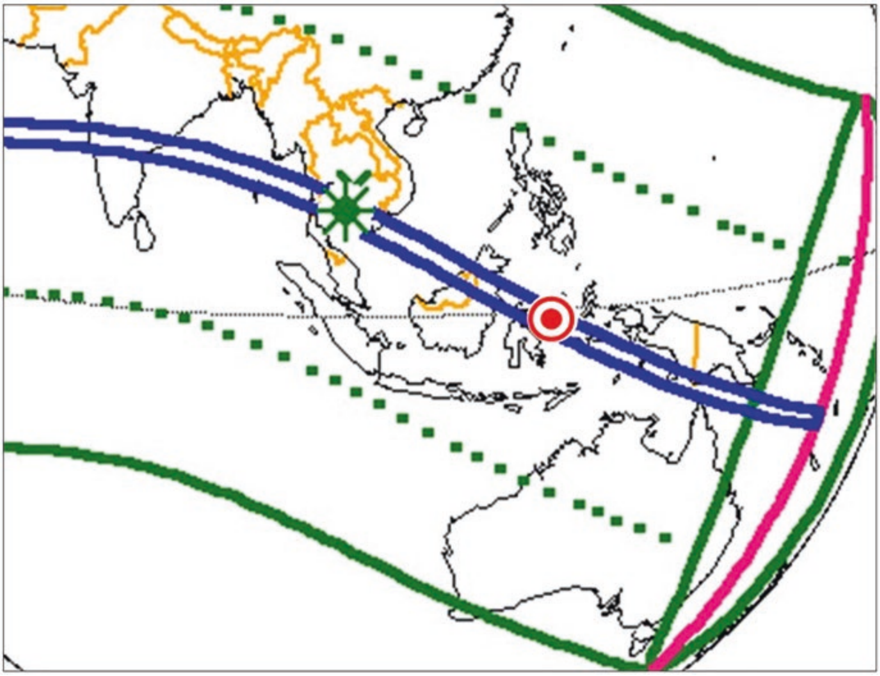


Fig. 7.8 A map showing part of the path of totality of the total solar eclipse of 18 August 1868 across islands in the Indonesian archipelago. Oudemans' eclipse station is marked by the red bullseye (base map adapted from Espenak and Meeus, 2006; map modifications: Wayne Orchiston).

The path of totality crossed India, Siam, Borneo and the Dutch East Indies (Fig. 7.8), and scientific observations were carried out in all of these places (see Launay, 2012; Mumpuni et al., 2017; Nath, 2013; Orchiston and Orchiston, 2017; 2022; Orchiston et al., 2017).

In the Dutch East Indies the path of totality (from east to west) crossed a number of small islands in the Spice Islands region, the Celebes (which is now Sulawesi) and the island of Borneo (present-day Kalimantan). Oudemans (1869a) calculated the start and end of totality at four sites, and his own expedition made their observations from Little-Mantawalu (now known as Mantalu Isle), a small coral island in the Tomini Bay of Sulawesi – indicated by the red bulls-eye in Fig. 7.8. Totality would last about 5^{m} 30^{s}, rather than the 6^{m} 57^{s} enjoyed by the French who observed from Siam, near the green asterisk (Orchiston and Orchiston, 2017).

Observations also were made from two Dutch warships archored at Ambon and Gorontalo, and from an English warship at a location where the path of totality enters the island of Borneo (now Kalimantan).

Oudemans (1869a) reports that he arrived in the Celebes port of Gorontalo on the Dutch warship *S.S. Sumatra* a few days before the 18 August eclipse. Gorontalo "… lay inside the path of totality, but near its [northern] edge, so that the duration of the eclipse there would be at most 2.5 minutes …" (Oudemans, 1869a: 1; our English translation). This differed markedly from Little-Mantawalu which was on the midline of the shadow path, and this small islet had another distinct advantage: "Because this was a deserted island, we were certain that we would not be distracted by the curiosity or noise of the natives." (ibid.).

Accordingly, on 16 August "… we left Gorontalo in the evening … and dropped anchor near our island the following morning. I determined the longitude of the observing site to be 123° 4′ 46″ east of Greenwich and the latitude 0° 32″ 36″ south." (ibid.). The short arrival-time before the eclipse was acceptable since Oudemans had few preparations to make. All of his observations would be made with a Repsold Universal Instrument (Fig. 7.9), one that he presumably had used during the triangulation of Java. Unlike the telescopes used by the British and French solar eclipse astronomers in India and Siam this portable instrument, which magnified only 32×, did not require a prefabricated observatory or substantial brick or concrete foundations. All of the eclipse observations that Oudemans would make would be carried out with the naked eye or with this simple instrument, for he lacked a spectroscope and photographic apparatus.

During the eclipse Oudemans was joined by the Captain of the *S.S. Sumatra*, who used a small marine telescope on a makeshift mounting, while three naval officers, Ehule, Commys and Rovers, used similar marine telescopes, but because they lacked solar filters were forced to project the solar image onto sheets of white paper. Oudemans arranged with the three officers that during the eclipse the four of them would observe the corona and note the presence of rays, and he also would concentrate on the prominences.

Clear skies over the atoll greeted the eclipse party on 18 August, and Oudemans' observing strategy worked perfectly. As totality approached Oudemans did not witness Baily's Beads, but

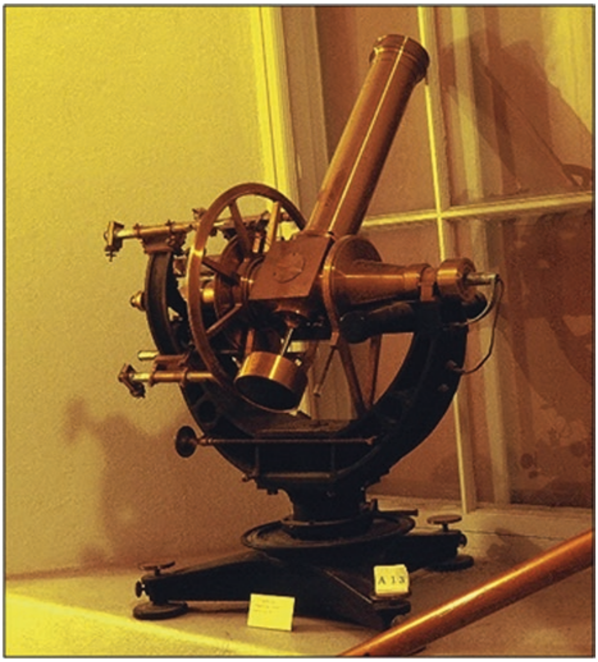


Fig. 7.9 A Repsold Universal Instrument similar to the one used by Oudemans to observe the 1868 solar eclipse (https://www.astro.uu.se/librarynew/instruments/images/repsold_vcirkel.jpg).

> Upon removing the solar filter, the great spectacle of the corona appeared. Immediately the two prominences a and b became visible, later c and d … [see Fig. 7.10]. Using the horizontal threads in the telescope, I measured the vertical height of prominence a three times [and] … derived from my measurements that prominence a must have extended 176″ above the solar edge, which corresponds to 10 Earth diameters. (Oudemans, 1869a: 3–4; our English translation).

The prominences were rose-coloured, and looked like clouds lit by the setting Sun.

It is hard to reconcile the various prominence drawings shown in Fig. 7.10, as included are two drawings made from Gorontalo (bottom centre and right). But even discrepancies visible in the four drawings made from Little-Mantawalu prompted Oudemans (1869a: 4; our English translation) to observe: “I believe that the existing differences in these drawings justify my request to the afore-mentioned gentlemen that they study the corona and its rays.” Having said that, prominence ‘a’ stands out in all the Little-Mantawalu drawings, and this feature is reminiscent of the ‘Great Horn’ that was widely reported by Indian and Siamese observers of this eclipse (e.g. see Orchiston et al., 2017: Fig. 25.8). Furthermore, Oudemans’ estimate of 10 Earth diameters (i.e. 79,260 miles) for its height is not dissimilar to Tennant’s (1869: 33) Indian-based measurement of 88,900 miles (i.e. more than eleven times the diameter of the Earth).

Although he focused on the prominences—as intended—Oudemans also found time to sketch the form of the corona, though his (1869a) report in *Astronomische*

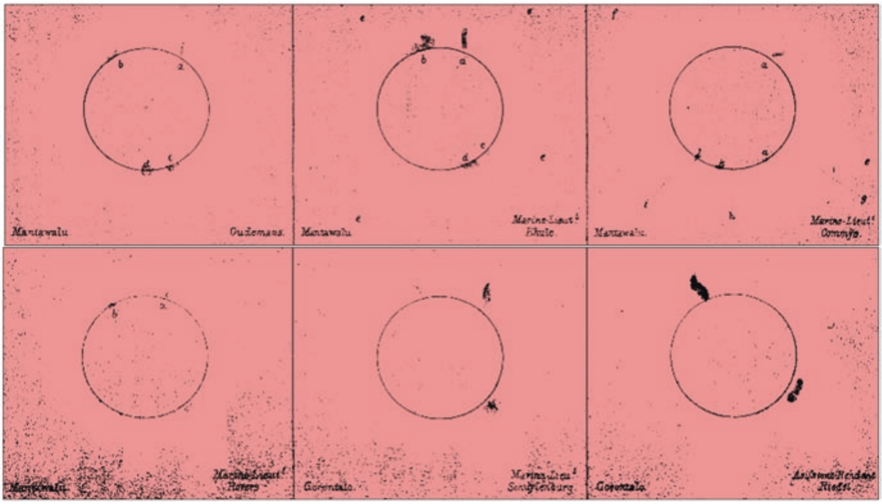


Fig. 7.10 Colour-enhanced drawings of the prominences that Oudemans and the three naval officers recorded during the 1868 solar eclipse (after Oudemans, 1869c).

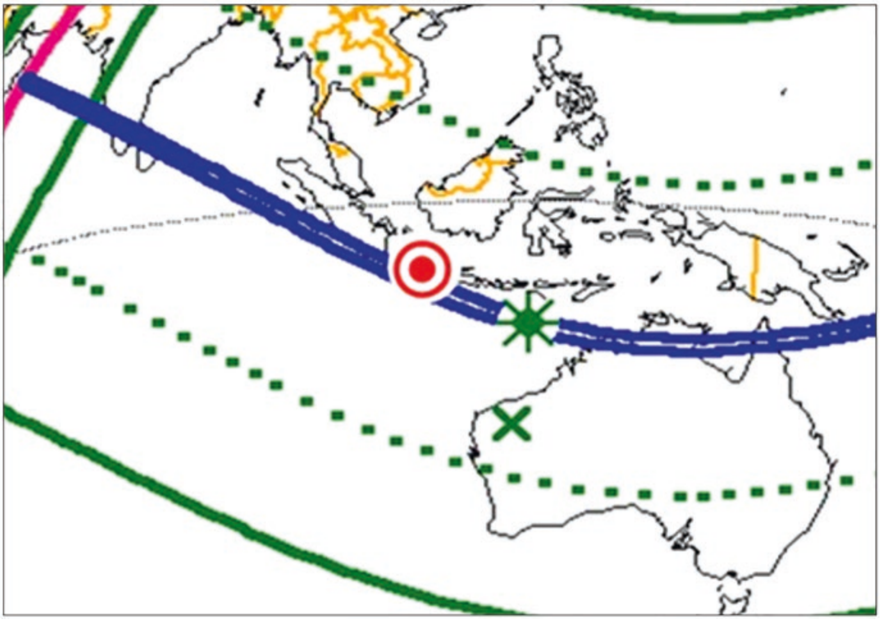


Fig. 7.11 A map showing part of the path of totality of the 12 December 1871 total solar eclipse across India, Ceylon, eastern Sumatra, western Java and northern Australia. Oudemans' observing site on Lawungan Island is marked by the red bulls-eye (base map adapted from Espenak and Meeus, 2006; map modifications: Wayne Orchiston).

Nachrichten does not include a description or a copy of the sketch. All that he does say is that the corona was "… pale peach-blossom …" in colour (Oudemans, 1869a: 5; our English translation).

In a later supplementary report on the 1868 eclipse observations, Oudemans (1869c) details the calculations that he made in order to determine the longitudes of the various Dutch East Indies observing sites.

This ends our account of Oudemans' observations of the 1868 solar eclipse. While he made some general comments about prominences, unlike his European colleagues in India and Siam he contributed little of scientific value. Would he fare any better during the 1871 eclipse?

7.4.2.2 The 12 December 1871 Total Solar Eclipse

This sub-subsection also draws heavily on Mumpuni et al., 2017. As Fig. 7.11 illustrates, the path of totality of the 12 December 1871 total solar eclipse passed through India, Ceylon (now Sri Lanka), the Dutch East Indies and northern Australia, and observations were made—or attempted, but prevented by the weather—in all four regions (Janssen, 1873; Launay, 1997; Lockyer, 1874; Lomb, 2016; Mahias, 2010; Tennant, 1875). In this sub-subsection we examine the observations made by Oudemans and others based in the Dutch East Indies.

As we have seen, the 1868 solar eclipse was a seminal event in the history of solar physics, particularly because of the spectroscopic observations that were carried out. Thus, as well as offering the potential to build on the results obtained in 1868, the 1871 eclipse invited further investigation of the green coronal line, K 1471, which the US astronomers Charles Augustus Young (1834–1908; Habashi, 2014) and William Harkness (1837–1903; Hirshfeld, 2014) had discovered during the 7 August 1869 eclipse and assigned to 'coronium' (see Maunder, 1899). There also was more to learn about the form and composition of the corona, so the 1871 eclipse offered various research options for Oudemans and others who planned to observe it from the Dutch East Indies.

But we have to query whether Oudemans really was up with the 'state-of-play' in international solar physics at this time, or whether the fact that he was not a solar specialist, and his relative isolation in the colonies, militated against this. Undoubtedly, he had not heard about the 'coronium line', but had he been able to read the five recently published papers by Janssen (1868; 1869a; 1869b; 1869c; 1869d) reporting the discoveries that he made in India during the 1868 eclipse? We have to doubt this, given the following 'research directive' that Oudemans prepared for colleagues in the Dutch East Indies intent on observing the December 1871 eclipse:

For those observing with the naked eye or an opera glass, the most important topics which can be noticed during totality mainly concern the corona, and include the following:

1. Out to what distance from the limb of the Sun does an obvious atmosphere appear to extend?

2. What are the lengths, directions and colours of the coronal rays, before, during and after totality?
3. What colour are the different layers of the chromosphere (the innermost part of the corona) and the terrestrial clouds and landscape? If the colours change, what is the colour sequence?
4. Are there dark spaces between the coronal rays, and if they change with time do they reach the Moon or end above the lower layers of the solar atmosphere?
5. What colour is the corona between the bright and dark rays?
6. What changes are apparent in the corona? Is there evidence of rotation or changes to the coronal rays as sometimes reported (some observers have spoken of rotation, as in fireworks)?
7. What colours are visible in the corona, and is there a correlation between prominences and coronal rays, or do rays generally appear opposite prominences?
8. Provide a drawing of the prominences visible at the start and end of the eclipse (and note the highest point reached by each prominence).
9. Is there any sign of light and dark shadow bands that pass over white paper laid on the ground (as claimed by some observers)?
10. Is there any sign that the Moon is darker than the sky, at some distance from the Sun?
11. What is the mean time of the start and end of the eclipse and the partial phase, and what is the latitude and longitude of your observing site? (Oudemans, 1873a: 2–3; our paraphrasing).

This list, inspired in part by input from the renowned British solar astronomer Joseph Norman Lockyer (1836–1920; Frost, 2014), is all well and good for naked eye and binocular observations, but Oudemans and his Dutch East Indies colleagues really needed to make photographic, polariscopic and spectroscopic, observations if they wished to contribute in a meaningful way to international solar physics.

Be that as it may, the position of the path of totality on this occasion was especially kind to them, offering an endless number of easily accessible observing sites on the southern tip of Sumatra and in the western part of Java.

Moreover Oedermans was in a much more powerful position to mount a successful solar eclipse expedition than in 1868 as the Colonial Government had instructed him to observe this internationally important event, and obviously agreed to supply the necessary funding. After researching the path of totality, Oudemans (1873a) chose as his camp site Lawungan Island (now Pulau Liwungan) in Lada Bay, just off the western coast of Java. This location and other sites from which eclipse observations were reported are shown in Fig. 7.12.

Oudemans' eclipse party totalled nine, a 'motley crew' that included four naval officers, two military surgeons, one of his own staff in the Trigonometrical Survey of Java, and a secondary school teacher with a passion for astronomy (see Table 7.1). Given their various backgrounds, it is a safe assumption that most—if not all—were familiar with observational astronomy. What is not clear, however, is the full suite of scientific instruments that went to Lawungan Island. We have included in Table 7.1 those that are specifically mentioned in Oudemans' (1873a) very long

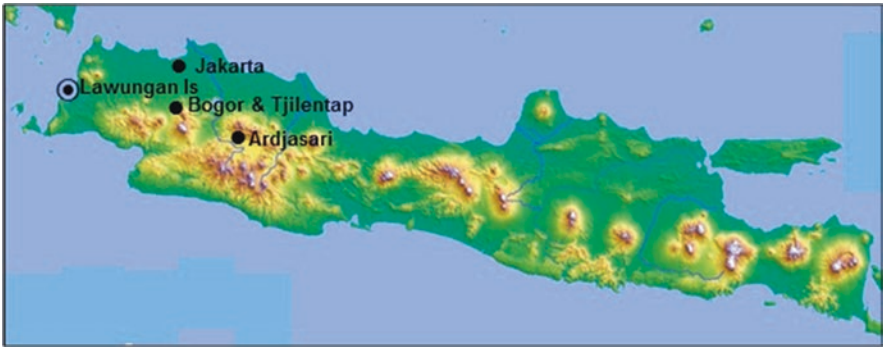


Fig. 7.12 A map of the island of Java showing locations from which observations of the 12 December 1871 eclipse were reported. Oudemans' site is marked by the bulls-eye (map modifications: Wayne Orchiston).

(36-page) paper in *Astronomische Nachrichten*, but unfortunately, no details are provided of the two telescopes, the Pistors and Martin 'patent circle', or the spectroscope and polariscope taken by Oudemans. However, the origin of the makeshift telescope used by Dr Gratama is briefly recounted:

> A few days before leaving Batavia, I [Oudemans] received, through the kind office of the former General Secretary Mr. Wattendorf, who was just back from a holiday in Europe, a lens from the French astronomer Janssen with a focal length of 3 meters, together with a letter from him … [outlining] the construction of an instrument that can project a celestial image onto a piece of paper … (Oudemans, 1873a: 3; our English translation).

The simple refracting telescope that Dr Janssen advocated was quickly assembled in Batavia and assigned to Dr Gratama. Where no instruments are listed alongside other observers in Table 7.1 (column 2), we can assume that most (if not all) of them relied on naked eye observations.

Oudemans (1873a) describes how the eclipse expedition reached Lawungan Island on 10 December, just two days before the grand event, only to be greeted by cloudy skies and rain—which continued into the morning of the 12th. Then, miraculously,

> After the eclipse had started the sun became visible, through the clouds, and I rapidly measured the time … Shortly before totality, about 10 o'clock, the sky fairly cleared, though it was mostly covered by moving clouds … (Oudemans, 1873a: 4; our English translation).

If he wished to make important observations Oudemans realized that he had to subject the eclipse to spectroscopic and polariscopic scrutiny, so just before totality, when the sky was clear enough for observations to be made, he started with the spectroscope:

> … now the telescope, equipped with the spectroscope, was put on the mounting … and directed to the sun. But due to the arduous handling of the instrument, which was not suited for this observation, it took some time to get the image of the sickle-shaped sun to fall exactly on the slit of the spectroscope …

Table 7.1 Dutch East Indies observers of the 12 December 1871 total solar eclipse.

Observers	Instruments	Observations	Comments
Lawungan Island			
J.A.C. Oudemans	Telescope; spectroscope; polariscope	Sketches of corona and prominences	Team leader
Blaaw		Sketch of corona	*SS Sumatra* officer
Frankamp		Sketches of corona and prominences	*SS Sumatra* officer
Dr Gratama	Lens f.l. = 3m	Sketches of corona and prominences	Military surgeon
Hardeman	Telescope 35×; Pistor and Martins 'patent circle'	Prominences; chromosphere; measured diameter of the corona	Secondary school physics teacher
Captain Meyer		Colour of the Moon	Captain of *SS Java*
Dr Pieters		Corona	Military surgeon
Rosenwald		Sketch of corona	*SS Sumatra* officer
Soeters		Corona; sketch of prominences	Engineer
Buitenzorg (= Botanical Gardens, Bogor)			
Dr Bergsma	Smart polariscope	Flying shadows; geomagnetism; corona; prominences	Team leader; engineer
Crone	Naked eye	Flying shadows; colour of flowers at totality	
Lang	Naked eye	Flying shadows; colour of flowers and landscape; corona;	
Scheffer		Flying shadows; sketch of corona	Botanic Gardens Director
Van Leeuwen	Dolland reflector	Flying shadows; prominences	
C. Woldringh	Naked eye	Flying shadows; prominences	Geographical Service Assistant
Tjilentap Trig Point (near Bogor)			
Metzger	Telescope	Prominences; corona; broken horns	Team leader; engineer
Bergmann		Broken horns	
Dietrich	Camera, 4- element portrait lens; no equatorial mounting or drive	Two photographs at totality	Photographer
Hensterman	Telescope	Looked for flyingshadows; colour of the Moon; corona	

(continued)

Table 7.1 (continued)

Observers	Instruments	Observations	Comments
van Alfensbeben		Broken horns	
van Emden	Telescope	Broken horns	
Telaga and Surranga (near Bogor)			
Clee			
Erxleben			
Sesink			
Ardjasari Tea Plantation (15 km south of Bandung)			
Messrs R.A. and R.E. Kerkhoven		Sketches of prominences	
Batavia (Garden of the Hydrology Section of the Navy) [Eclipse not quite total]			
J.F.F. Bruyn	Telescope	Sketch of eclipse	Naval Midshipman

> [However] Although the slit was made as narrow as possible, to my disappointment no Fraunhofer lines appeared, although they had been clearly seen previously with the same instrument. I concluded that the spectroscope lenses, which were carefully cleaned by me the previous day, were now fogged due to the humid air; to dismantle, clean and re-assemble the spectroscope would take too much time so I did not consider it and instead I decided to remove the spectroscope and attach a common eyepiece to the telescope [in its place] in order to make my observations … (Oudemans, 1873a: 4; our English translation).

So much for Oudemans' spectroscopic observation of the eclipse. Instead he chose to focus on the location and nature of the prominences and the appearance of the corona.

Since totality would last a merely 3^m 50^s at Lawungan Island (Oudemans, 1873a: 20) and spectroscopy was a lost cause, how did the polariscopic observations fare? Sadly, in this context, Oudemans (1873a: 6–7; our English translation) had to confess:

> Throughout the morning [of 12 December] I had a strong headache, and adding to this was the fact that our preparations were constantly disturbed by heavy rain, and moreover, that I was constantly distracted by different people around me, because of the need, already mentioned above, to change the original observing program. This may well explain why I was not concentrating enough when making the observations, and even though I had installed the polariscope in order to study the polarization of the coronal light … I was overtaken by the end of totality without having used this instrument.

So much for Oudemans' spectroscopic and polariscopic observations of this eclipse! But all was not lost for Dr Bergsma, who led the eclipse party at the Botanical Gardens in Bogor (see Fig. 7.13; Table 7.1), had a Smart polariscope that had been sent out from Holland, and when he directed it at the Sun he found that the tenuous light of the corona *was* polarized (Oudemans, 1873a: 14).

The third astrophysical technology in the observational arsenal that the Dutch could rely on was photography, but unfortunately Oudemans had no photographic equipment at Lawungan Island. Instead it was Dietrich, a photographer in Metzger's observing team at Tjilentap Trig Point (near Bogor) who had a camera. This had

> … four lenses, the first pair consisting of a biconvex crown glass and biconcave flint glass, similar to a telescope objective by Fraunhofer, but the curvature of the focal plane was nullified by a second double lens, made of a diverging meniscus of flint glass and a biconvex lens of crown glass. (Oudemans, 1873a: 21; our English translation).

The camera was not equipped with an equatorial mounting, and during totality (which lasted here for about 3^m 54^s) Dietrich was only able to obtain two photographs, with estimated exposures of 1/3 and 1/2 seconds. Oudemans (ibid.) noted that "… the latter image was better exposed, the light of the corona is larger, and at its inner side already so black that the prominences cannot be distinguished … many coronal details are visible …" It is much to be regretted that Oudemans was not able to include a print of this photograph in his paper, but we can judge what the corona must have looked like by referring to Fig. 7.13.

All that Oudemans could provide *in lieu* of Dietrich's photograph was a series of drawings of the corona (and prominences) supplied by various observers based at Lawungan Island, the Botanical Gardens at Bogor (Buitenzorg) and the Tjilentap Trig Point near Bogor. These are shown in Fig. 7.14, where the advantage of securing photographic records is very obvious. For the purposes of research, it has to be admitted that these drawings are next to useless.

So what was Oudemans able to conclude about the corona, based on the suite of Dutch East Indies observations available to him?

(1) Most observers confirmed that the colour of the corona was white and unchanging, and most noted the existence of coronal rays (although few—if any—had the artistic skill to depict these realistically). For example, Mr Frankamp reported that the lower corona "… was a regular garland of rays, visible for up to one lunar radius from the limb." (Oudemans, 1873a: 11; our English translation).
(2) The coronal rays did not exhibit any rapid or sudden changes, only slow ones.
(3) The positions of the coronal rays were not correlated with the positions of the prominences.
(4) Using the Pistor and Martens patent circle, Mr Hardemann measured the maximal diameter of the corona as 41′ 50″, rather similar to the value of 38′ obtained

Fig. 7.13 This photograph, supplied by Lord Lindsay, provides a good indication of the appearance of the corona during the 12 December 1871 solar eclipse (https://en.wikipedia.org).

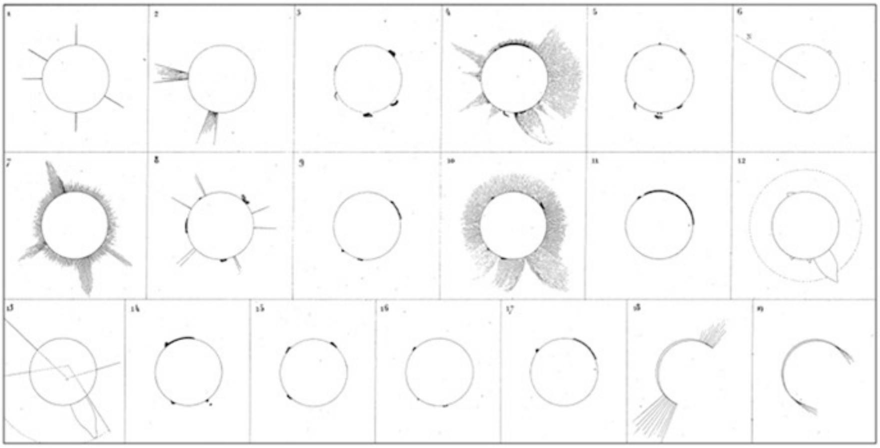


Fig. 7.14 Drawings of prominences and the corona during the 12 December 1871 total solar eclipse by Oudemans and his observing team (after Oudemans, 1873a: 32A).

from measuring the diameter of the faint images projected by Dr Gramata's simple telescope (Oudemans, 1873a: 9).

(5) As we have seen, Metzger found the light of the corona to be polarized, confirming the conclusion reached during the Indian observations of the 1868 eclipse (see Tennant, 1869: 25–26).

Oudemans' comments about the chromosphere are interesting. He noted that "If a real chromosphere existed, then it must have been very insignificant." (Oudemans, 1873a: 5; our English translation). Other observers confirmed this, noting that at most it was only a few arc seconds in height.

By way of contrast, the prominences were obvious, but the actual number seen and their relative positions differed from observer to observer (see Fig. 7.14). Nonetheless, their colour always was "… soft charming roseate, extending to stone red, with a large richness of tinges …" (Oudemans, 1873a: 8; our English translation). In 1870, the Italian Jesuit astronomer Angelo Secchi (1818–1878; Cenadelli, 2014) proposed a typology of prominences (Secchi, 1870), and three of his types were seen during the 12 December 1871 eclipse: jets, heaps and clouds. Unfortunately, no major discoveries relating to prominences resulted from the 1871 eclipse observations in the Dutch East Indies.

Finally, there was an unusual terrestrial feature of the 12 December 1871 eclipse that was noticed by those assembled at the Botanical Gardens in Bogor (Buitenzorg), and this was the 'flying shadows'. Oudemans (1873a) devotes nearly three pages to them in his *Astronomische Nachrichten* paper. Although these shadows had been noted during some previous eclipses, the reason for their occurrence still was not understood in 1871. Dr Bergsma noted that

> This phenomenon was seen particularly clearly at Buitenzorg, even by inexperienced people who had never heard about them. Everyone who joined me near the botany museum saw them clearly.
>
> The northern side of our observing site was bordered by a white wall. The shadows were visible on this wall and also on a piece of white paper lying on the table; i.e. they were visible on vertical and horizontal surfaces …
>
> The shadows on the wall moved from east to west …
>
> The shadows had a width of 5 or 6 centimeters, limited by lines forming small irregular waves. The shadows were separated by evenly illuminated parts, I [Bergsma] estimated the distance between the shadows as about 15 centimeters, while Mr. Lang found about 1 foot [i.e. 30.5 centimeters].
>
> The shadows moved slowly and uniformly, the speed on the wall was about that of a moderately trotting horse. I [first] saw the shadows about 3 minutes before totality started.
>
> According to Mr. Lang, whom I asked to watch this phenomenon, it was not seen during totality …
>
> [But] Immediately after totality the shadows reappeared, alternating in intensity, but getting weaker and weaker. They remained visible for about 5 minutes after totality, and then they definitely were gone. (Oudemans, 1873a: 15–16; our English translation).

The amazing flying shadows were not seen at any of the other 12 December 1871 eclipse sites, not even at the nearby Tjilentap Trig Point.

7.4.3 The 1874 Transit of Venus

In the nineteenth century, one of the most pressing problems in professional astronomy was to accurately determine the mean distance from the Earth to the Sun and pin down a scale for the Solar System. Arguably, the best way of doing this was to observe a transit of Venus from different sites on Earth widely separated in latitude. These transits are rare events, occurring in pairs eight years apart, then with more than 100 years until the next pair of transits (Cottam and Orchiston, 2015).

Conflicting results were obtained from observations of the 1761 and 1769 transits (Orchiston, 2017a; Woolf, 1959), so astronomers were committed to making careful observations of the 1874 and 1882 transits. Meanwhile, in the interim since the eighteenth century transits there had been improvements in instrumentation and observing techniques (e.g., the introduction of photography and spectroscopy), and the latitude and longitude of observing sites could be determined with more precision. So, great results were anticipated, and teams of astronomers from many nations organised transit expeditions to observe the 8 December 1874 event (e.g., see Dick, et al., 1998; Kurtz, 2005; Orchiston, 2004; Ratcliff, 2008; Sheehan and Westfall, 2004).

The 1874 transit was only visible across part of the Earth, and as Fig. 7.15 shows, weather permitting, the entire 4-hour transit could be viewed from Batavia and elsewhere in island Southeast Asia, and from India, China, Japan, Australia and New Zealand. However, far northern or southern observing locations were favoured rather than those near the equator, so Batavia was not deemed an ideal location.

On 7 January 1873, nearly two years before the transit, British Astronomer Royal George Biddell Airy (1873) wrote Oudemans and encouraged him to observe the 1874 transit. Oudemans (1873b) was quick to reply, pointing out that he hoped to view it from Japan. However, the Dutch Government decided to mount two expeditions, one to Japan and the other to the French island of Réunion in the Indian Ocean (see Fig. 7.15). The outcome was that Oudemans went to Réunion not to Japan. Back in the Netherlands, van de Sande Bakhuyzen was charged by the Government with co-ordinating the 1874 expeditions (Pyenson, 1989: 34–36), and it is not clear whether he decided that Oudemans would lead the Réunion expedition, or if Oudemans had a change of heart when he saw an opportunity to link the transit to a visit to India, and he lobbied van de Sande Bakhuyzen accordingly. Certainly, Japan was far easier to reach from Batavia than Réunion, but for those astronomers coming all the way from the Netherlands Réunion was a much closer destination (see Fig 7.15).

Be that as it may, Oudemans' transit team comprised

> … Pieter Jan Kaiser, instrument examiner for the navy and son of the late director of the Leiden observatory; Oudemans's chief assistant at Batavia, the former lieutenant in the Prussian engineering corps Carl Albert Emil Metzger; Ernst Frederik van de Sande Bakhuyzen, observer at Leiden and eventually successor to his brother H. G. as director there; and two young Dutch astronomers, Martinus Bernardus Rost van Tonningen and T.F. Blanken. (Pyenson, 1989: 37).

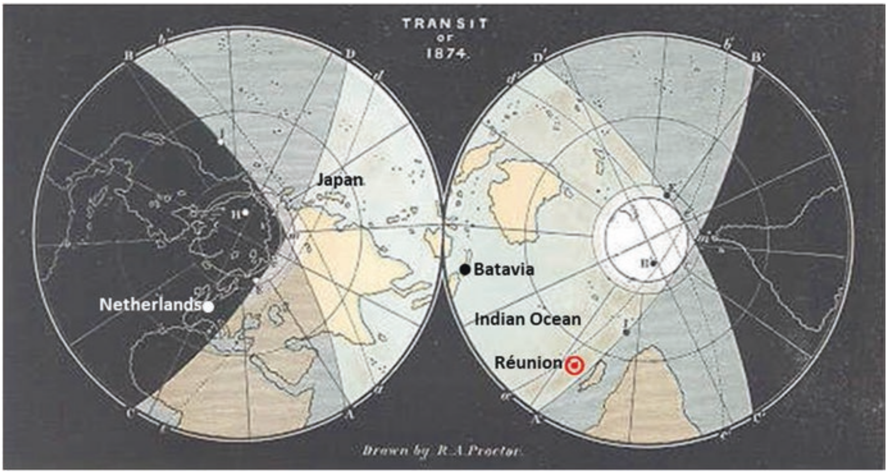


Fig. 7.15 Maps showing those areas of the globe (in pale blue where part or all of the 1874 transit of Venus would be visible (base maps after Proctor, 1874: Plate VI; map modifications: Wayne Orchiston).

The members of the expedition from the Netherlands met up with Oudemans and Metzger in Reunion. Their main aim was to photograph the transit using the Dalmeyer photoheliograph shown in Fig. 7.16, and for this they selected a suitable observing site at St. Denis, near the seashore (Fig. 7.17). All of the instruments were installed and ready for the grand event, then fate intervened and transit day dawned cloudy. So all the effort, not to mention the ƒ55,000 that the Government and private sponsors had contributed to fund the expedition (Pyenson, 1989: 38), was for nought. The Government and sponsors would not have been amused.

Although inclement weather may have prevented any observations of the transit being made from Réunion in 1874, this did not prevent Oudemans later on from publishing papers about the transit. Thus, in 1875 he wrote a 9-page paper in French

Fig. 7.16 The Dallmeyer photoheliograph that was taken to Réunion for the 1874 transit of Venus (http://www.mi-aime-a-ou.com/photo_la_reunion.php?id_img=5326).

about the best method of making heliometer observations of the transit, since the information and guidelines sent observers by Germany's Professor Arthur Auwers (1838–1915) from the University of Königsberg did not allow for heliometer observations. What is surprising is that Oudemans chose to publish his paper in the *Memorie della Societa Degli Spettroscopisti Italiani*, given that Italian astronomers were the masters of spectroscopic (not heliometer) observations of the nineteenth century transits of Venus (e.g. see Pigatto and Zanini, 2001; 2004). How his paper was received by the Italian astronomical community is not known, but begs the question of why he did not decide to publish in *Monthly Notices of the Royal Astronomical Society* or *Astronomische Nachrichten* (where most of his papers ended up)—unless he felt that to criticize a German astronomer in a German astronomical journal would not be 'politically correct'.

A great many years later—indeed, long after his retirement—Oudemans published two papers (actually an original paper, followed by a supplement) on their determination of the longitude of the Réunion Island observing site (Oudemans, 1904; 1905). The 1905 paper was destined to be his final scientific publication, and he passed away one year later.

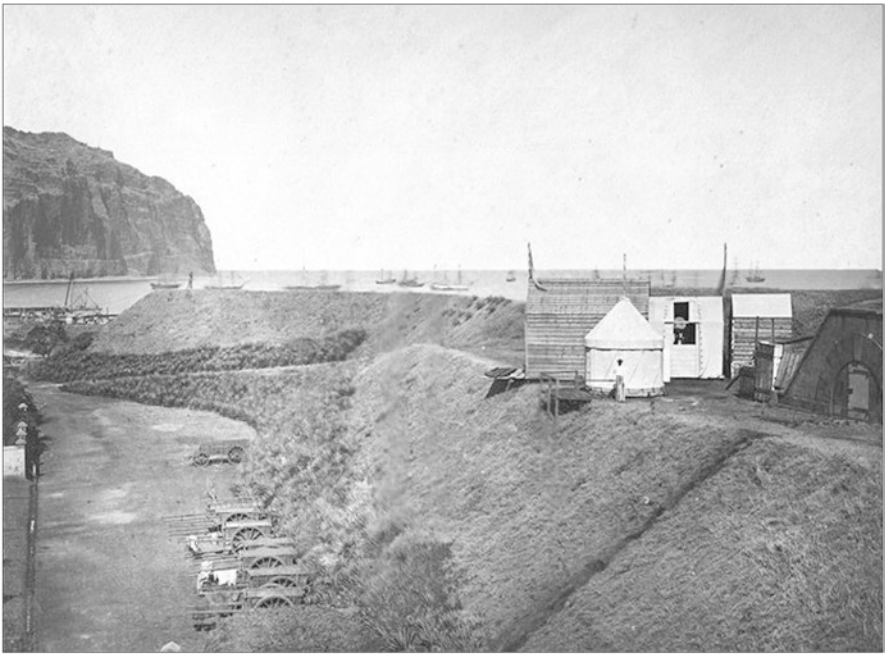


Fig. 7.17 The Dutch transit of Venus observing site at St Denis, Réunion (http://www.mi-aime-a-ou.com/photo_la_reunion.php?id_img=5326).

7.4.4 *Other Astronomical Activities*

In sympathy for his passion for astronomy, while in Java Oudemans apparently wrote a popular work on astronomy for schools (van de Sande Bakhuyzen, 1907). Thus far, our endeavours to learn more about this publication have been unsuccessful.

7.4.5 *Return to the Motherland*

The 'Pogson Affair' mentioned in Section 7.3 merely added to Oudemans' woes and reinforced his desire to quit the tropics and return to the Netherlands. Indeed, from the early 1870s he had been surveying Dutch academia in search of a suitable position in astronomy. In 1872 his' friend Hendricus Gerardus van de Sande Bakhuyzen (1838–1923) assumed the Chair at Leiden following Frederick Kaiser's death. Then the following year Johannes Bosscha (1831–1911) informed Oudemans that Utrecht's Martin Hoek (1834–1873; Fig. 7.18) had died at a comparatively young age, and asked if Oudemans was interested in returning to Utrecht and his old appointments. He mentioned that "Some people feel that his place should be kept open until you get back from the Indies …" and he gave Oudemans the distinct impression that the Utrecht position was his for the asking (Bosscha, 1875). As Pyenson (1989: 33) says, "Bosscha relayed clear signals that Oudemans had to wind up his affairs at Batavia if he did not want to miss an Utrecht professorship." Yet this was all hear-say—there was no form job offer! This would come later.

Meanwhile, it turned out that the two solar eclipses and the 1874 transit of Venus would be Oudemans' last chance to contribute to an international observational astronomy project while based in Batavia, and in 1875, soon after returning to Batavia from Reunion and India, he and Paulina decided to go home. The East Indies sojourn was over.

7.5 Concluding Remarks

Indonesia has an interesting astronomical history (e.g., see Hidayat, 2000, 2004; Hidayat et al., 2017). Although this is not discussed by Bambang Hidayat and his colleagues, we can hypothecize that Indonesian astronomical history may have begun more than 1.5 million years ago when the first hominids at Sangiran gazed in wonder at the star-filled skies on clear moonless nights. These initial settlers of the Indonesian region belonged to the genus *Homo erectus* and, sadly, we know nothing about their astronomical beliefs and practices. How did they react, we wonder, when an asteroid struck the Earth near the present borders of Cambodia, Laos and Thailand around 800,000 years ago (Lee and Wei, 2000), and tektites rained down on Central Java (Langbroek and Roebroeks, 2000).

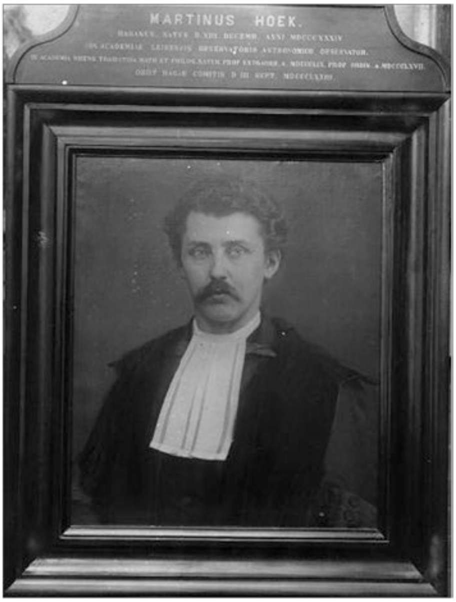


Fig. 7.18 Utrecht astronomer and experimental physicist Martin Hoek (http://4.bp.blogspot.com/-x48SoVQV8nU/UVQgaRga0dI/AAAAAAAABGM/7iU10IacJ-g/s1600/mh1.jpg).

Between 50,000 and 60,000 years ago modern humans, *Homo sapiens*, first ventured into what is now island SE Asia, and although they were replaced within the past 4000 years, first by Austronesian-speaking farmers from Taiwan and then Austro-Asiatic-speaking farmers—ancestors of the present-day populations of Indonesia—from South China, some of the earlier populations have survived through to the present day in the guise of the distinctive negrito ethnic groups of southern Thailand, Malaysia and the Philippines. We can learn something about ancestral hunter-gather astronomical systems from these people, long before the rice-growing Pranotomongso calendar (Daldjoeni and Hidayat, 1987) was developed in Java, probably 1,500–2,000 years ago (Orchiston and Orchiston, 2018).

Major changes have occurred in Indonesian astronomy over the past 1,000–2,000 years, with the appearance of Hinduism, Buddhism and Islam, and in the case of the first of these religions, we see this reflected in temple architecture and function (e.g. see Khairunnisa et al., 2021). Meanwhile, Islam permeates the everyday lives of most contemporary Indonesians. Further changes to Indonesian astronomy occurred during the colonial era, with the appearance of 'Western' astronomical instruments, beliefs and practices. Johan Maurits Mohr's is the stand-out example of an eighteenth century European astronomer, who maintained an impressive observatory in Batavia (Zuidervaart and van Gent, 2004).

After Mohr died in 1775 there was a hiatus of about a century before another European astronomer with international visibility made the Dutch East Indies his home. That man was Jean Abraham Chrétien Oudemans, the subject of this chapter.

Oudemans came to Batavia in 1857 and spent nearly 20 years in the colony, leading the team conducting the trigonometrical survey of Java. The survey involved astronomical observations in order to determine latitude and longitude, and Oudemans saw himself as an astronomer, not an 'engineer' (his official title') or even a geodesist. He maintained a correspondence with leading professional astronomers in Britain, the Netherlands, Germany and India, and successfully observed the 1868 and 1871 total solar eclipses. He also tried to observe the 1874 transit of Venus but cloudy weather prevented this. During his time in the 'Indies' Oudemans published a number of short papers on his non-meridian astronomical work, and when he (and his wife) returned to the Netherlands in 1875 it was to a Chair in Astronomy at the University of Utrecht and as Director of the University Observatory.

Dr Oudemans is an example of a scientist who was able to successfully exploit the parameters of his official position in Java so that he could continue to indulge his passion for astronomy. In the process he was the only nineteenth-century Indonesian-based astronomer to build an international reputation, but to claim, as Pyenson (1989: 32) has done, that "Oudemans was one of the most accomplished Southern Hemisphere astronomers …" of the nineteenth century is unjustified. There were many astronomers at the Royal Observatory in Cape Town (e.g. see Warner, 1979), at Adelaide, Melbourne, Sydney and Williamstown Observatories in Australia (e.g. see Haynes et al., 1996), not to mention Australia's leading nineteenth-century astronomer, the remarkable amateur, John Tebbutt (see Orchiston, 2017b), all of whom built international reputations and would rank ahead of Oudemans. But Oudemans *was* known internationally, and it is a just reward that a crater on Mars has now been named after him (see Fig. 7.19).

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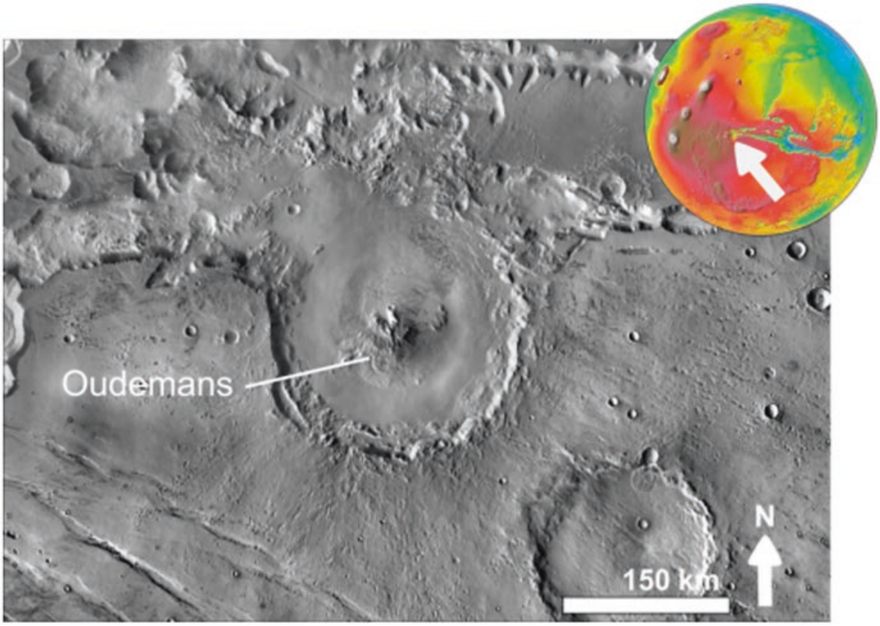

Fig. 7.19 The crater Oudemans on Mars (Martian_impact_crater_Oudemans_based_on_day_THEMIS.png).

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Chapter 8
The 1875 British Solar Eclipse Expedition to Siam Led by Dr Arthur Schuster

Visanu Euarchukiati

8.1 Introduction

Inspired by the research paper "The King Rama V total solar eclipse of 1875: Schuster's expedition to Siam" by Hutawarakorn-Kramer and Kramer (2006), I decided to conduct further research into related contemporary documents in English and Thai, as well as the Schuster Papers and Photographs Archive at the Royal Astronomical Society in London, where manuscripts and original photographs from the expedition were discovered. As a result, a far more detailed picture of the expedition has emerged.

Franz Arthur Friedrich Schuster FRS, FRSE (1851–1934) was a British physicist known for his work in spectroscopy, electrochemistry, optics, X-radiography and the application of harmonic analysis to physics. Born in Germany, Schuster moved to join his parents in Manchester, UK, where their textile business was based, and he became a British citizen in 1875. He contributed to making the University of Manchester a major centre for the study of physics, and was Knighted in 1920 (Arthur Schuster, n.d.).

8.2 The 1875 Total Solar Eclipse

A total solar eclipse was predicted to occur on 6 April 1875. The path of totality (Fig. 8.1) started from the southern tip of Africa, crossing the Indian Ocean and extended across mainland Southeast Asia (Eclipse Predictions). The Royal Society of London considered three possible observation stations: the Nicobar Islands, the

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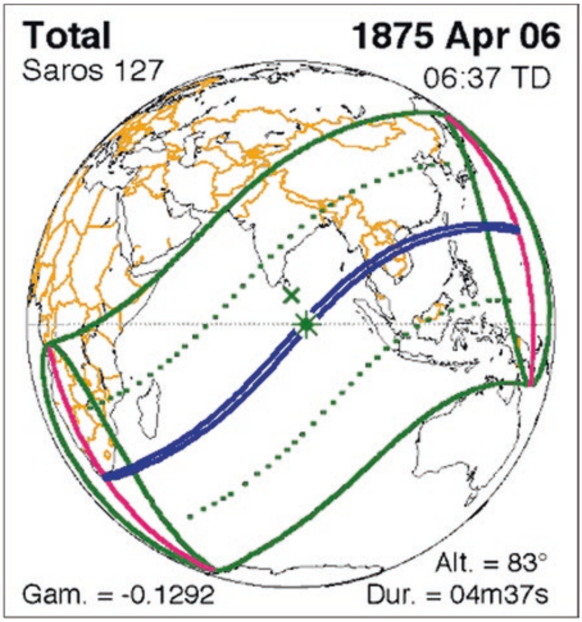


Fig. 8.1 A diagram showing the path of totality of the 6 April 1875 total solar eclipse (courtesy: NASA).

western coast of the Malayan Peninsula (in Burma), and the eastern coast of the Malayan Peninsula (in Siam) (Lockyer and Schuster, 1878).

In Siam, the circumstances of the total solar eclipse of 6 April 1875 had also been calculated by Prince Maha Mala (Fig. 8.2), and he submitted the following prediction to the King:

> I, Prince Maha Mala, calculate the solar eclipse for Your Majesty.
>
> On the Tuesday on the 1st day of the waxing moon, 5th month of the year of the pig, 1236, the Sun and the Moon will move north and be in conjunction in Pisces.
>
> At 12:46 the Moon will touch the southwest corner of the Sun and will move to cover the Sun's disk until 14:06 when it will eclipse the Sun entirely. The crimson totality will last 4 minutes and 10 seconds. The Moon will then move northeast. The Sun will reappear starting from the southwestern corner. At 15:18 the Moon will reach the outer edge of the Sun. The disk of the Sun will be full again (Maha Mala 1875).

The eclipse came seven years after the fateful 1868 total solar eclipse whose observation at Wah-koa brought the reign of King Mongkut, Rama IV, to an end. His son, King Chulalongkorn, Rama V (Fig. 8.3), survived the 1868 observation expedition. The young monarch wished to commemorate the late King Rama IV by inviting European astronomers to observe the phenomenon in Siam, offering full support and location preparations. The astronomers would be treated as the King's personal guests.

Fig. 8.2 A cropped photograph of Prince Maha Mala, "Brother of the 1st king, Siam, (Thailand)" (courtesy: Wellcome Library, London, and used under CC BY 4.0).

In a memorandum from King Rama V to the Minister for the South (Kralahom), and the Prime Minister, Phraya Surawong Waiwat, after the astronomer's visit, the King shared his thoughts:

> Previously, I have known that there was going to be a solar eclipse in this year of the Pig. I think this speciality was very dear to His Majesty. His name was recognised as an astronomer. Many of his acquaintances were astronomy correspondents in these different societies. I am His Majesty's son. Although he is gone, I do not want to lose the connection and the interest in his favourite subject …
>
> About the manner that I received these scholars, it was because I sent my private invitation. Therefore, I received them privately, the merit is so that I can personally be of service to His Majesty's speciality and accomplishments. (Munsin, 2012).

With the King of Siam's invitation, and since Mergui in Burma became inaccessible, the two remaining observation stations were Camorta in the Nicobar Islands and Lem Chulie in Siam (Lockyer and Schuster, 1878). The Royal Society received a £1,000 Government grant for the expeditions and decided that, due to greater

Fig. 8.3 King Chulalongkorn (Rama V) (1858–1910) became King in 1868, but assumed full authority after his second coronation in 1873, two years before the 1875 total solar eclipse (courtesy: National Archives, Bangkok).

emphasis on studying the chemical composition in the Sun's atmosphere, all scientific eclipse observations would be "... limited to photographing the spectra of the chromosphere and coronal atmosphere." (Lockyer, 1875). Visual observations that had been the main method in previous eclipses were now inadequate for these new inquiries.

8.3 The Expedition

8.3.1 Preparations

Norman Lockyer had been marked to lead the expedition since the planning stage, and he invited Arthur Schuster, a recent PhD graduate from Heidelberg University who had been working on spectrum analysis and was living in the UK, to join his expedition. The 23-year-old Schuster gladly accepted the invitation.

However, because Lockyer was also the Secretary of the Duke of Devonshire's Royal Commission on Scientific Instruction, his long absence was not possible. The Royal Society, therefore, appointed Schuster to be the expedition leader (Schuster, 1932). In the final arrangement Schuster would lead the expedition to Siam while Rafael Meldola, Lockyer's assistant, would lead a separate expedition to Camorta in the Nicobar Islands.

Schuster spent the first months of 1875 preparing the necessary equipment. During that time he was sent to Paris for one week to study the silvering process for the expedition's siderostat from Martin at Paris Observatory. In early February, a letter from Sir George Stokes (Fig. 8.4), the Secretary of the Royal Society, appointed Schuster to lead the whole expedition from England until the two teams parted, and to lead the team that went to Siam:

> I am to inform you that the Eclipse Committee of the Royal Society have appointed you to take charge of the whole expedition proceeding from England, so long as it remains united, and afterwards of that branch of it which is to go to Siam.
>
> Also that the Committee have passed a resolution that the whole of the observations taken by the Siam party be considered the property of the Royal Society, and be sent to that body for discussion.
>
> I am. Dear Sir,
>
> Yours faithfully,
>
> (signed) G. G. Stokes,
>
> 4th February 1875.
>
> (Schuster 1932: 69).

8.3.2 *The Voyage*

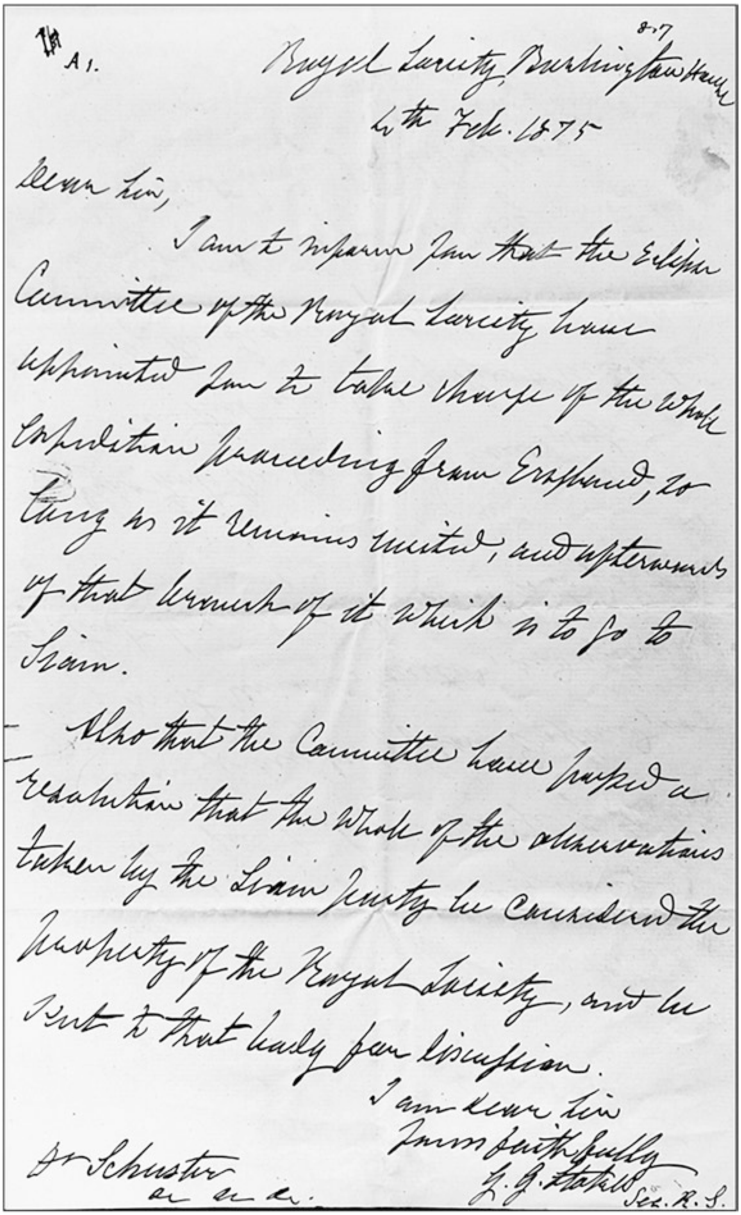
The Royal Society 1875 total solar eclipse expedition teams sailed from Southampton on 11 February 1875 aboard the Peninsular and Oriental S.S. *Surat*. The two teams were:

The Siamese expedition team

Arthur Schuster (leader),
Frank Edward Lott (assistant), and
Frederick Beasley (photographer)

And the Indian (Camorta) expedition team

Raphael Meldola (leader) and
J. Reynolds, and



A1.

8.7

Royal Society, Burlington House
4th Feb. 1875

Dear Sir,

I am to inform you that the Eclipse Committee of the Royal Society have appointed you to take charge of the whole Expedition proceeding from England, so long as it remains united; and afterwards of that branch of it which is to go to Siam.

Also that the Committee have passed a resolution that the whole of the observations taken by the Siam party be considered the property of the Royal Society, and be sent to that body for discussion.

I am dear Sir
Yours faithfully
G. G. Stokes Sec. R.S.

Dr Schuster
&c &c &c.

Fig. 8.4 The letter dated 4 February 1875 from Sir George Stokes, Secretary of the Royal Society, to Dr Schuster (courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

H. Vogel who joined at Suez.

There were many delays during the long voyage. After a stop in Malta, the ship passed through the Suez Canal where an accident caused damage to the propeller on 27 February. The teams had to board a new steamer, the S.S. *Baroda*, heading for Galle, Ceylon (Sri Lanka) on the evening of 28 February. Schuster (1932: 73) noted of the equipment transshipment that although most cases were light, the siderostat weighed half a ton, yet four Arabs could carry it across easily.

The expedition teams reached Galle at 7 a.m. on 16 March. The Indian party led by Meldola separated, bound for Calcutta and the Nicobar Islands (Lockyer and Schuster, 1878: 142). The Siamese expedition team boarded a new ship, the *Peru*, and sailed for Penang on the same day. The voyage took six days, strong headwind delaying their arrival by 24 hours.

With many hours before the ship continued to Singapore, Schuster and Lott went on a short excursion to a waterfall (the Penang Botanical Gardens Waterfall). Losing their way, they were separated in the jungle. It was with much physical exertion and anxiety before Schuster could get back on a proper path and return to the ship. It left for Singapore that same day, in the afternoon (Schuster, 1875a).

Arriving in Singapore on 23 March, 24 hours later than scheduled, the expedition found that the gunboat H.M.S. *Charybdis* that was assigned to take the party to Bangkok had unexpectedly left for Hong Kong. H.M.S. *Lapwing* sent an offer to help, but by the advice of Sir Andrew Clarke, the Governor of the Straits Settlements, the expedition traveled to Bangkok aboard a Siamese merchant steamer *Kromahtah*. Equipment transshipment took longer than usual because the *Peru* and *Kromahtah* were in different harbours. All cases were transported by cars.

8.3.3 Bangkok

8.3.3.1 Arrival

The voyage from Singapore was delayed by engine troubles and another day was lost when the ship arrived at the bar of Chao Phraya River at noon on 28 March, too late for the morning high tide. The ship finally crossed the bar at 7 p.m. to arrive in the southern part of Bangkok at 11:30 p.m.

The expedition's arrival had been anticipated. By midnight boats came with Bietje, a Dutch assistant to Henry Alabaster, to welcome the Royal Society astronomers and to take the expedition from their ship to Alabaster's house. Henry Alabaster (Fig. 8.5), a former British Deputy Consul to Siam, had become King Rama V's personal advisor in 1873 and helped establish mapping operation, road construction, telephone, telegram and postal services and the Palace Museum in Siam. Bietje would also join the expedition and was mentioned among those who gave assistance during the eclipse (Lockyer and Schuster, 1878: 147).

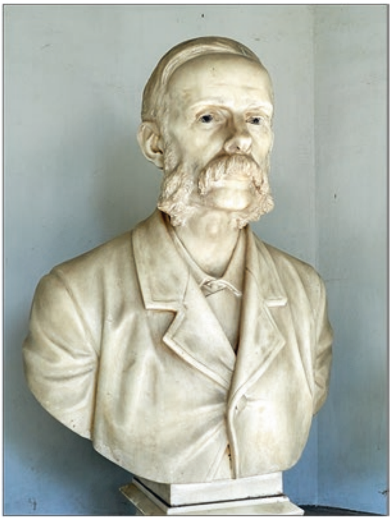


Fig. 8.5 The bust of Henry Alabaster at the Protestant Cemetery in Bangkok (photograph: Visanu Euarchukiati).

The boats reached Alabaster's house after 1 a.m. At a meeting with Alabaster, a number of matters were discussed. The expedition learned that an observatory had been set up by Captain Loftus, on the spot suggested by the Royal Society, and that they had to get to the site quickly.

Another inconvenience was that transshipment the next morning would not be in time for the 11 a.m. high tide out of Bangkok, even if there was a ship to take the expedition to the observatory. Authorities also had to be contacted. The journey on 29 March was not possible. For his short rest period on the first night in Bangkok, Schuster (1932: 79) wrote of the difficulty sleeping in the tropics among the mosquitoes, geckos and bullfrogs.

Although the expedition would be staying in Alabaster's house, they were treated as the King's guests:

> During the whole time we were in Siam we were the guests of the King, dining off Royal plate and drinking out of glass which had the Royal arms engraved upon it, but the King had asked Alabaster to look after us and lodge us at his house. (ibid.).

On the morning of 29 March, after breakfast, the expedition visited many authorities, travelling by boat along the houseboats of the Chao Phraya River. The first call was Phraya Bashakarawongse, the King's Private Secretary, whose signature appeared on the invitation letter to the Royal Society. The next person visited was Chao Phraya Bhanuwongse, or Kromatah (Minister of Foreign Affairs), who treated the expedition to another breakfast. The Prime Minister (Kralahom), Chao Phraya Surawong Waiwat, was not at home, but would see them that evening.

The expedition also visited Newman, the acting English Consul, asking him to help rush H.M.S. *Lapwing* to the observatory.

8.3.3.2 A Royal Audience

The expedition returned home around 2 p.m., had their third breakfast, and prepared for an audience with the King.

The King was not yet ready when they got to the palace and they waited in the new Museum (Fig. 8.6) until they were called. Phraya Bashakarawongse, the King's Private Secretary, joined them there. In front of the palace they were greeted by Prince Kap Kanokrat, Commander of the King's newly-established Cavalry—described by Schuster (1932: 80) as "... a nice-looking young man in cavalry uniform."—who led them to the King's chamber. The King met them at the door and after a formal introduction they sat round a table.

Schuster (n.d.: 9) wrote of the King's appearance: "He was then not yet 23 years of age and dressed in a mixture of Siamese and European costume which is exceedingly pretty." And of the conversation:

> His Majesty expressed the great interest which he took in the objects of the expedition. He referred to the well known great knowledge of astronomy which his father possessed. The late King had died in consequence of a fever contracted on a journey made to observe the total solar eclipse which had taken place in 1868 in the southern parts of his kingdom. Finally His Majesty said that he had given orders that every possible help should be given to the expedition. (Lockyer and Schuster, 1878: 43).

The King's support amounted to underwriting the expedition for the whole time they were in Siam. His Majesty also sent with the expedition two of Siam's historic personalities. Young Mom Daeng, officially Mom Thewathirat (Mom Ratchawong Daeng Israsena), was to accompany the expedition, help with the transshipment and "... afterwards proved a very great help." (Schuster, 1932: 82). Mom Dang was Prince Kap's cavalryman, but would later work under Alabaster to lay the foundation of the Siamese telegraphic service.

Fig. 8.6 While waiting for an audience with the King, Dr Arthur Schuster's expedition waited in the Museum—the first museum in Siam and the predecessor of the present-day National Museum—which was housed in the Concordia Hall, which was later renamed Sahathai Samakhom Hall and was used for Royal functions. In this photograph, the pavilion in front is a recent addition (photograph: Visanu Euarchukiati).

Another personality was Francis Chit, Siam's first commercial photographer who also took a picture of the 1868 total solar eclipse. Chit would help with the development of photographic plates at the observatory.

Throughout the audience, the King did not speak English, even though he could understand and speak the language. Acting as interpreters were Alabaster and Phraya Bashakarawongse. The audience lasted half an hour.

In his *Biographical Fragments*, Schuster (1932: 81) stated that in all subsequent interviews the King spoke English to him. Since there would be no time for Schuster to meet the King before leaving for the observatory on 30 March, the meetings would have to be after the expedition ended, but no record of such meeting has been found.

8.3.3.3 The Young Siam Lecture

After dinner on the night of 29 March at the Alabaster residence there was a meeting of the Young Siam Society—a group of progressive royalists and noblemen who wanted to transform Siam into a proper modern state. Schuster (1875a) was asked at short notice to give a lecture on spectrum analysis and its application during solar eclipses.

The lecture was translated by three interpreters: Alabaster, Phraya Bashakarawongse (the King's Private Secretary) and Prince Dewan (17-year-old future Minister of Foreign Affairs). The questions asked after the lecture indicated that the Siamese understood the subject. Schuster (1875b) wrote a separate paper in *Nature* recalling the event and spoke favourably of the state of science in Siam.

8.3.4 Chulai Point

8.3.4.1 Traveling from Bangkok

Around 9 a.m. on 30 March the expedition set sail from Bangkok bound for the observatory. The ship that carried them was the Royal Steamer *Northern Siam Enjoying* (Praphat u-don Siam). They stopped at Pak Nam (Samut Prakan) to wait for a pilot who was needed to lead the steamer across the bar, but the pilot came one hour late, which meant that they again missed the morning high tide (Schuster, 1932: 83).

The steamer crossed the bar at 7 p.m. Once on the open sea the expedition saw H.M.S. *Lapwing* at anchor, waiting for her turn to cross the bar into Bangkok. The expedition's attempted communication with the *Lapwing* failed because all officers were dining. The intended message was to make sure the *Lapwing* would follow them as soon as possible since there was less than one week of preparation time before the eclipse.

By the time the officers took notice, the expedition's steamer had been carried too far away by the tide for any communication (Schuster, n.d.: 16).

The wind picked up and the sea became rough. The original plan had been to reach the observatory in the evening, but the delay meant that the expedition had to spend the night on the steamer's deck, along with their instruments.

At 3 a.m. on 31 March the steamer had to anchor, due to concern of overshooting their destination, before starting again at 7 a.m. Although Captain Loftus had put up a prominent beacon (Fig. 8.7) to make the observatory more noticeable on the monotonous sea shore, the steamer could not find it. They finally met a fisherman who had seen the landmark and could guide the steamer to the observatory (cf. Hutawarakorn-Kramer and Kramer, 2006).

8.3.4.2 The Observatory

Captain Alfred Loftus (Fig. 8.8), an English naval officer under a hydrographic contract with the Siamese Government, had determined the location of the observatory at latitude 13° 0′ 30″ N and longitude 100° 2′ 10″ E, using the Royal Society's calculated point where the line of totality of the eclipse would cut the Siamese coast (Schuster, 1932: 84). The site was about 1.5 miles southwest of the central line (Lockyer and Schuster, 1878).

The observatory was built on the beach at Bang Thalu, south of Chulai Point, an important landmark appearing on the Admiralty Chart. In their report Lockyer and

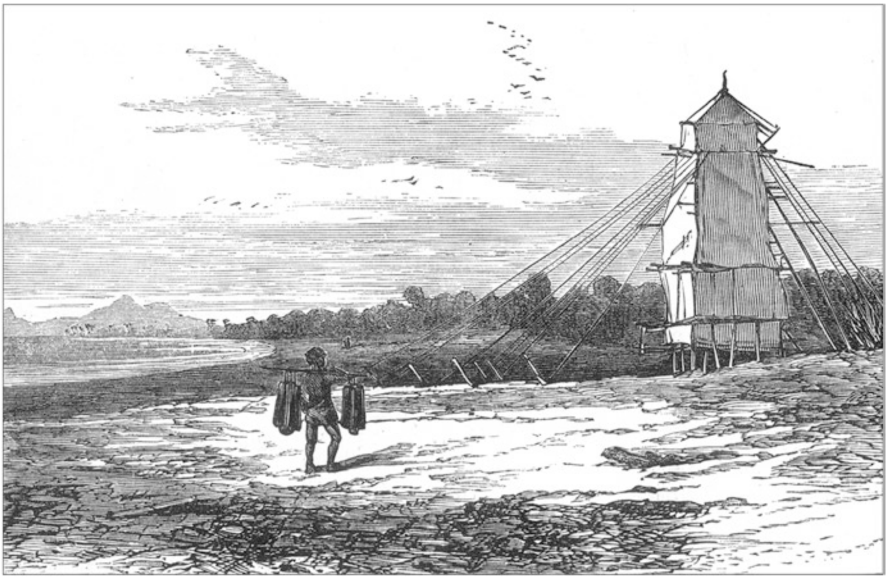


Fig. 8.7 An engraving of Captain Loftus' beacon, erected as a landmark for ships coming to the observatory near Chulai Point (after *Illustrated London News*, 19 June 1875).

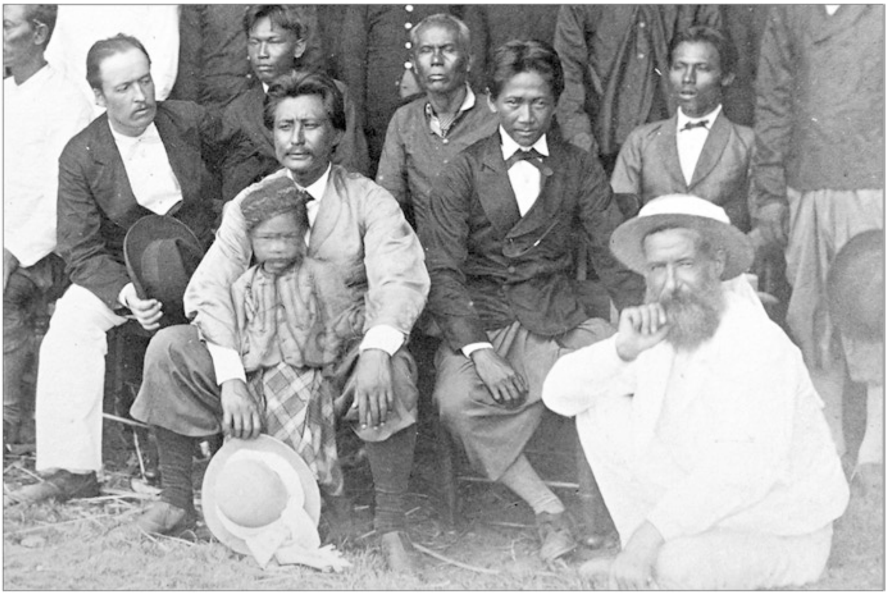


Fig. 8.8 Front row, from left to right: Frank E. Lott (?), Governor of Phetchaburi (with child), Mom Daeng and Captain Loftus (on the floor) (cropped photograph courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

Schuster (1878: 141) referred to the observatory location as Lem Chulie, while Schuster (1875b) gave a more specific location name of Bangtelue in his “Science in Siam” paper in *Nature*.

The location may have been selected because there was a small brook that ran into the sea nearby. There was also a channel into the sea that allowed instrument-carrying boats into the brook and to unload at a platform built for the purpose (Lockyer and Schuster, 1878: 143).

The whole observatory complex on the coast stood in a seaside forest, approximately 90 m. from the sea (Shore, 1881: 477). An area had to be cleared; and in the process, a village of workmen had also been established. Captain Loftus was the project supervisor (Schuster, 1932: 85). Construction labour were conscripted Siamese from the nearby town of Phetchaburi whose Governor also came to oversee the work (Schuster, n.d.: 18).

The observatory (see Fig. 8.9) itself was a platform with high roof covered with palm leaves. There were densely covered huts designated as darkrooms on either side of the platform. About 35 m. away there was a smaller observatory (Fig. 8.10) reserved for the siderostat (Schuster, n.d.: 21). In addition, there were two mobile darkrooms that could be moved to the spots they were needed (Lockyer and Schuster, 1878: 144).

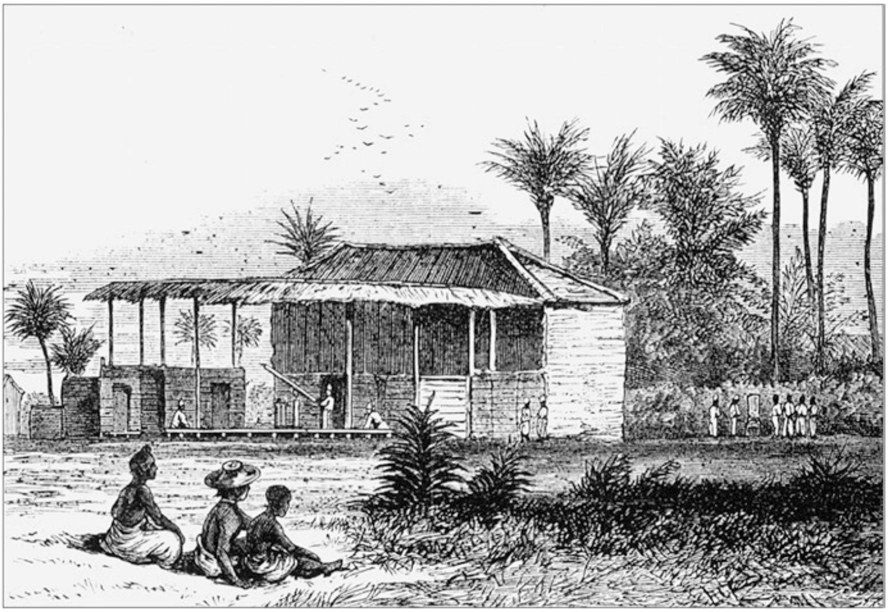


Fig. 8.9 An engraving of the Principal Observatory (after *Illustrated London News*, 19 June 1875).

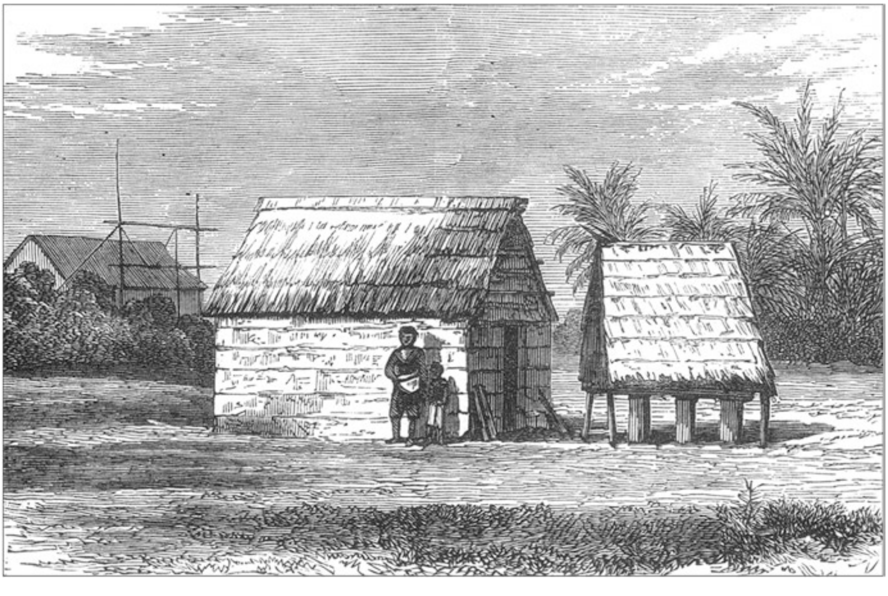


Fig. 8.10 An engraving of the Siderostat observatory, mistakenly labeled No. 1 observatory (after *Illustrated London News*, 19 June 1875).

8.3.4.3 Accommodation

Apart from the observatory, there were living quarters, store rooms and bathrooms. The expedition was given a raised house with one long room running the length of the house serving as dining room, with many bedrooms on either side, and a verandah in front of the house facing the sea (see Fig. 8.11). Dr. Jules Janssen, the renowned French astronomer, who had also accepted the King's invitation and arrived at the observatory earlier, had another house of the same size.

Another large bungalow belonged to the ex-Regent of Siam, Somdet Chaophraya Borom Maha Sri Suriyawong (Schuster, 1932: 85), who had come by sea on 1 April to observe the eclipse (Lockyer and Schuster, 1878: 143).

There was not enough clean water at the site, so drinking water had to be brought in from a distant source by sea. A steamer would tow a number of barges containing large water jars to supply the observatory complex (Shore, 1881: 483). Even ice was available, having been imported from Singapore (Schuster, n.d.).

8.3.4.4 Equipment and Preparations

Although the expedition arrived on 31 March, strong winds prevented the unloading of the instruments until the next day. Starting from 3 a.m., Lott would arrange for small boats to take instrument cases from the steamer to the landing stage in the

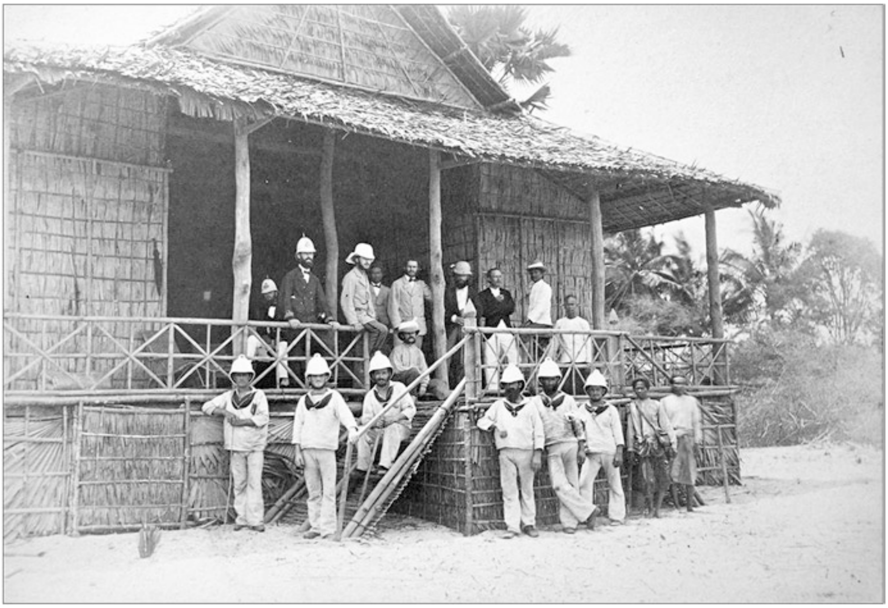


Fig. 8.11 The expedition and H.M.S. *Lapwing* officers posing in front of their accommodation (courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

brook (Fig. 8.12). Several trips were needed before all cases were completely transferred by midday on 1 April.

Getting the instruments ready for work would take the expedition up to the eclipse day. There were two sets of instruments, the prismatic camera and the spectroscopic cameras. The prismatic camera was attached to the equatorial telescope in the main observatory. The equatorial telescope itself was for the camera with a spectroscope. The siderostat (Fig. 8.13) in the small observatory had its own telescope and a spectroscopic camera (Lott, 1875; cf. Hutawarakorn-Kramer and Kramer, 2006).

Many instruments were damaged in transit and needed repairs. The equatorial telescope was set up on a brick foundation separate from the observatory platform, but the telescope's latitude mechanism was not made for low latitude:

> When the latitude adjustment had to be made, a serious difficulty arose. The instrument was intended to be secured by four screws, but, when used at the low latitude at which we were, two of these fell outside the supporting stand, so that the whole weight had to be support by two; of these, one had been broken in the journey, and the other did not fit without an additional washer. (Schuster, 1932: 86).

The collimator tube for the spectroscope also had to be cut. All repairs had to wait for the skilled crew and necessary equipment from H.M.S. *Lapwing* which would not arrive until two days before the eclipse.

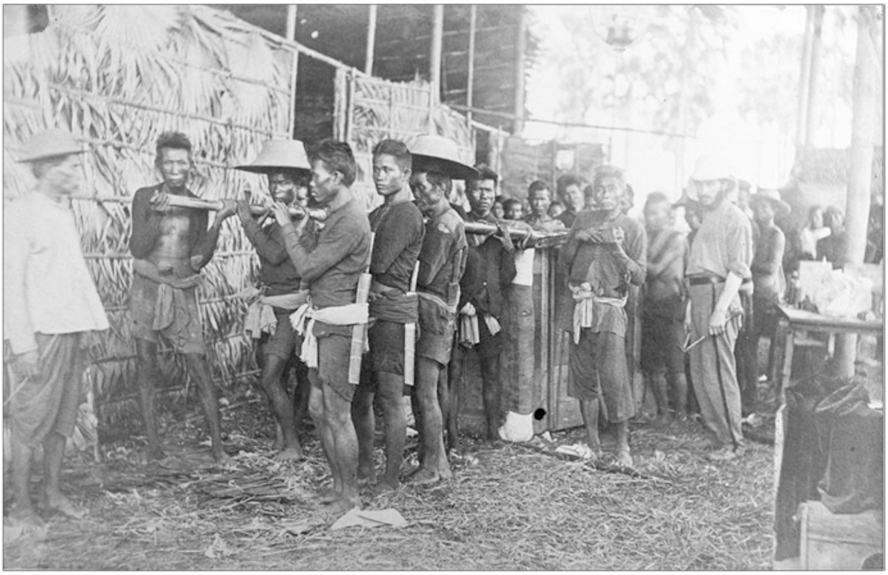


Fig. 8.12 "The transshipment and carrying of the siderostat gave considerable trouble. What was done by four Arabs at Suez could only be accomplished by fifty Siamese." (Schuster, 1932: 85) (courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

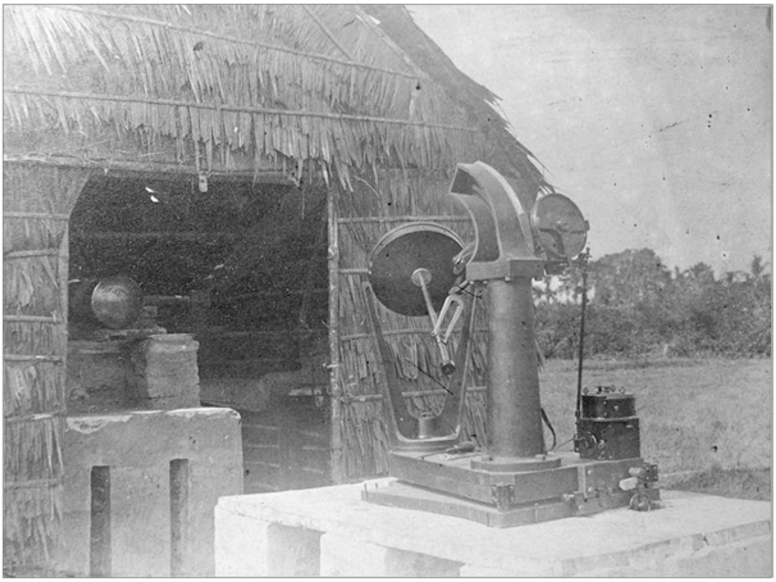


Fig. 8.13 The siderostat, with protective roof removed, and its telescope and spectroscopic camera in the hut (courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

In the meantime, the expedition team was organised into departments. Beasley was in charge of all photographic matters, mainly chemicals preparation. Lott took care of unpacking all cases. Captain Loftus helped take sextant readings and managed the Siamese labour while 10-year-old Edward Loftus, the Captain's son, was the interpreter for English, Thai and Malay.

8.3.4.5 H.M.S. Lapwing

One day after the expedition's arrival, a steamer arrived on 1 April, but it only brought a letter from H.M.S. *Lapwing's* Commander asking if the expedition needed any assistant. The encounter at the bar was completely unnoticed. H.M.S. *Lapwing* finally arrived in the night of 3 April (Lockyer and Schuster, 1878: 145). Two officers and two sailors were posted permanently on shore. One officer, Henry N. Shore (1881: 467–497) later wrote a memoir *Flight of the Lapwing* whose last chapter 'A visit to Siam' was devoted to describing the ship's voyage to assist the eclipse expedition. With help from H.M.S. *Lapwing*, instruments could be repaired and set up properly.

Another historic personality arrived with the *Lapwing*. Oscar Eschke, a German painter and photographer who traveled to Siam after helping with the German expedition to observe the 1874 Venus transit in China (Duerbeck, 2004), wished to see the eclipse. He was sent to the observatory and volunteered to help.

The preparation—including three rehearsals of everyone's duty during the 4-minute totality (Shore, 1881: 479)—finished just in time, at 11 a.m. on the morning of 6 April, the day of the eclipse.

> It was only by working 12 hours a day in the hottest month of the year, and sometimes during additional hours of the night to adjust the clocks, that the instruments were in working order a few hours before the beginning of the eclipse. (Lockyer and Schuster, 1878: 146).

8.3.4.6 Totality

There was no record of the start of totality. (The time mentioned by Lockyer and Schuster (1878: 147) was a quote of Sir Harry Ord's writing on the 1868 eclipse; cf. Hutawarakorn-Kramer and Kramer, 2006). Shore (1881: 479) wrote that the first contact took place soon after 11 a.m. The sky was clear. Thirty Siamese were posted around the observatory to guard the ground, especially in case the ex-Regent's elephants might be frightened (Schuster, 1932: 89).

The corona was as bright as the Full Moon and was well defined (see Fig. 8.14), but there were few prominences. Schuster assigned a number of time-tellers to call out the remaining time through to the end of totality after he himself called the start of totality. The practice was adopted from Schuster's visit to France just before embarking on the Siamese expedition, and would also be used in his subsequent expeditions (Schuster, 1932: 68).

Activities during the totality were performed according to plan, with help from officers from H.M.S. *Lapwing*, Europeans from Bangkok and a number of Siamese. In his *Nature* paper, Lott (1875) reported each person's task:

> **The Expedition.**
>
> Dr. Arthur Schuster – Chief of the Expedition; in charge of large Observatory, attending to the Equatorial.

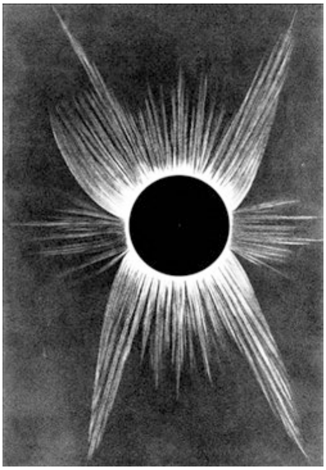


Fig. 8.14 Drawing of the total solar eclipse of 6 April 1875 seen from Chulai Point Observatory by Henry Shore (after Lockyer and Schuster, 1878: Figure 16).

> Frank Edward Lott – Dr. Schuster's Assistant. In charge of the Siderostat Observatory.
>
> F. Beazley, Jun. – Photographic Department. Developing negatives in dark room No. 1.
>
> Oscar Eschke – Photographic Department. Preparing plates in dark room No. 2.
>
> Officers from H.M.S. Lapwing.
>
> Hon. H. N. Shore, Lieut. R.N. – Taking drawings of Corona in large observatory.
>
> Andrew Leslie Murray, Nav. Lieut. R.N. – Keeping time in large Observatory by Chronometer from H.M.S. Lapwing.
>
> W. J. Firks, Assist. Eng., R.N. – Attending to the clock of Mr. Penrose's instrument.
>
> **Europeans and Siamese from Bangkok.**
>
> Capt. A. J. Loftus, R.S.N. – Founder of the Observatory and Camp. In charge of Mr. Beazley's Camera, taking direct photographs of Corona with 2-4-8-16 seconds exposure.
>
> Mrs. M. Loftus – Keeping time for Capt. Loftus.
>
> Francis Chit – Royal Photographer to the King. Preparing and developing in dark room No. 3 for Capt. Loftus.
>
> W. Bray – Attending to plates for Capt. Loftus.
>
> F. G. Patterson – Keeping time in large Observatory with Mr. Murray.
>
> Hendricke and W. H. Lang – Attending to the Prismatic Camera in large Observatory
>
> C. Bethje – Dr. Schuster's amanuensis during totality.
>
> Capt. J. Thompson, R.S.N., and Edward H. Loftus – Signaling time between the large Observatory and the Siderostat Observatory ground.
>
> **Six Seamen from H.M.S. Lapwing.**
>
> Carpenter, Blacksmith, and Two Seamen in large Observatory, taking plates between dark rooms and instruments.

Fig. 8.15 shows a group photograph that probably was taken after the end of totality.

8.3.4.7 Results

Scientific results were obtained solely from the prismatic camera attached to the equatorial telescope in the main observatory. Spectroscopic cameras on the equatorial and in the siderostat hut did not yield any results. The former did not get enough

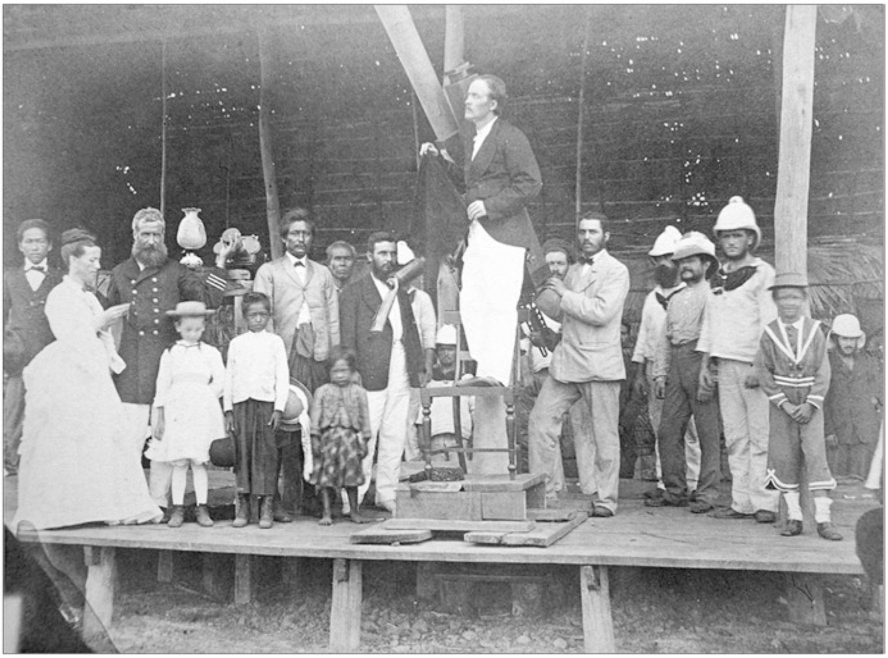


Fig. 8.15 Group portrait of the expedition, H.M.S. *Lapwing* officers and crew, the Europeans and the Siamese, most likely taken after the end of totality. Schuster is the man in white suit next to the telescope wearing a bow tie (courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

light for the sensitivity of the plates (Lockyer and Schuster, 1878: 151) while the latter received even less light so that no spectrum showed at all (Lott, 1875).

Apart from the images obtained with the prismatic camera, another camera—belonging to Beasley—was used by Captain Loftus to take photographs of the corona (see Fig. 8.16).

The results from the prismatic camera have been summarised by Hutawarakorn-Kramer and Kramer (2006: 21). The major discovery from the expedition, though suspected, was not apparent at the time the results were reported. In hindsight, the importance of calcium in the chromosphere and prominences was first proved by the observations made in Siam during the total solar eclipse of 6 April 1875 (Schuster, 1932: 93; cf. Hutawarakorn-Kramer and Kramer, 2006).

8.3.4.8 Present-day Place Names and the Location of the Observatory

The location of the observatory site used by the British for their observations of the 6 April 1875 total solar eclipse have been called by various names:

- Lem Chulie (Lockyer and Schuster, 1878: 141).

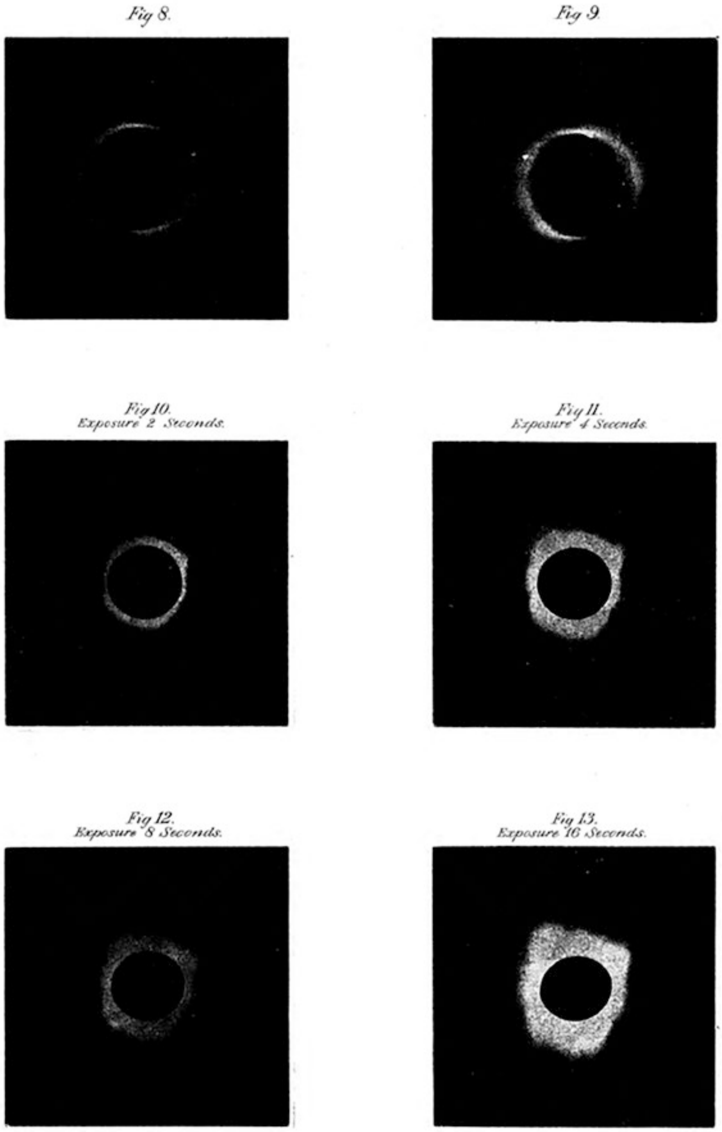


Fig. 8.16 Photographs of the corona taken with the prismatic camera (upper two images) and with Beasley's 13-inch focal length camera (lower four images). The first two images were taken 1 minute and 2 minutes into totality but no exposure times were given, whereas the times were not specified when the four Beasley camera images were taken, but the exposure times were listed as 2, 4, 8 and 16 seconds respectively (after Lockyer and Schuster, 1878: Plate 10).

- Chulai Point (Schuster, 1932: 89 and Shore, 1881: 476).
- Choulai Point (Lott, 1875).
- "the observatory, which is erected at Bangtelue, near Chulie Point" (Schuster, 1875b).
- Bangchallô (Janssen, 1876).

Chulie, Chulai and Choulai are approximations of the Thai word เจ้าลาย (chao-lai, /tɕâw laːj/ in the IPA phonetic transcription). It is the name of the protagonist in a popular folktale in Phetchaburi and Prachuap Khiri Khan provinces of Thailand. The name is given to places in the region, possibly including a cape, thus Lem Chulie is likely to have come from แหลมเจ้าลาย (laem chaolai, /lɛ̌ːm tɕâw laːj/), *laem* is the Thai word for cape.

A preliminary search for Cape Chaolai was unsuccessful. No place name in present-day Thailand has that name, although it was most likely that the Cape was in Phetchaburi or Prachuap Khiri Khan due to its folktale association.

Bangtelue and *Bangchallô* do not have the element of folktales in their names, but the word *Bang* is a prefix for a village or a settlement in central Thailand. Documentary investigation eventually led to Bang Thalu, an old fishing village in Phetchaburi province, whose name was changed to Hat Chao Samran in 1918, and whose location is near a possible location of the observatory.

Although Lockyer and Schuster (1878) clearly state a coordinate of latitude 13° 0' 30" N and longitude 100° 2' 10" E, maps used in 1875 and today's GPS refer to different geodetic standards. GPS uses WGS 84, a standard defined in 1984 (World Geodetic System 2018). For this reason, the observatory's location cannot be located readily with present-day equipment.

An Admiralty Chart for the area that was the one most likely used by Captain Loftus has been obtained and the coordinate plotted. This location (Fig. 8.17) matches closely with Hat Chao Samran.

The Admiralty Chart also shows the name Chulai Point which corresponds to a Cape which is now called แหลมผักเบี้ย (Laem Phak Bia, /lɛ̌ːm pʰàk bîːa/).

Near Hat Chao Samran there is a small stream that flows into the sea to the north of the town centre (see Fig. 8.18). This fact corresponds to Lockyer and Schuster's statement (1878: 143) that "... a small brook ran into the sea close by."

This location is the place where the 1875 total solar eclipse observatory most likely stood. The north bank of the stream is logistically the most probable site (Fig. 8.19); otherwise ox carts and elephants from Phetchaburi—about 20 Km to the northwest—that brought people and materials would have had to cross the stream to get to the observatory. However, since no material evidence has been found, the actual observing site cannot be confirmed.

Fig. 8.17 The cross on the map on the left marks the position 13° 0′ 30″ N and 100° 2′ 10″ E on Admiralty Chart OBC2720 from 1860, and the circular icon on the right marks present-day Hat Chao Samran (formerly Bang Thalu) (left: Admiralty Chart sourced from the UK Hydrographic Office, www.ukho.gov.uk); right: courtesy Google Maps, 2018).

Fig. 8.18 On the left is the central area of Hat Chao Samran. The stream enters the sea 2.8 km north of Hat Chao Samran (courtesy: Google Maps, 2018).

Fig. 8.19 The mouth of Bang Thalu (Welu) Stream with a channel leading out to the sea. Without the channel the flat beach would prevent boats from entering the stream. This photograph was taken from the side of the stream most logistically reasonable for the site of the observatory (photograph: Visanu Euarchukiati).

8.3.5 The Return Trip

8.3.5.1 A Stop in Phetchaburi

After acknowledging people who helped during the eclipse Lockyer and Schuster's observation report (1878) provided no more activity of the expedition. Subsequent sections discuss the eclipse, the results, and the drawings from Shore and other Royal observers in Bangkok. What the expedition did after the eclipse is given in Schuster's *Biographical Fragments* (1932) and his unpublished manuscripts kept in the Schuster Papers and Photographs Archive at the Royal Astronomical Society, London (Schuster, 1875a and n.d.). Another colourful source of the same activities is Shore's *Flight of the Lapwing* (1881).

Immediately after the eclipse, the expedition started packing their instruments, following the Governor of Phetchaburi's advice that everything must be done by 11 April when the Siamese would start their New Year celebration (Songkran) and there would be no labour available. The packing was completed early on 11 April. The observatory complex was quickly dismantled while the expedition was leaving on the *Northern Siam Enjoying* Royal Steamer for Phetchaburi (Schuster, 1875a).

The visit to Phetchaburi was by invitation of the Governor who had already received the expedition at the observatory. Going with the expedition were a number of Europeans from Bangkok as well as officers of H.M.S. *Lapwing*. The party was accommodated in a house belonging to the Prime Minister, Chao Phraya Surawong Waiwat (Schuster, 1932).

The Governor of Phetchaburi hosted the expedition party for three days, from 12 to 14 April. The party was taken on a tour of Phra Nakhon Khiri, King Mongkut's (Rama IV) palace on the hill in the centre of Phetchaburi (Fig. 8.20), Khao Luang cave near Phetchaburi town (Fig. 8.21) and a nearby Laotian settlement (Shore, 1881: 485–493).

Fig. 8.20 A recent photograph of Phra Nakhon Khiri, King Rama IV's palace on the hill in the centre of Phetchaburi, with his 2-storey observatory building on the left (photograph: Visanu Euarchukiati).

Fig. 8.21 Left: one of Schuster's sketches of Khao Luang Cave in Phetchaburi that he visited on 13 April 1875. The place has changed little. In the photograph are Schuster's 3 temples, 70 sitting gods, sitting god, and kneeling goddess (left: after Schuster, 1875a; right: photograph by Visanu Euarchukiati).

8.3.5.2 A Stay in Bangkok

After a grand and formal banquet on the night of 14 April, the expedition left Phetchaburi in the morning on 15 April and reached Bangkok on the same day (Shore, 1881: 494). They then stayed on in Bangkok for an extended period at Alabaster's invitation (Schuster, 1932: 101).

As stated in Sub-subsection *8.3.3.2*, there is no record of Schuster's second audience with the King, but it is likely that an audience did take place. Otherwise, Schuster would not have written that the King had spoken English to him. The expedition must have received, also, a set of sketches of the corona and prominences by the Siamese court while they were back in Bangkok. Some of these sketches were selected for publication by Lockyer and Schuster (1878).

At the end of their stay, the expedition left Bangkok for Singapore. From there Schuster went on to India to visit Simla before returning to England. Beasley was bound for Japan and China, so it was Lott (1875) who took the results of the expedition back to England, possibly along with the sketches from the King's solar eclipse drawing contest.

8.3.5.3 The Royal Palace Drawing Contest

The centre line of the 6 April 1875 total solar eclipse also passed through Bangkok. At the Royal Palace, the King arranged an eclipse observation gathering on the ground in front of Chakri Mahaprasat Throne Hall and organized an eclipse drawing contest (Charoenwong, 2015: 49). Many sketches of the corona and prominences were made by the King, the Royal Family and noblemen. The sketches (e.g. see Figs. 8.22 and 8.23) must have been made available to the Royal Society expedition

Fig. 8.22 A sketch of the total solar eclipse of 6 April 1875 by King Chulalongkorn (Rama V) (after Lockyer and Schuster, 1878).

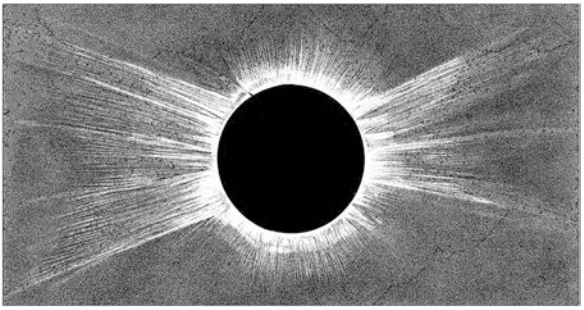


Fig. 8.23 A sketch of the total solar eclipse of 6 April 1875 by Prince Tong (Prince Thong Kong Kon Yai), noted for its similarity to a coronal drawing made by another observer during the total solar eclipse of 1874 (after Lockyer and Schuster 1878).

during their second stay in Bangkok. Details of this drawing contest are provided in the next chapter in this book (Euarchukiati, 2021).

8.3.5.4 The Meeting with Prince Maha Mala

During his long stay in Bangkok it is likely that Schuster also paid a visit to Prince Maha Mala, who wrote the total solar eclipse prediction in the *Royal Gazette*. This is evident in his writing:

> The chief astronomer at the present moment is the late King's youngest brother. When I went to see him he at once fetched his Nautical Almanac, which, by the way, is the English book most in use in Siamese libraries. He explained to me the method by which he had calculated eclipse … (Schuster, n.d.: 11)

The information was later elaborated on by Schuster (1875b):

> H.R.H. Chowfa Maha Mala, uncle of the King, is the chief astronomer of the Siamese at the present time. He showed me the way in which he had determined the time and duration of the eclipse at Bangkok. Taking the sun and the moon's apparent diameter from the Nautical Almanac, he determined by means of the project of their paths and their apparent velocity the time of the different contacts.

The above text followed immediately from the description of Schuster's lecture at Alabaster's house to the Young Siam Society. However, since there was no time after that lecture and the next day's voyage, the meeting with Prince Maha Mala could not have taken place that same day.

8.4 Concluding Remarks

The total solar eclipse of 6 April 1875 in Siam was a relatively unknown event only a few decades later. Siam in 1875 was poised to face economic and social upheavals propelled by internal reforms and colonial encroachments. Many personalities involved with the Royal Society expedition would go on to be instrumental in the country's transformation. In present-day Thailand the eclipse of 1875 is largely forgotten, swept away by more captivating matters, and overshadowed by the celebrated 1868 total solar eclipse predicted by King Mongkut (Rama IV). Most source materials about the 1875 eclipse in Siam are written in English. A few Thai sources briefly mention the event, but they often mistake it for the 1868 eclipse.

As far as the impact on the scientific world, the results from the Royal Society's total solar eclipse expedition to Siam in 1875 were not groundbreaking. It was the first time total solar eclipse observations depended solely on photography, and also the first time the camera had an objective prism, but the dispersion was so small that the results were far inferior to later observations (see Hale, 1897). Nevertheless, in this regard, the expedition was pioneering in its use of the prismatic camera.

The 1875 expedition was Sir Arthur Schuster's first professional responsibility, launching him on a long and successful career in physics, which included many more total solar eclipse expeditions. His writings relating to his experiences in Siam have illuminated a largely-forgotten episode in Thai history. The photographs from his 1875 expedition are preserved in the Schuster Papers and Photographs Archive at the Royal Astronomical Society in London and are valuable historical records for Thailand.

The King of Siam initiated the total solar eclipse expedition in 1875 by his invitation to the Royal Society, which would otherwise have not considered the country as an expedition destination. It was, therefore, an unusual episode for European science in Asia in the nineteenth century, one where Asians made the first move. An optimistic Siam was making herself known in the world. Schuster's glowing hope (1875b) was for the advancement of science in Siam, and this has indeed been achieved, especially in the field of astronomy.

Acknowledgements Thanks are due to the Thai Astronomical Society for trusting the author, in 2004, to translate into Thai Lockyer and Schuster's Report on the Total Solar Eclipse of April 6, 1875 allowing a better understanding of the event; the National Astronomical Research Institute of Thailand (NARIT) for trusting the author with writing a chapter in Thai on the 1875 total solar eclipse; the Royal Astronomical Society (RAS), London for allowing the NARIT research team access to, and to make photographic duplications of, items in their Schuster Papers and Photographs Archive; and Dr Sian Prosser, RAS Librarian and Archivist, for information regarding their Schuster Archive and for generous assistance during the visit by the NARIT research team.

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Chapter 9
Observations of the 6 April 1875 Total Solar Eclipse from the Grand Palace in Bangkok

Visanu Euarchukiati

9.1 Introduction

This is a further investigation into the events that took place in Siam, present-day Thailand, in connection to the 6 April 1875 total solar eclipse. Lockyer and Schuster mentioned in their "Report on the Total Solar Eclipse of April 6, 1875" and Schuster again stated in his "Biographical Fragments" that, in addition to the observations at Chulai Point, observations also took place in Bangkok at the Grand Palace. Mom Chao (Princess) Duangchit Chitraphong states in her biographical preface that her father, Prince Narisara Nuwattiwong, participated in an eclipse drawing contest organised by King Chulalongkorn (Rama V) before the start of totality. The Prince's name was one of the drawers' names given in Lockyer and Schuster's report, thus it is most likely that the eclipse observations and the drawing contest happened at the same place and at the same time.

A few historic personalities are mentioned in the documents. Some were already at the height of their careers, e.g., Prince Maha Mala, while others would go on to make their marks in arts, politics and society. Not one of the names mentioned would be forgotten. All were important figures in the history of Siam and Thailand, even as late as the mid-twentieth century.

Apart from compiling a list of people who definitely observed the eclipse from the Grand Palace, it may be possible to pinpoint the location where the observations took place. Clues are provided by a little-known mural at Wat Ratchapradit, a temple near the Grand Palace built by King Mongkut (Rama IV).

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9.2 Events Surrounding the 6 April 1875 Total Solar Eclipse

9.2.1 British Activities

Responding to King Chulalongkorn's invitation to observe the total solar eclipse in Siam, a British eclipse expedition led by Sir Arthur Schuster (1851–1934; Fig. 9.1) sailed from England on 11 February 1875, reaching Bangkok on 28 March 1875 and had an audience with the King on the next day. The expedition departed Bangkok on 30 March 1875 to arrive at Bang Thalu near Chulai Point on 31 March 1875. Jules Janssen (1908–2005; Fig. 9.2), the French astronomer, had arrived one week earlier (Lockyer and Schuster, 1878: 142–143).

Members of the British eclipse expedition observed the 6 April 1875 solar eclipse from late morning until the afternoon at Bang Thalu. They packed up by 11 April 1875 and went to stay in Phetchaburi, a provincial city, as guests of the Governor of Phetchaburi (Schuster, Biographical fragments, 1932: 94–100), before returning to Bangkok on 15 April 1875 (Shore, 1881: 494).

The expedition team stayed on in Bangkok for a few more days (Lott, 1875: 172; Schuster, 1932: 172). They must have had another audience with the King since they received many drawings by the Siamese, including one by the King himself. Further details of the activities of the British expedition are presented in the preceding chapter of this book (Euarchukiati, 2021).

Fig. 9.1 Arthur Schuster, aged about 38 (courtesy: Wellcome Library, London, and used under CC BY 4.0).

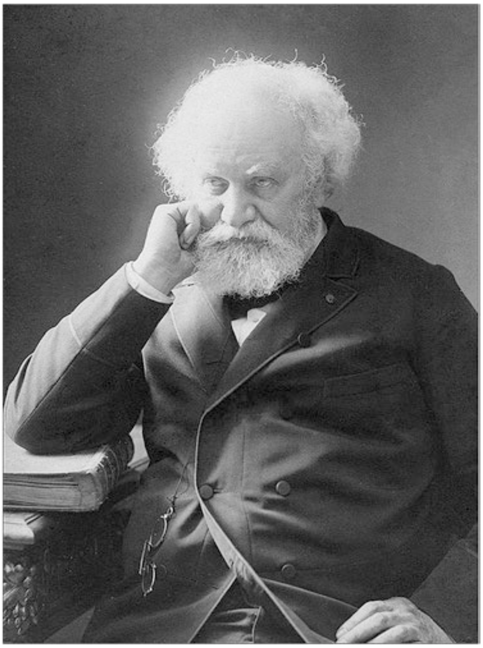

Fig. 9.2 Pierre Jules César Janssen, French astronomer (https://en.wikipedia.org/wiki/Pierre_Janssen#/media/File:Jules_Janssen_3.jpg).

9.2.2 Thai Activities

King Chulalongkorn considered the astronomers as his private guests (Munsin, 2012: 264–265). Having met the British eclipse expedition on 29 March 1875, the King must have received Jules Janssen about a week earlier.

Bangkok was on the path of totality for the 6 April 1875 total solar eclipse. A number of people in Siam must have known about the event, while some could even calculate its occurrence ahead of time. Mom Chao (M.C., or Princess) Duangchit Chitraphong (1908–2005; Fig. 9.3), a daughter of Prince Narisara Nuwattiwong (Prince Chitcharoen) wrote in her biographical preface to a collection of letters by Prince Narisara, recounting an episode that her father must have told her:

> There was going to be a total solar eclipse visible in Bangkok on Tuesday of the first day of the waxing moon of the fifth lunar month, on 48 minutes after noon. As usual, European astrologers requested permission to set up telescopes for observation. His Majesty designated the front of Chakri Maha Prasat Throne Hall as the observation site. At that time, the King also gave paper sheets to the royalty and noblemen present, announcing an eclipse drawing contest. (Narisara Nuwattiwong, 1963: [6]).

Schuster's account of the event in Bangkok, given in his *Nature* article "Science in Siam", adds to M.C. Duangchit's:

> On the day of the eclipse several telescopes, one of which had been lent to the King by Dr. Janssen, were set up on the lawn in the front of the palace. The exact time was determined by Mr. Alabaster and Capt. Bush in order to find the exact time of the different contacts. As totality approached, the King made a speech to the members of the Royal Family, who were all assembled, telling them why solar eclipses were observed, and why large sums of money were spent for that purpose. (Schuster, 1875).

Fig. 9.3 Princess Duangchit Chitraphong, a daughter of Prince Narisara Nuwattiwong (Prince Chitcharoen)(Euarchukiati Collection).

9.2.3 Judges and Winners

The drawing contest was properly administered, with a panel of judges:

> A number of senior royalty were the judges. There were three winners in the contest, but only two could be recalled. They were Prince Bhanurangsi Sawanwongse and Prince Kashemsri Subhayok. The winning drawings were finely drawn in coloured pencils. (Narisara Nuwattiwong, 1963: [6]).

M.C. Duangchit's father was not a winner, but he could remember his drawing:

> Prince Chitcharoen, who was 10 at the time, also entered the contest. He drew a rough pencil sketch, with random lines just enough to show the radiating corona. It was a straight-to-the-basket type. (ibid.)

Prince Chitcharoen, or Prince Narisara Nuwattiwong, was born on 28 April 1863 (Narisara Nuwattiwong, n.d.), so on the eclipse day he would have been nearly 12. The age given from memory is a near enough approximation. His drawing might not be up to the judges' standards, but was considered remarkable by the British eclipse expedition (Lockyer and Schuster, 1878: 153):

> A great number of drawings have been made by the Siamese. We especially note the drawings made by the following gentlemen :—
>
> H.R.H. Chau fa Maha Mala (fig. 17, Plate 14).
> H.R.H. Prince Devanndaywongse (fig. 18, Plate 14).
> H.KH. Prince Chetochereun (fig. 19, Plate 13).

Prince Chetochereun was Prince Chitcharoen. The published drawing was the first work of art by the boy who would grow up to be Siam's supreme artist. Lockyer and Schuster's Report must have been available in Siam, because M.C. Duangchit knew about it:

> The European astrologers who set up the telescopes were interested in the contest pictures, asked to see them and took them away. The astrologers later wrote a report for an astrological journal and illustrated it with two drawings that best matched the actual appearance, and the names of the artists were shown under the reproductions. (Narisara Nuwattiwong, 1963: [6]–[7]).[1]

In fact, there are more than two drawings presented in the report. One drawing was made by King Chulalongkorn:

> His Majesty the King has sent a drawing of the prominences as seen by him during the eclipse (fig. 20, Plate 14). (Lockyer and Schuster, 1878: 153).

Earlier, Schuster (1875) had written that during totality His Majesty observed the corona and the protuberances through a telescope, carefully noting down what he saw and making a sketch of the protuberances.

What is even more interesting is the mention of two plates of photographs of the eclipse taken in the Grand Palace:

> [His Majesty] had ordered one of the princes to take photographs of the corona. Two photographs were thus secured which by no means are inferior to those taken at the observatory of Bangtelue. The original negatives of those photographs have been sent to England as a present from the King to the Royal Society. (ibid.).

The current status of these plates deserves further investigation.

There were two drawings where M.C. Duangchit provided the names of the artists, and more information about them:

> One picture was drawn by Prince Devan Udayawongse who is now praised as the father of foreign affairs, but for astrology enthusiasts he was known as Thailand's authority on astrology. Another picture was by Prince Chitcharoen who in later life would become the great craftsman of Siam (Narisara Nuwattiwong, 1963: [7]).

9.3 Personalities at the Grand Palace

The personalities known to be involved in the total solar eclipse observations at the Grand Palace of Bangkok on 6 April 1875 were historic figures. Many of them drew the eclipse. Three different sources allow us to identify many of those who observed the eclipse.

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[1] At the time M.C. Duangchit was writing there was no clear distinction between astronomy and astrology and there were no separate Thai words for astronomer or astronomy. Instead, the word 'astrology' also was used for all matters astronomical. Thus, in Duangchit's account, the astronomers in Siam for the eclipse were 'astrologers', and they published their report in an 'astrological' journal. With this translation I decided to retain Duangchit's original terminology, rather than to use the modern terminology.

9.3.1 *From Lockyer and Schuster's* Report on the Total Solar Eclipse of April 6, 1875

9.3.1.1 King Chulalongkorn

Title: Phra Chulachomklao Chaoyuhua
Posthumous name: Rama V
Born: 20 September 1853
Died: 23 October 1910

First son by a Royal Queen in the reign of King Mongkut. He was only 15 years old when his father died in October 1868, and he succeeded to the throne under the regency of Somdet Chao Phraya Borom Maha Sri Suriyawong. Over the next five years he was prepared to assume his duties by observing court business and by travels to British Malaya and the Dutch East Indies in 1871 and to Malaya, Burma (Myanmar), and India in 1871–1872.

Following his coronation in November 1873, the young King (Fig. 9.4) enacted a series of ambitious reforms, beginning with the abolition of slavery, the improvement of judicial and financial institutions, and the institution of appointed legislative councils. His reforms antagonized conservative factions and precipitated a political crisis early in 1875, the same year in which he observed the solar eclipse (see Fig. 9.5).

In 1892 he created 12 ministries organized on Western lines, responsible for such functions as Provincial Administration, Defense, Foreign Affairs, Justice, Education, and Public Works.

France provoked war with Siam in 1892, and by treaties with France up to 1907 Siam had to give up its rights in Laos and western Cambodia. In 1909 Siam ceded to Great Britain the four Malay states of Kelantan, Trengganu, Kedah and Perlis.

In relations with the West, Chulalongkorn even-handedly balanced the colonial powers against one another and consistently sought to have Siam treated as an equal among nations. During tours of Europe in 1897 and 1907, he was received as an equal by Western monarchs (Liesangthern, 2007).

9.3.1.2 Prince Maha Mala

Born as: Chaofa Chai Klang
Title: Chaofa (Prince) Maha Mala Krom Phraya Bamrap Porapak
Born: 24 April 1819
Died: 1 September 1886

Prince Maha Mala (Fig. 9.6) started his career during the reign of King Rama III. In the reign of King Rama IV (Mongkut) Prince Maha Mala worked in the Office of the Lord Steward of the Royal Household with the duties to oversee the Royal Palace and to judge cases of disputes. He also assumed responsibilities in the

Fig. 9.4 King Chulalongkorn (Rama V) (https://en.wikipedia.org/wiki/Chulalongkorn#/media/File:Chulalongkorn_LoC.jpg).

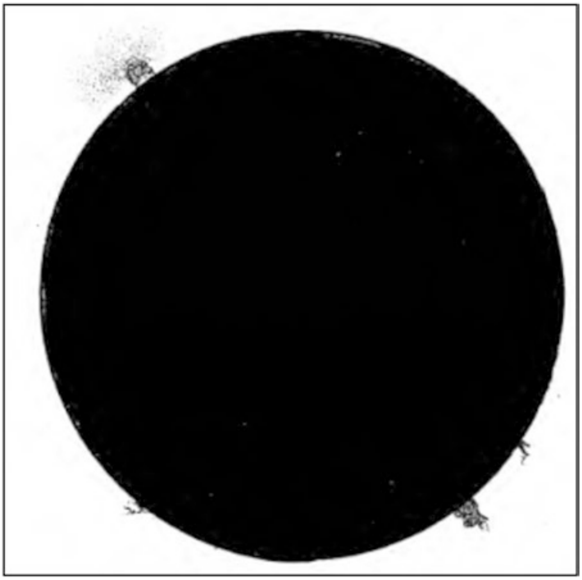


Fig. 9.5 A sketch of the total solar eclipse of 6 April 1875 by King Chulalongkorn (Rama V), showing prominences that were visible (after Lockyer and Schuster 1878).

Fig. 9.6 Prince Maha Mala (1819–1886) (adapted from Wellcome Library, London, and used under CC BY 4.0).

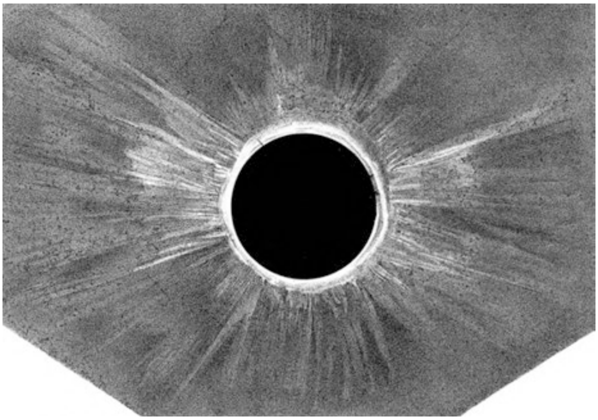


Fig. 9.7 A sketch of the total solar eclipse of 6 April 1875 by Prince Maha Mala (after Lockyer and Schuster, 1878).

Royal Elephant Department and the Department of Religious Affairs. In the reign of King Chulalongkorn the Prince was responsible for the Royal Treasury and was the Minister with the authority over cities of the North Zone (Krom Mahatthai) (Chaofa Maha Mala …).

As a poet, Prince Maha Mala wrote many short poems and a book of poems describing royal ceremonies throughout the year (Vajirayana Digital Library, 2020).

The Prince studied King Mongkut's astronomical calculations and became one of the few astronomers who could predict the transit of Venus in 1874 and calculate the time and location of the total solar eclipse of 6 April 1875 (Bhumadon, 2012: 85). His drawing of the eclipse is shown in Fig. 9.7.

9.3.1.3 Prince Thong Kong Kon Yai

Born as: Phra-ongchao (Prince) Thong Kong Kon Yai
Title: Krom Luang Prachak Silapakhom
Born: 5 April 1855
Died: 25 January 1925

Prince Thong (Fig. 9.8) was a son of King Mongkut, and one of the students of Anna Leonowens, the renowned English governess. He was ordained as a novice in 1868 and became a monk in 1875 (Krom Luang …). It was not known whether the Prince was still a novice when he drew his solar eclipse picture, but it was unlikely since he would not remain in monkhood for an extended period. It is assumed that he drew the picture (shown in Fig. 9.9) before entering monkhood, having turned 20 just one day before the eclipse.

The Prince was instrumental in keeping Siam's territorial integrity in the Northeast region during the 1892 Franco-Siam dispute. Prince Thong became the Viceroy of the Northeast, and a major provincial city of Udon Thani grew up and

Fig. 9.8 Prince Thong Kong Kon Yai (Prince Tong) (courtesy: National Archives, Bangkok).

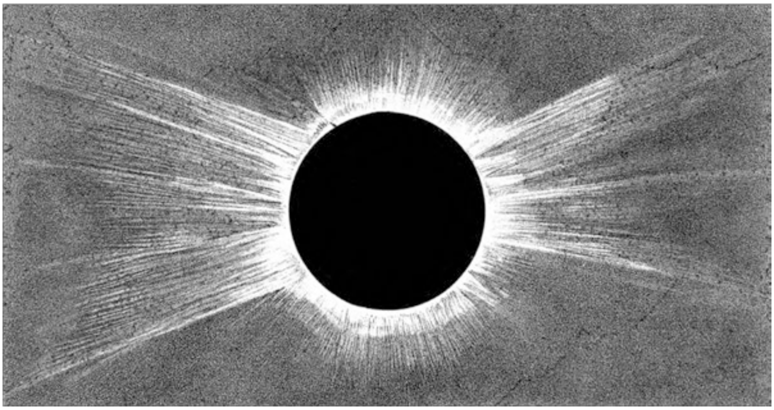


Fig. 9.9 A sketch of the total solar eclipse of 6 April 1875 by Prince Thong Kong Kon Yai (after Lockyer and Schuster 1878).

prospered as the center of the Prince's administration. The Prince is highly revered by the people of Udon Thani to this day.

In 1899 Prince Thong was appointed the Admiral of the Navy. However, in 1910 he was banished from the Royal Court after being involved in a court scandal (Krom Luang …).

Prince Thong's drawing was singled out by Lockyer and Schuster (1878: 52), who referred to him as Prince Tong:

> The west side of the corona seems much more compact, the east side broken up into what the Siamese called fishtails. The similarity is, perhaps, most striking between Mr. Bright's drawing (L. C, p. 51) of the corona in 1874, and the drawing made by Prince Tong (fig. 14, Plate 13), by order of His Majesty the King of Siam, of the corona in 1875. The two drawings could certainly pass for representations of one and the same eclipse.

9.3.1.4 Prince Devan Udayawongse

Born as:	Phra-ongchao (Prince) Devan Udayawongse
Title:	Somdet Krom Phraya Devawongse Varoprakar
Born:	27 November 1858
Died:	28 June 1923

A son of King Mongkut, Prince Devan (Fig. 9.10) studied English in the Grand Palace (Devawongse Varoprakar, n.d.). His proficiency in English was such that when Schuster was giving a lecture in Bangkok on the night of 29 March 1875, the young Prince was one of the interpreters (Schuster, 1875). His eclipse drawing (Fig. 9.11) did not win the contest, but was included in Lockyer and Schuster's Report.

At 20, Prince Devan became King Chulalongkorn's personal secretary where he gained experience in Foreign Affairs. In 1885, at 27, he assumed the responsibility of the Minister of Foreign Affairs and started restructuring the Ministry as well as studying the organization of governments in European countries. With this

Fig. 9.10 Prince Devan Udayawongse, Devawongse Varoprakar (https://en.wikipedia.org/wiki/Devawongse_Varoprakar#/media/File:Prince_Devan_Uthayavongse.jpg).

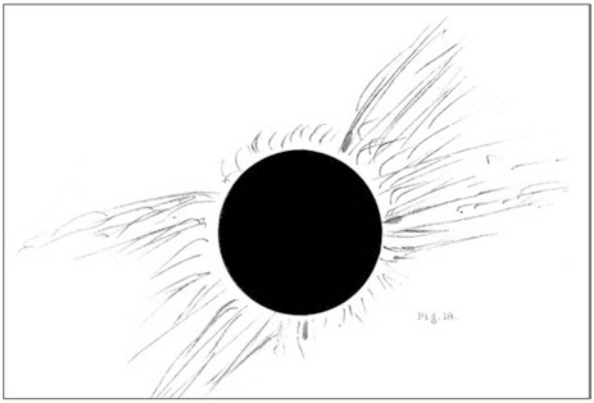


Fig. 9.11 A sketch of the total solar eclipse of 6 April 1875 by Prince Devan Udayawongse (after Lockyer and Schuster 1878).

knowledge, Prince Devan helped King Chulalongkorn establish the basis of modern Government Ministries.

Prince Devan was instrumental in propelling Siam to be recognized as a modern nation and its monarch would attain a status equal to that of other world monarchs. His diplomatic skills kept Siam an independent Kingdom after the Franco-Siam War of 1893 (May Kyi Win, 2005: 90–91).

9.3.1.5 Prince Chitcharoen

Born as: Phra-ongchao Chitcharoen
Title: Somdet Phrachao Borommawongthoe Chaofa Krom Phraya Narisara Nuwattiwong
Born: 28 April 1863
Died: 10 March 1947

A son of King Mongkut, Prince Chitcharoen (Fig. 9.12) held many important positions in Government and the military, culminating in the regency while King Rama VII was not in Siam. He became known by his title as Prince Naris. However,

Fig. 9.12 Prince Chitcharoen, or Prince Narisara Nuwattiwong, photographed with his mother and his first daughter (courtesy: National Archives, Bangkok).

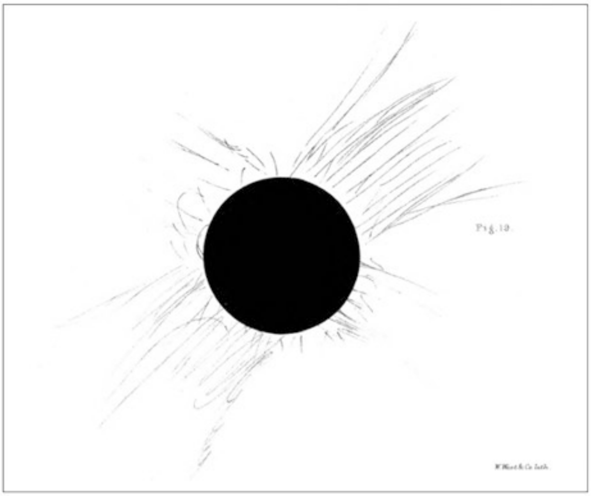


Fig. 9.13 A sketch of the total solar eclipse of 6 April 1875 by Prince Chitcharoen (after Lockyer and Schuster 1878).

as professed in his early drawing of the total solar eclipse (Fig. 9.13), the Prince was a genuine artist. He was the architect of Wat Benchamabophit, the famous marble temple. He created many paintings, drawings, illustrations and sculptures, composed music and musical plays (Chaofa Krom …)

Prince Naris was a polymath (Narisara Nuwattiwong, n.d.). His correspondence with Prince Damrong Rachanuphap, another son of King Mongkut, constitutes a treasure trove of knowledge on Thai history and culture. It is through the collection of his correspondence with another scholar, Phraya Anuman Rajadhon, that the story of the eclipse drawing contest was told, as a story in Prince Naris' biography by his daughter, M.C. Duangchit.

9.3.2 From Schuster's 1875 "Science in Siam" Research Paper

9.3.2.1 Henry Alabaster

Born: 22 May 1836
Died: 9 Aug 1884 (Garnier, n.d.-b)

After graduation from King's College, London, Henry Alabaster (Fig. 9.14) started work in Siam as a Deputy Consul in 1857. He was one of the surveyors for the construction of the New Road, the first modern road in Siam. When King Mongkut went to Wah-koa to view the total solar eclipse of 18 August 1868 (Soonthornthum and Orchiston, 2021), Alabaster led a contingent of French astronomers to the site (see Orchiston and Orchiston, 2017). In 1873, after resigning from the British Civil Service, Alabaster returned to Siam and became King Chulalongkorn's personal adviser.

Fig. 9.14 A bust of Henry Alabaster in a monument dedicated to his memory by King Chulalongkorn at Bangkok Protestant Cemetery (photograph: Visanu Euarchukiati).

Alabaster's accomplishments include setting up the first museum in Siam, founding the Survey Office, planning the telegraph service (with Mom Daeng, pictured in the Chulai Point eclipse observation camp), mapping the Gulf of Thailand (with Captain Alfred Loftus, who also was at Chulai Point) and recruiting James McCarthy from the Survey of India to map the frontiers of Siam. Alabaster also helped Prince Bhanurangsi Savangwongse (see Sub-section 9.3.3.1 below) in starting the postal service in Siam. On a less stately matter, it was Alabaster who first introduced the cattleya orchid for cultivation in Siam (Garnier, n.d.-b).

At the Grand Palace on the total solar eclipse day of 6 April 1875, Alabaster and Captain John Bush provided the King with the exact time during the eclipse (Schuster, 1875).

9.3.2.2 Captain John Bush

Title: Phraya Wisut Sakhoradit
Born: 4 August 1819
Died: 3 April 1905 (Garnier, n.d.-a)

Captain Bush arrived in Siam during the reign of King Mongkut and commanded Royal yachts for King Mongkut and King Chulalongkorn. He was the principal shareholder and Director of the successful Bangkok Dock Company. More importantly, he was the first Harbour Master of the port of Bangkok for thirty years. The post was a Royal appointment and Captain Bush received the initial title of Luang Wisut Sakhoradit Chao Tha.

When Anna Leonowens and her son arrived in Bangkok for the first time, it was Captain Bush who received them. In an old sector of Bangkok there is Soi Captain Bush (Captain Bush Lane) that leads to the river. The old family home belonging to the Captain used to stand at the end of this lane (Garnier, n.d.-a).

The Royal Yacht that took King Mongkut to the total solar eclipse observing site at Wah-koa in 1868 was captained by John Bush, but in 1875 he was at the Grand Palace, calculating the time of the eclipse for King Chulalongkorn. He confirmed the total solar eclipse time on 6 April 1875 at 2pm 13min 34sec.

9.3.3 From M.C. Duangchit

9.3.3.1 Prince Bhanurangsi Sawangwongse

Born as: Chaofa (Prince) Bhanurangsi Sawangwongse
Title: Krom Phraya Bhanubandhu Wongseworadej
Born: 11 January 1859
Died: 13 June 1928 (Bhanurangsi Savangwongse, n.d.)

A son of King Mongkut, Prince Bhanurangsi (Fig. 9.15) was also a maternal brother of King Chulalongkorn. He was educated in the palace and later received a military education in the Royal Guards Division. While starting to learn English in 1873 he also became an apprentice in court procedures under Prince Maha Mala (see Section 9.3.1.2).

Prince Bhanurangsi was a military man. His positions include Minister of War, Minister of Defence, the first Field Marshall, Admiral, and a member of Supreme Council of State of Siam. He was the first Director of the Post and Telegraph Office, having previously started the first postal delivery of Court newspaper within and around the Grand Palace (Amonrat Chueachan …).

Although Prince Bhanurangsi's eclipse drawing was one of the three winners in the contest, Lockyer and Schuster did not show it in their Report.

9.3.3.2 Prince Kashemsri Supayok

Born as: Phra-ong Chao Kashemsri Supayok
Title: Krom Muen Thiwakon Wongprawat
Born: 17 August 1857
Died: 3 January 1916

A son of King Mongkut, Prince Kashemsri (Fig. 9.16) directed the Department of Mother-of-pearl Artists, participated in the Temple of the Emerald Buddha restoration project and was the Director of the State Property Department. The Prince had a short civil service career due to illness, but took on temporary assignments from time to time.

Fig. 9.15 Prince Bhanurangsi Savangwongse (courtesy: siamimage.net).

Prince Kashemsri was a keen practitioner of performing arts—traditional musical theatre, modern plays and music. His instruments were the Thai 3-string fiddle and Thai xylophone. His traditional Thai music ensemble was well known in the capital. The Prince also wrote many poems (e.g., see Fig. 9.17) and contributed articles to Prince Bhanurangsi's Court newspaper (Thai Literature Directory, n.d.-a).

Although Prince Kashemsri's eclipse drawing was one of the three winners in the contest, Lockyer and Schuster did not show it in their Report.

9.4 Location Where the Observations Were Made

Bangkok was on the total solar eclipse path on 6 April 1875 (see Fig. 9.18). The previous total solar eclipse visible from Siam occurred only seven years before, and many, including King Chulalongkorn, had seen the phenomenon. It was *the* event to observe for the new generation of Siamese.

Fig. 9.16 Prince Kashemsri Supayok (https://en.wikipedia.org/wiki/Kashemsri_Subhayok#/media/File:His_Royal_Highness_Prince_Kashemasri_Supayok.jpg).

Fig. 9.17 Prince Kashemsri's poem telling an episode from the Ramakian (Thai Ramayana), among the Ramakian murals in the cloister, the Temple of the Emerald Buddha; Thotsakan (Ravana) had a nightmare and asks his brother Phiphek, the astrologer demon, to interpret the omen (photographs: Visanu Euarchukiati).

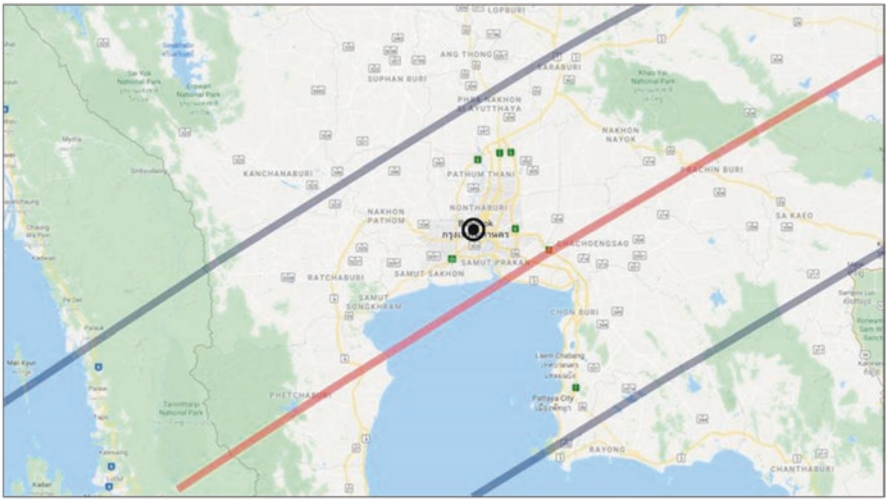


Fig. 9.18 Bangkok is on the path of totality for the total solar eclipse of 6 April 1875, although not right on the centerline; totality at the Grand Palace (the black bull's-eye) lasted more than three minutes (courtesy: Google Maps).

Fig. 9.19 The front of Chakri Maha Prasat Throne Hall is a very large space (photograph: Visanu Euarchukiati).

It is already known generally where the King observed the total solar eclipse:

> His Majesty designated the front of Chakri Maha Prasat Throne Hall as the observation site. (Narisara Nuwattiwong, 1963: [6]).

> On the day of the eclipse several telescopes, one of which had been lent to the King by Dr. Janssen, were set up on the lawn in the front of the palace. (Schuster, 1875).

However, as Fig. 9.19 indicates, the lawn in front of the Charki Maha Prasat Throne Hall is very large. Can we determine a more specific location from existing records?

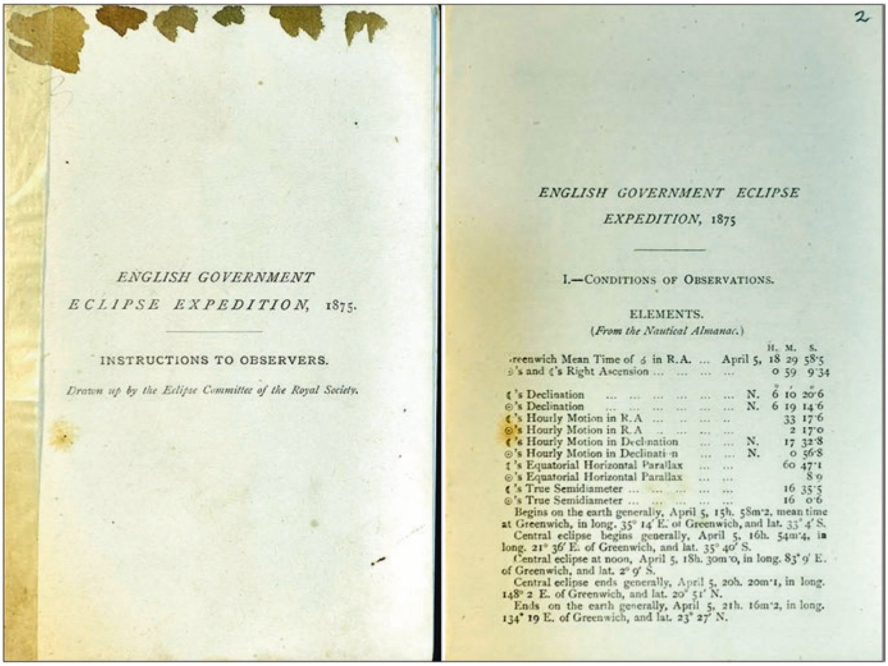
9.4.1 Determining Direction

It can be assumed that totality was the most crucial period for the eclipse observation. Calculations from the past (see Fig. 9.20) provided us with an approximate timings:

> Bangkok (Siam) will be found to lie rather north of the central. The circumstances of the eclipse at this point are as follows (long. 6h. 42m. 6s. E.; lat. 13° 42′ 5″ N.).
>
> The partial eclipse begins at 0h. 51m. 6s. mean time at Bangkok, 134° from the north point towards the west, and 168° from the vertex eastward, for direct[i] image; the sun at an altitude of 76°. The total begins at 2h. 13m. 7s. and continues 3m. 54s., the sun about 57° high, and the partial phase ends at 3h. 33m. (Eclipse Committee of the Royal Society, 1875).

In Siam, Captain Bush provided the times in a note (in Thai) to the King, which was then published in the *Royal Gazette*:

> Your servant, Phra Wisut Sakhoradit, humbly presents about the solar eclipse as follows. On Tuesday of the fifth lunar month, the first day of the waxing moon, the year of the pig, still the year ending with 6, I set up an eclipse viewing apparatus in the Grand Palace at latitude 13° 45′ 28″ N and longitude 6h 41m 52s when the eclipse started. It did not appear certain when the Moon very lightly touched the Sun. The chronometer clock was noon 57m 23s, but the clock was wrong by 4m 35s and a half. True mean time was noon 52m 47s and a half.



ENGLISH GOVERNMENT
ECLIPSE EXPEDITION, 1875.

INSTRUCTIONS TO OBSERVERS.

Drawn up by the Eclipse Committee of the Royal Society.

2

ENGLISH GOVERNMENT ECLIPSE
EXPEDITION, 1875

I.—CONDITIONS OF OBSERVATIONS.

ELEMENTS.
(*From the Nautical Almanac.*)

		H.	M.	S.
reenwich Mean Time of ☌ in R.A. ...	April 5,	18	29	58·5
☉'s and ☾'s Right Ascension		0	59	9·34
		°	′	″
☾'s Declination	N.	6	10	20·6
☉'s Declination	N.	6	19	14·6
☾'s Hourly Motion in R.A			33	17·6
☉'s Hourly Motion in R.A			2	17·0
☾'s Hourly Motion in Declination	N.		17	32·8
☉'s Hourly Motion in Declination	N.		0	56·8
☾'s Equatorial Horizontal Parallax			60	47·1
☉'s Equatorial Horizontal Parallax				8·9
☾'s True Semidiameter			16	35·5
☉'s True Semidiameter			16	0·6

Begins on the earth generally, April 5, 15h. 58m·2, mean time at Greenwich, in long. 35° 14′ E. of Greenwich, and lat. 33° 4′ S.

Central eclipse begins generally, April 5, 16h. 54m·4, in long. 21° 36′ E. of Greenwich, and lat. 35° 40′ S.

Central eclipse at noon, April 5, 18h. 30m·0, in long. 83° 9′ E. of Greenwich, and lat. 2° 9′ S.

Central eclipse ends generally, April 5, 20h. 20m·1, in long. 148° 2 E. of Greenwich, and lat. 20° 51′ N.

Ends on the earth generally, April 5, 21h. 16m·2, in long. 134° 19 E. of Greenwich, and lat. 23° 27′ N.

Fig. 9.20 The *English Government Eclipse Expedition, 1875: Instructions to Observers* (courtesy: Schuster Papers and Photographs Archive, Royal Astronomical Society).

> TOTALITY
>
> The clock read 2h 18m 10s, but the clock was wrong by 4m 36s. True time was 2h 13m 34s. Totality lasted 3m 45s. At the end of the eclipse the clock was 3h 37m 45s, but the clock was wrong by 4m 36s. True time, mean time, was 3h 33m 9s. May it please Your Majesty (Phra Wisut …).

The Grand Palace was located on the eastern bank of the Chao Phraya River, a little north of the eclipse centreline, but well within the zone of totality. Astronomical convention before 1925 was to start the day at noon. This means that totality occurred in the afternoon. Details are as follows (after Eclipse predictions by Fred Espenak …):

Lat.: 13.7501° N
Long.: 100.4913° E

Duration of Totality: 3m 51.5s

Event	*Date*	*Time (UT)*	*Alt*	*Azi*
Start of partial eclipse (C1):	1875/04/06	06:09:35.6	75.8°	239.5°
Start of total eclipse (C2):	1875/04/06	07:31:28.6	57.0°	260.3°
Maximum eclipse:	1875/04/06	07:33:24.6	56.5°	260.6°
End of total eclipse (C3):	1875/04/06	07:35:20.0	56.1°	260.8°
End of partial eclipse (C4):	1875/04/06	08:51:10.6	37.7°	267.4°

Note that at maximum eclipse, at 2:33 pm local time, the Sun would be at an altitude of 56.5° and about 10° to the south from west. This orientation is shown in Fig. 9.21.

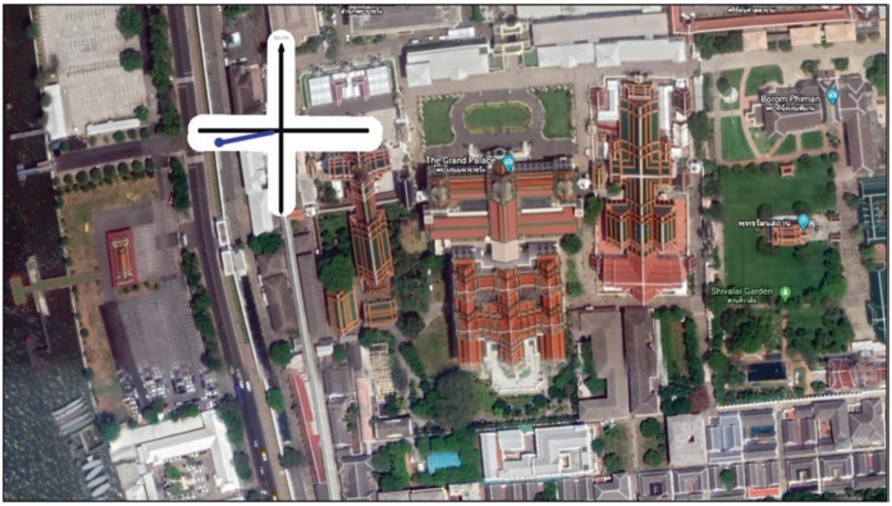


Fig. 9.21 A satellite view of the Grand Palace, showing the direction of the totally eclipsed Sun on 6 April 1875 (courtesy: Google Earth, 2020; illustration: Visanu Euarchukiati).

9.4.2 The Murals at Wat Ratchapradit

Wat Ratchapradit (Fig. 9.22) is a temple that was built by King Mongkut in 1864 near the Grand Palace. In the ordination hall (Ubosot) there are beautiful murals depicting Royal ceremonies of the twelve months, including the Giant Swing Ceremony, Songkran, Visakha Puja (Wat Ratchapradit …, n.d.). In addition, on both sides of the main door are astronomical murals (see Fig. 9.23).

From inside the hall, the mural on the right shows a completely eclipsed Sun, with visible corona, shining black light on the land. It is highly inauspicious for a King to be under an eclipsed Sun. This may be the reason why the King is not drawn in this panel. Instead he is in the left-hand panel standing on a high platform, looking through a hand-held telescope at a celestial object. It is generally believed that the King in the picture is King Mongkut (Rama IV), the only astronomer King Thailand has known (see Soonthornthum and Orchiston, 2021). This is his temple, and he is famous for predicting and observing the 18 August 1868 total solar eclipse from Wah-koa, in the company of distinguished local and international guests (e.g. see Orchiston and Orchiston, 2022; Soonthornthum and Orchiston, 2021) and a contingent of French professional astronomers (Orchiston and Orchiston, 2017). For many Thai people, this is Thailand's archetypal total solar eclipse, and King Mongkut is their revered 'Father of Thai Science'.

9.4.2.1 Dating the Murals

The murals of the Royal ceremonies were painted during the reign of King Chulalongkorn, and their subject matter was taken from the book *Phra Ratchaphiti Sibsong Duen* (*Royal Ceremonies over the 12 Months*) written by King Chulalongkorn in 1888 (Thai Literature Directory, n.d.-b). The eclipse murals were painted at the same time. It is reasonable to assume that the murals were painted after the book's publication, i.e., at least 13 years after the total solar eclipse was observed from the Grand Palace.

9.4.2.2 Painting from an Experience of the Event in 1875

It is unlikely that the painter had been to Wah-koa in 1868. On the other hand, the painter may have been old enough to have witnessed the total solar eclipse observation at the Grand Palace, or had at least been told about the event from someone who did observe it first-hand. As Fig. 9.25 illustrates, the mural is very accurate in depicting the Dusidaphirom Throne Hall (Wat Ratchapradit …, n.d.), where the King is standing and looking through a telescope. This Throne Hall is adjacent to Chakri Maha Prasat Throne Hall and is one of two throne halls with jutting-out palanquin mounting platforms.

Fig. 9.22 The entrance of Wat Ratchapradit leads directly to the ordination hall (https://en.wikipedia.org/wiki/Wat_Ratchapradit#/media/File:วัดราชประดิษฐสถิตมหาสีมารามราชวรวิหาร_เขตพระนคร_กรุงเทพมหานคร_27.jpg).

Fig. 9.23 Eclipse murals at Wat Ratchapradit; the left-hand panel shows a king looking through a telescope, and the right-hand panel shows an eclipsed Sun (photograph: Visanu Euarchukiati).

If the Sun was at an altitude of 56° during totality, then King Chulalongkorn would have had to look up quite steeply in order to see the total eclipse. He also would have had to look through the telescope several times in order to draw his sketch. The artist who painted the temple mural must have seen this, or have heard about it. The King's telescope probably would have been on a mounting or a stand, but such equipment was not familiar to the lay public, or artists, at the time, so is not included in the mural.

Fig. 9.24 Close up view of the mural at Wat Ratchapradit showing a king observing a celestial object through a telescope (photograph: Visanu Euarchukiati).

Fig. 9.25 Side-by-side comparisons of the Dusidaphirom Throne Hall in the mural (left) and a present-day photograph (right); allowing for perspective and the slightly different orientation of the mural depiction, the match is remarkable (photographs: Visanu Euarchukiati).

9.4.3 The Royal Observing Site

The palanquin mounting platform at the Dusidaphirom Throne Hall was a convenient location for the King to have made his observations, as depicted in the mural. Furthermore, in 1875 the adjacent open ground was far more extensive than is the case today (see Fig. 9.26), because the Chakri Maha Prasat Throne Hall had not been built. Its foundation stone was laid in 1876 and a completion celebration was

Fig. 9.26 A recent westward view showing Dusidaphirom, Chakri Maha Prasat and Dusit Maha Prasat Throne Halls, but in 1875 the space between the Dusidaphirom and Dusit Maha Prasat Throne Halls was empty (photographs: Visanu Euarchukiati).

staged in 1882 (Nepenthes, 2020). So, on the day of the total solar eclipse in 1875 the ground should have been empty, having already been cleared for the construction of the new Throne Hall.

There is another raised platform on the opposite side of the paved courtyard. The building is the Aphon Phimok Prasat Throne Hall, a small pavilion next to Dusit Maha Prasat Throne Hall. Both buildings were built before 1875, but the platforms on the Aphon Phimok Prasat Throne Hall would have been inconvenient: the east-facing platform was in the wrong direction for observation, while the view from the west-facing platform would have been blocked by the Dusit Maha Prasat Throne Hall.

With the likely observation location converging on the Dusidaphirom Throne Hall, it is appropriate to try to simulate the view of the eclipsed Sun from this location. On the day of the total solar eclipse, 6 April 1875, there were no tall buildings to the left or the right. The Sun would have shone high above Dusit Maha Prasat Throne Hall, clearly visible to everyone, standing or sitting, on the very large vacant ground between the Dusidaphirom and Dusit Maha Prasat Throne Halls. If the figure of the King with his upturned telescope is now superimposed on the above picture (see Fig. 9.27), and adjusted to allow for the perspective distortion by aligning the umbrella pole with the edge of the window, the angle of the telescope becomes plausible given the simulated position of the Sun in this photograph.

Fig. 9.27 A wide angle westward view from Dusidaphirom Throne Hall including the simulated eclipsed Sun at totality and a superimposed figure of the King shown in the eclipse-viewing mural (photograph and illustration: Visanu Euarchukiati).

9.5 Concluding Remarks

The total solar eclipse of 6 April 1875, although visible in Thailand, remains largely forgotten. Even though existing documents provide enough details to inform the public of the event, not all major records have been translated from English into Thai. This investigation into the personalities and location of solar eclipse observations at the Grand Palace in Bangkok presents another aspect of the story, whose main narrative centres on the scientific observations that were made at Chulai Point and are discussed in the previous chapter in this book (Euarchukiati, 2021).

A few surprising gaps in knowledge turned up during the author's research. One example is the lack of information about the state of the ground of Chakri Maha Prasat Throne Hall before it was built. Another piece of overlooked past is the importance of the Dusidaphirom Throne Hall as the King's observation post. If this fact can be confirmed by other sources, the place should be prominently commemorated.

One should always be open to more information concerning the total solar eclipse of 6 April 1875 from new sources. The two photographic plates taken at the Grand Palace and sent to the Royal Society may still exist. Other records may exist in Thailand or southern Laos, or central Vietnam. Huế, in central Vietnam was on the path of totality and Nguyen court astronomers might have kept some records.

Almost all of the individuals known to be present at the Grand Palace total solar eclipse drawing contest were recognised historic personalities. The event was a special one since it was not brought about by politics or social coercion, but by nature's grand phenomenon. Now that the locations where the total solar eclipse of 6 April 1875 were observed are known, it should be easy to create public awareness of the occasion. The basic elements of the story are complete.

Acknowledgements A humble thank is due to Phra Dhamma Trilokacharya, the Abbot of Wat Ratchapradit for permitting the author to photograph the murals in the temple's ordination hall. Thanks are also extended to Natthaphat Chawiwong and Kamonnat Chawiwong, lay ministries of Wat Ratchapradit, who showed the murals and guided the author around the temple. Thanks to Professor Wayne Orchiston who suggested that the Grand Palace drawing contest could benefit from further research. It led the author to find much new and interesting information along the way, including a few visits to the Grand Palace and the Temple of the Emerald Buddha, trips on which the author is always happy to go.

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Chapter 10
The Total Solar Eclipse of 9 May 1929: The British and German Expeditions to Pattani in Southern Siam

Boonrucksar Soonthornthum, Visanu Euarchukiati, and Wayne Orchiston

10.1 Introduction

As Fig. 10.1 indicates, the path of totality of the 9 May 1929 total solar eclipse crossed the Indian Ocean, the Dutch East Indies (today's Indonesia), the Unfederated Malay State of Kehah (now belonging to Malaysia), the southern part of Siam (present-day Thailand), French Indochina (the part now belonging to Vietnam), the Spratly Islands, the Philippines and the South Pacific Mandate of Japan (which is now part of Micronesia).

Fairly accessible observing stations could be selected where the Sun would be high in the sky at the time of totality. Therefore, several sites in Southeast Asia were selected for the expeditions of astronomers from various countries who wished to observe this total solar eclipse. About fifteen different groups of astronomers mounted expeditions to different sites along the path of totality (Ittisan, 1995: 20–21), and they were located in

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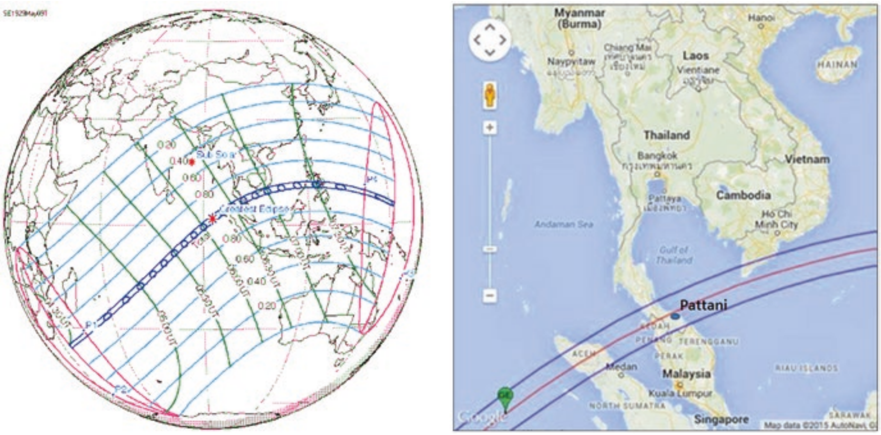

Fig. 10.1 The path of totality of the total solar eclipse of 9 May 1929 (http://en.m.wikipedia.org/wiki/Solar_eclipse_of_May_9_1929).

- Sumatra, Dutch East Indies (Indonesia): American (1 observing team), Dutch (1), German (1), Japanese (1)
- Kedah, Malaya (Malaysia): British (1), American (1), Japanese (1)
- Poulo Condore Island, Indochina (Vietnam): French (1)
- Philippines: American (4), German (1)
- Pattani, Siam (Thailand): British (1), German (1)

This chapter is about the British and German observing teams that went to Pattani in far southern Thailand.

During the 9 May 1929 total solar eclipse the Moon was just one day before perigee, and the apparent angular diameter of the Moon was 33.47′ while the apparent angular diameter of the Sun was 31.68′. This caused totality to last for about 5 minutes. While the longest possible total solar eclipse could last for more than 7 minutes, the 9 May 1929 total solar eclipse was considered to be one of the most interesting for astronomical research, especially for confirmation of the Einstein's 'General Theory of Relativity' (see Crelinsten 2006). Thus, in 1928 F.J. M. Stratton, the Professor of Astronomy at Cambridge University, forewarned colleagues when he wrote:

> The eclipse of next year with its maximum duration of totality of over 5 minutes, is one of the best eclipses for some years to come. The Sun is in a reasonably good field of stars for the Einstein experiment, totality is long and a number of observing stations, well separated in position, are accessible. (Stratton, 1928b: 199).

The 'General Theory of Relativity', as we now understand it, was published in four installments by Albert Einstein (1879–1955) in 1915 (Einstein 1915a, 1915b, 1915c, 1915d). His theory predicted that the path of starlight is bent in a gravitational field so that light passing a massive body is deflected by that body. Einstein realized that this effect could be investigated by observing the light from stars during a solar eclipse, and he calculated that the amount of this deflection would be

1.75″ for "… rays passing the sun tangentially – [but] as the distance *r* increases, the effect decreases by 1/r …" (Henschel, 1994: 148). After Einstein's 1915 publications,

> … the matter was taken up by Dr. E. Freundlich, who attempted to collect information from eclipse plates already taken; but he did not secure sufficient material. At ensuing eclipses plans were made by various observers for testing the effect, but they failed through cloud or other causes. After Einstein's [1915 papers] had appeared, the Lick Observatory expedition attempted to observe the effect at the eclipse of 1918 … but the eclipse was an unfavourable one … (Dyson et al., 1920: 292).

The total solar eclipse on 29 May 1919 was the most spectacular astronomical phenomenon that potentially could prove Einstein's Theory of General Relativity. At totality, the Sun and the Moon were in the vicinity of the Hyades, an open cluster in Taurus. There were several bright background stars near the position of the Sun at the time of the total solar eclipse, and observations by Sir Arthur Stanley Eddington's expedition to the Canary Island for the first time proved Einstein's theory (see Coles, 2001). Further confirmatory observations were then made during the 21 September 1922 total solar eclipse by observers based in Australia (see Campbell and Trumpler, 1923, 1928; Chant and Young, 1924; Dodwell and Davidson, 1924). This made future total solar eclipses important so that the astronomical community could follow up these observations and re-confirm Einstein's theory.

10.2 The British Expedition to Pattani, Southern Siam

The British plan for the expedition to observe the 9 May 1929 total solar eclipse was initiated three years before the event. In 1926, Astronomer Royal Sir Frank Dyson (1869–1939; Fig. 10.2), who was in charge of the solar eclipse mission, asked the British Embassy in Bangkok to send a letter to Siam's Ministry of Foreign Affairs informing them of the total solar eclipse on 9 May 1929, and that the path of totality would pass across southern Siam between latitude 5° 57′N, longitude 99° 38′.1E and latitude 6° 42′.7N, longitude 102° 44′.4E. The letter should also ask the Siamese to provide hospitality and facilities for the British astronomers and astronomers from other countries located at observing sites in southern Siam at the time of the eclipse (Ittisan, 1995: 20–21). This total solar eclipse could provide very important scientific knowledge, especially the confirmation of Einstein's Theory of General Relativity.

As it had been decided earlier that a new attempt should be made to test Einstein's theory during the long total solar eclipse observable in 1929, the British Admiralty agreed to send a team of astronomers led by Dr John Jackson (1887–1958) from the Royal Observatory at Greenwich and Dr John Carroll (1899–1974) from the Solar Physics Observatory at Cambridge to carry out spectroscopic observations, and in particular to study the solar corona during the eclipse. The proposal was submitted

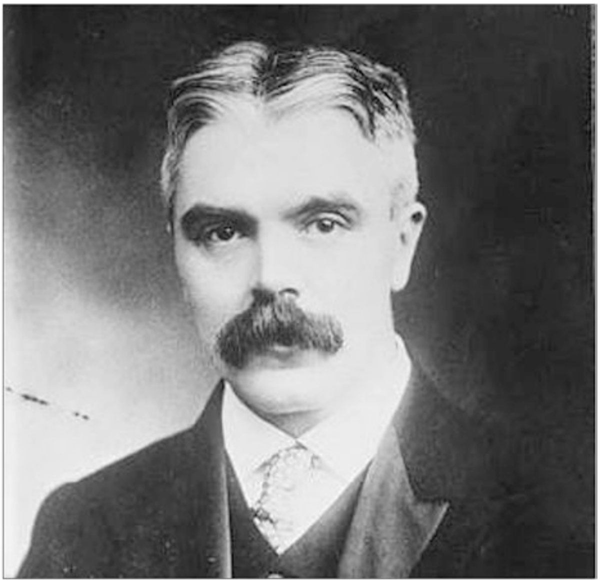

Fig. 10.2 Sir Frank Dyson, Astronomer Royal (https://en.wikipedia.org/wiki/Frank_Watson_Dyson#/media/ File:Frank_Watson_Dyson.jpg).

to and reviewed by the Joint Permanent Eclipse Committee, which decided to approach the Government Grant Committee of the Royal Society for funding. The proposal was approved and it was decided that Professor F.J.M. Stratton of Cambridge (1881–1960; Fig. 10.3) and Mr. P.J. Melotte (1880–1961) of Greenwich also should be invited to join the expedition.

Colonel J. Waley Cohen (d. 1948), who assisted the British Solar eclipse expedition to Benkoelen in 1926, had visited Malaya and Siam in 1928 on behalf of the British team of observers to identify two appropriate sites along the path of totality. Given climate considerations it was important that at least one observing team would meet with favorable conditions, and that the sites selected were easily accessed and within one day's journey of each other so that the astronomers from the two parties could keep in touch. It was finally decided that Drs Jackson and Carroll would be stationed at Alor Star in Kedah, Malaya (see Noor and Orchiston, 2021), and Professor Stratton and Mr Melotte at Pattani in southern Siam. In addition, a number of volunteer observers would participate in this event, including Dr Aston at Alor Star and Colonel J. Waley Cohen at Pattani. Dr Thomas Royds (1884–1955), the Director of the Kodiakanal Observatory, also was sent by the Indian Government to join the British observing team in Siam.

The instruments used for the observations were prepared at the workshops at Greenwich and Cambridge under the direction of the Astronomer Royal and Professor Newall. All the instruments were shipped from Liverpool on 16 February 1929 to Alor Star and Pattani.

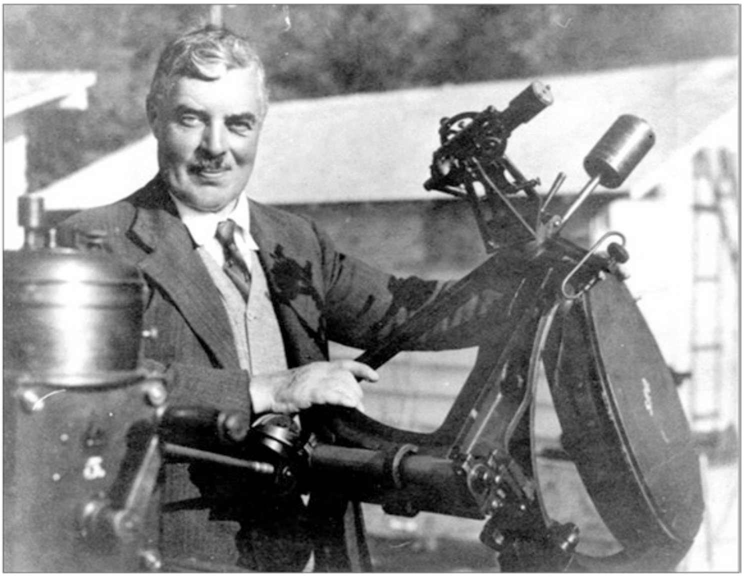

Fig. 10.3 Professor Frederick J.M. Stratton from Cambridge University at a later solar eclipse, in Japan in 1936 (https://es.wikipedia.org/wiki/F._J._M._Stratton#/media/Archivo:F.J.M._Stratton_astrophysicist.png).

Fig. 10.4 A map showing the locations of the German and British eclipse camps relative to Central Pattani and the railway station at Khok Pho; for scale, the two eclipse camps are 24 km apart, as the crow flies (map: Visanu Euarchukiati).

In Siam, the British camp and observing site allotted by the Siamese authorities was located close to the Pattani River near the centre of Pattani (see Fig. 10.4). The following instruments (after Anonymous, 1929: 130–132) were set up and prepared for the eclipse observations:

(1) An equatorially-mounted f/10.4 13-inch astrograph for measuring the displacement of the stars near the vicinity of the eclipsed Sun.
(2) A Littrow spectrograph with a plane grating fed by a 16-inch coelostat and a 15-inch mirror of 29-foot focal length, for measuring the flash spectrum at 8800 A.
(3) The Hills quartz spectrograph fed by a coelostat with a 12-inch speculum flat and a 9-inch concave speculum mirror, for measuring the line spectra and the continuous spectrum of the solar corona during totality.
(4) The 19-foot coronagraph fed by the 8-inch coelostat with a 4-inch lens for photographing the solar corona during totality.
(5) A double tube polariscope of 6-foot focal length, with a large Nicol prism in front of one tube for observing prominences and other features at the solar limb.

10.3 The German Expedition to Khok Pho, Near Pattani

During arrangements for the reception of the British team of astronomers the Charge D'affairs of the German Embassy in Bangkok informed the Siam Ministry of Foreign Affairs that three German astronomers, namely Professor H. Rosenberg, Dr D. Stobbe and Mr W. Pape, and a volunteer from Chãa-yaa Nora-sing photo-studio in Bangkok, Mr E. Groate, would arrive in Penang on 12 March 1929 and enter Siam with several astronomical instruments (see Fig. 10.4) that they intended to use to observe the 1929 eclipse. Siamese officials had prepared for the German team of astronomers by building guesthouses near the railway station at Khok Pho (24 km southwest of the British camp at Pattani River) and preparing an observing site nearby (Ittisan, 1995: 23–24). The location of the German eclipse camp is also shown in Fig. 10.4.

Prior to the eclipse, Professor F.J.M. Stratton (1928a: 339) had reported that "A German expedition also will be in Siam … The photometry and spectrophotometry of the corona and its spectrum will be examined over a wide range of spectrum with the aid of a spectrograph of high light-gathering power." Two different instruments would be used for these observations (Ittisan, 1995: 25–26):

(1) An astrograph weighed approximately 1 ton with three 4,000 mm focal length photographic cameras, all supported by the one equatorial mountings; and

(2) A spectrograph with four short focal length photographic cameras with red, orange, yellow and deep violet filters mounted on each camera.

The instruments (see Fig. 10.5) were shipped from Kiel, Germany to Siam in March 1929 and the German observers arrived in Penang, Malaya on 18 March

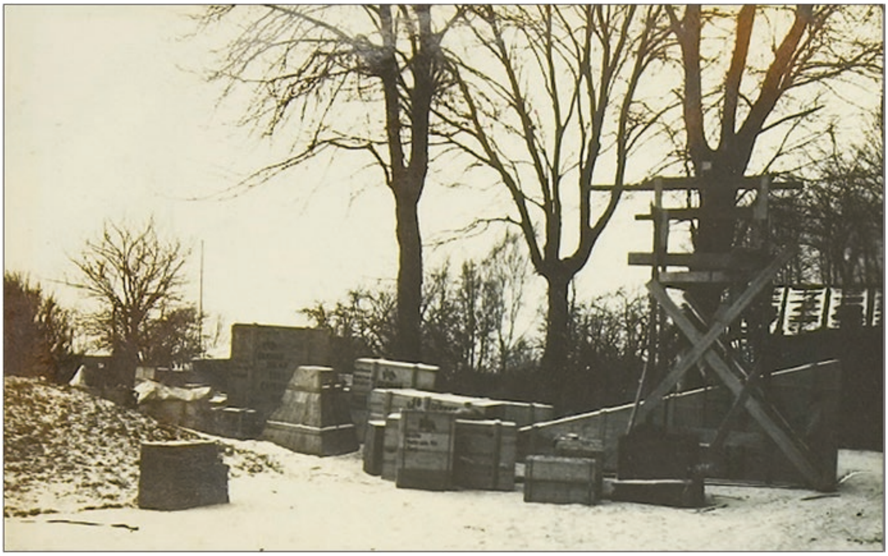

Fig. 10.5 The instruments ready to be shipped from Kiel (photograph: King Prajadhipok Museum).

Fig. 10.6 The arrival of the instruments at Khok Pho, Pattani (photograph: King Prajadhipok Museum).

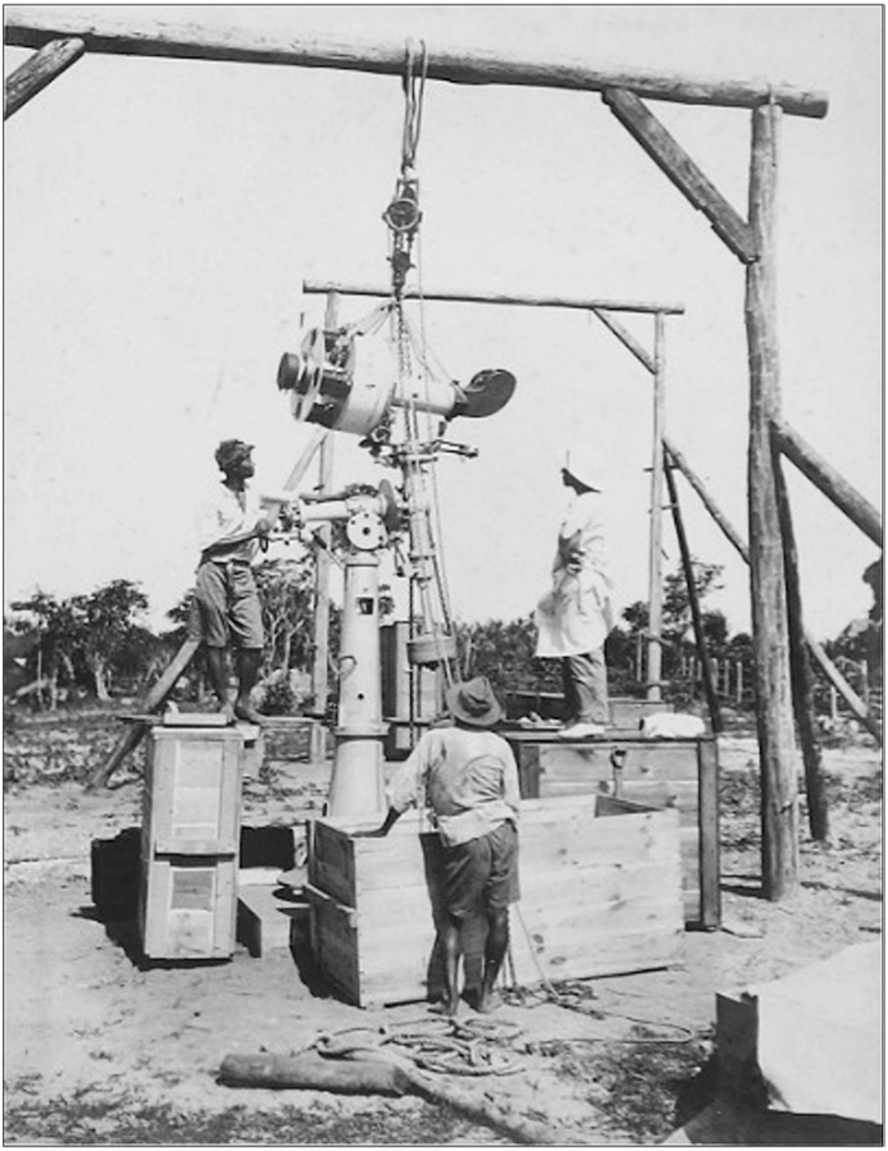

Fig. 10.7 Installation of the mounting for the three astrographic cameras (photograph: King Prajadhipok Museum).

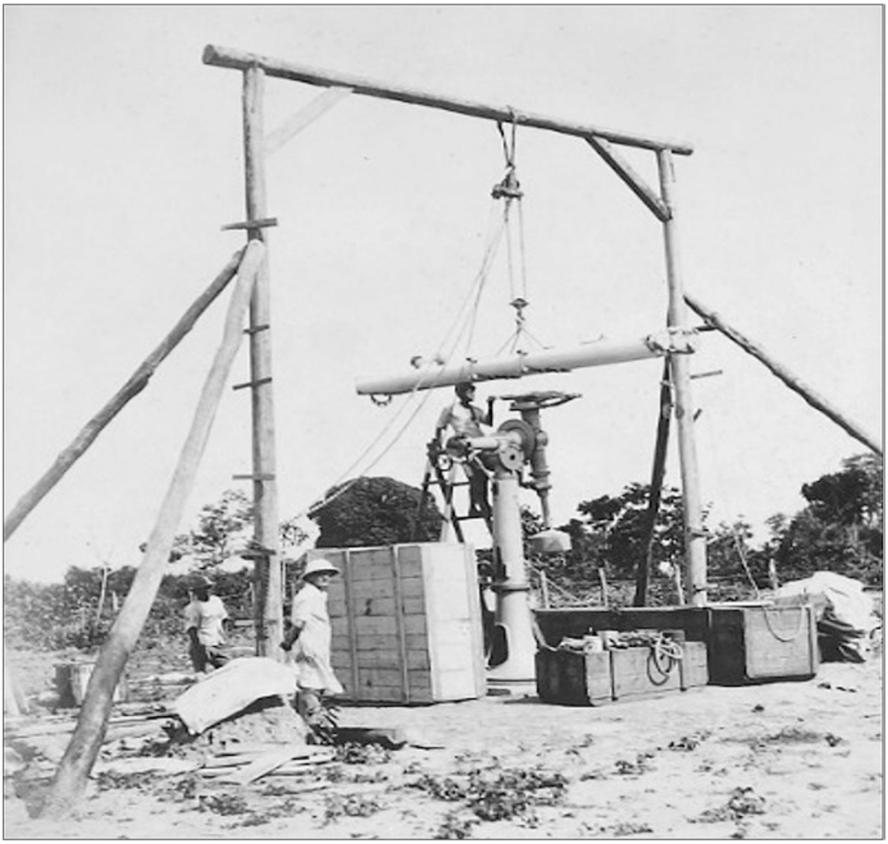

Fig. 10.8 Installation of the three astrographic cameras (photograph: King Prajadhipok Museum).

1929 and immediately entered the Kingdom of Siam and went to their observing site at Khok Pho. Fig. 10.6 shows the instruments arriving in Khok Pho.

The German astronomers then supervised the installation of the scientific instruments at the observing site (see Figs. 10.7, 10.8, 10.9, 10.10), with assistance from Siamese officers and local workers:

10.4 A Cordial Reception from His Majesty The King and the Government of Siam

The British and German Embassies in Bangkok asked the Government of Siam to provide strong support for their respective observing expeditions. After hearing that official approval had been granted by the Foreign Affairs Ministry, the Interior Minister, Marshall-Admiral Paribatra Sukhumbandhu, the Prince of Nakorn Sawan

Fig. 10.9 The astrograph safely installed in its 'observatory' (photograph: King Prajadhipok Museum).

(1881–1944), suggested to His Majesty King Prajadhipok (King Rama VII) that observations of the eclipse would benefit modern scientific knowledge and would create good relations between Siam and European countries. The King then approved a proposal to appoint a Reception Committee comprised of the following members (Anonymous, 1929: 134) to welcome the two astronomical expeditions:

- Rear-Admiral Phya Rajvansen, A.D.C. – Chair
- Colonel Phra Salvidhan Nides (Fig. 10.11)
- First Councillor Phya Srishdikar Barnchong
- Second Councillor Phya Sri Sena
- Mr. Brandli, Government Meteorologist
- Commander Phra Riem Virajbhakaya – Secretary

This Committee communicated independently with officials in various Government Ministries to ensure that the British and German accommodation facilities and observing sites were prepared in good time. In specific reference to the British astronomers, for example, the published account of the expedition mentions that

> In addition to building a comfortable and well-equipped bungalow camp to house the expedition, the committee also paid all the expenses for labour in building the pillars and atap shelters, and provided electric lighting sets both for the eclipse camp—for electric arcs, dark-room, etc.—and for the bungalow camp. Further, they and the local authorities saw to it that every facility possible was available to help the expedition … The club room of the local troop of boy scouts, which adjoined the eclipse camp, was made available as a store for the apparatus, and the hut dark-room was set up inside it. Local police guarded the camp day and night without any charge on the funds of the expedition. Customs facilities for the

Fig. 10.10 The astrograph being demonstrated to a Siamese officer by Professor Rosenberg (photograph: King Prajadhipok Museum).

> entrance, duty free, of all the apparatus and personal luggage of members of the expedition were granted freely …[and a] doctor from Bangkok, Luang Jarn Vidli Bej, was stationed at Pattani while the expedition was there … (Anonymous, 1929: 134–135).

On 5 May 1929 their Majesties the King and Queen of Siam left the Klai Kangwon Palace in Hua Hin and proceeded to Pattani on the Royal Cruiser *Maha Chakri* (Fig. 10.12), arriving there on 8 May (Ittisan, 1995: 26–27). During the cruise, Rear-Admiral Phya Rajvansen, A.D.C. gave a presentation about the total solar eclipse to their majesties. Upon their arrival, their Majesties visited both German and British observing camps to greet the observing teams and inspect the instruments (see Figs. 10.13). The German camp also was visited by a group of Thai Royal Navy officers (Fig. 10.14) and some local boy scouts (Fig. 10.15).

On the day before the eclipse, their Majesties visited the British observing camp, where they

> … inspected the instruments and watched a rehearsal of the eclipse programme; in the evening they returned to look at some celestial objects through the Astrographic Telescope and the Greenwich 4-inch portable telescope.

Fig. 10.11 Colonel Phra Salvidhan Nides (courtesy: Office of the National Research Council of Thailand).

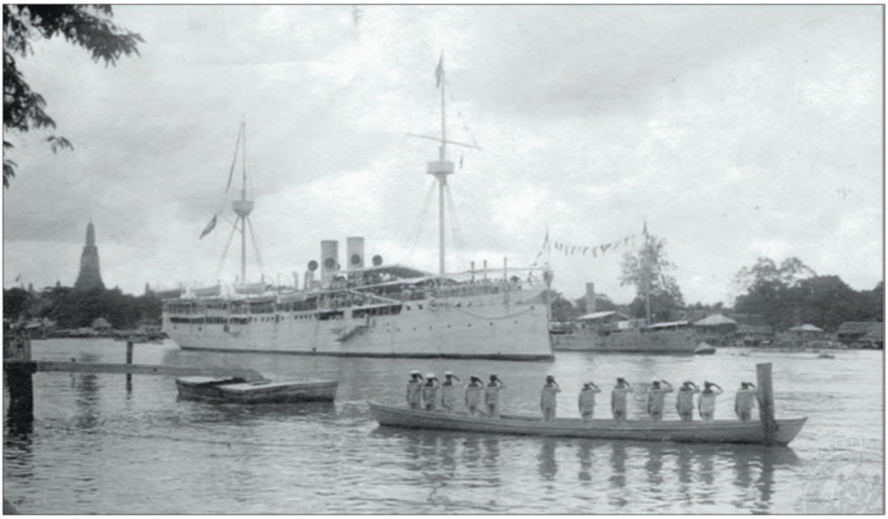

Fig. 10.12 The Royal Cruiser *Maha Chakri* (http://pantip.com/topic/32770533).

10.5 The Day of the Total Solar Eclipse, 9 May 1929

During the weeks prior to the eclipse, the weather for the most part was hot and fine, and "The Sun was clear at eclipse time six days out of seven during the seven weeks preceding the eclipse." (Anonymous, 1929: 134). Thus, all preparations were com-

Fig. 10.13 His Majesty King Prajadhipok (King Rama VII) and the Queen of Siam visiting the German observing camp and examining the astrograph (photograph: King Prajadhipok Museum).

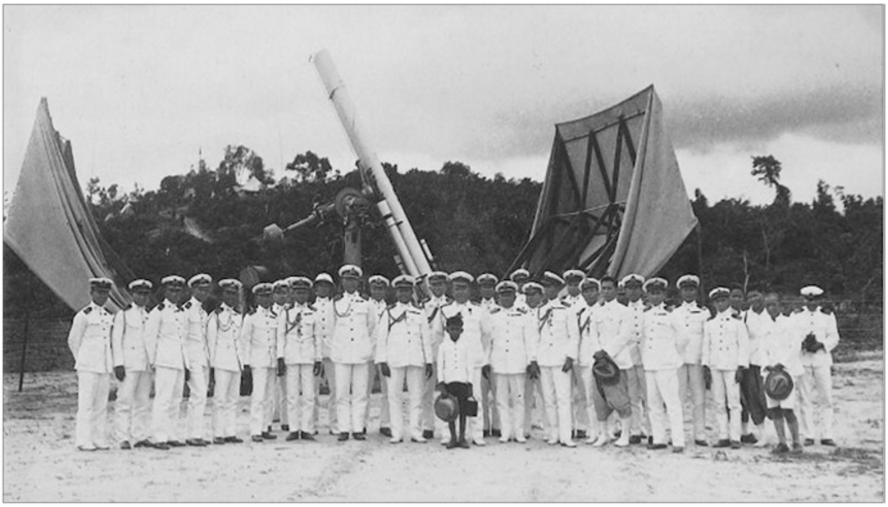

Fig. 10.14 A group of Royal Navy officials at the German observing camp (photograph: King Prajadhipok Museum).

Fig. 10.15 A local troop of local boy scouts at the German observing camp (photograph: King Prajadhipok Museum).

pleted in good time, but unfortunately three days before the day of the eclipse the weather became bad, and there was heavy rain on the night before the eclipse, both at Pattani and Khok Pho.

On 9 May 1929, at the British observing camp the sky was so cloudy and the Sun was mostly obscured, and by 11.30 am. it looked like rain would fall. From 0.47 pm. a partial eclipse was glimpsed from time to time through the clouds, but the Sun was not visible during totality, which was estimated to last from 1.38 to 1.43 pm local time. Sadly, given all of the preparations, and the high expectations, it was not possible to carry out any of the proposed observing programmes (Anonymous, 1929: 134), so "… from a scientific viewpoint, all the preparations and expense had been for nought." (Orchiston et al., 2019: 203).

On the day of the eclipse their Majesties and a small group of accompanying guests visited the British observing camp,

> … and took up a position in a Royal pavilion inside the camp. It was a special disappointment to the members of the eclipse expedition that the cloudy sky prevented the Royal visitors, to whom they were so heavily indebted, from seeing the wonderful spectacle of the eclipsed Sun. (Anonymous, 1929: 135).

Meanwhile, the cloud cover was lighter at the German observing camp 24 km from Pattani, and totality was visible. At this time a few exposures were taken with the astrograph, and one of these is shown here in Fig. 10.16. Note the prominences on the right hand side of the Sun. However, none of these photographs showed details

Fig. 10.16 An image of totality taken by with the astrograph at the German observing camp (Photograph: King Prajadhipok Museum).

of the solar corona and it was not possible to obtain spectra of the corona, so the scientific results from the German endeavours also were limited.

Before their departure from Pattani on 10 May, H.M. the King hosted a lunch on the *Maha Chakri* Royal Crusier for the British and German expedition teams. Professors Stratton and Rosenberg also were invited to visit Bangkok, and on 30 May they gave plenary lectures at Chulalongkorn University, presided over by their Royal Majesties.

Meanwhile, the observing teams at Pattani and Khok Pho continued to observe the Sun and the Moon for two weeks after the eclipse before completing their missions and leaving the Kingdom of Siam.

10.6 Concluding Remarks

From an international scientific perspective, the 9 May 1929 total solar eclipse was an important astronomical event. Because it was observable from Siam His Majesty King Prajadhipok (King Rama VII) invited British and German observing teams to Pattani province in far southern Siam, and the Government provided generous support throughout. Unfortunately, inclement weather severely limited the range of scientific observations that could be made during the eclipse, although some photographs of prominences and the inner corona were obtained at the German camp.

However, solar eclipses are about more than mere science. In this instance, it is reported that approximately 25,000 visitors came to Pattani province to see the telescopes and other scientific instruments at the observing sites and to watch the eclipse (http://kingprajadhipokstudy.blog.com/2013/08/2.html). So this eclipse had enormous public appeal and inspired an interest in science, astronomy and new technology. Meanwhile, the warm welcome from their Majesties, the excellent facilities provided at the two eclipse camps, and the splendid support offered by Government officers and local authorities prior to, during and after the eclipse, made a very favourable impression with the British and German observing teams. This then led to closer relations between Siam and European nations.

An additional outcome of the 1929 eclipse was that some years later Colonel Phra Salvidhan Nides began teaching astronomy courses at Chulalongkorn University for science and engineering students, thus marking the start of tertiary astronomy education in Thailand (see Orchiston et al., 2019: 205–207).

Acknowledgements We are grateful to the King Prajadhipok Museum (Bangkok), for kindly supplying Figs. 10.5–10.10 and 10.13–10.16, and The National Research Council of Thailand for kindly supplying Fig. 10.11.

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Chapter 11
The Total Solar Eclipse of 9 May 1929: The British Expedition to Alor Star in the Unfederated Malay State of Kedah

Nor Azam bin Mat Noor and Wayne Orchiston

11.1 Introduction

Fig. 11.1 shows that in the SE Asian region the path of totality of the 9 May 1929 eclipse crossed northern Sumatra, the Malay Peninsula, the southern tip of French Indochina, and islands in the Philippines. Between them, one or more American, British, Dutch, French, and German eclipse expeditions was based at each of these locations (see details, see Soonthornthum et al., 2021, and Sub-section 11.4.2 below).

The attraction was the relatively long duration of totality, and the opportunities this would provide to photograph stars in the vicinity of the eclipsed Sun. Cambridge University's Professor Frederick John Marrian Stratton (1881–1960) alluded to this in 1928 in a research paper that he published in the *Journal des Observateurs*:

> The eclipse of next year with its maximum duration of totality of over 5 minutes, is one of the best eclipses for some years to come. The Sun is in a reasonably good field of stars for the Einstein experiment, totality is long and a number of observing stations, well separated in position, are accessible. (Stratton, 1928: 199).

This led to a decision to send an eclipse expedition to the Malayan Peninsula (an area of which at the time was part of the British colonial system).

This chapter is about the British expedition to Kedah, and is a companion to the preceding chapter about the British and German expeditions that were based at Pattani, in far southern Thailand, close to the Siam-Kedah border (Soonthornthum

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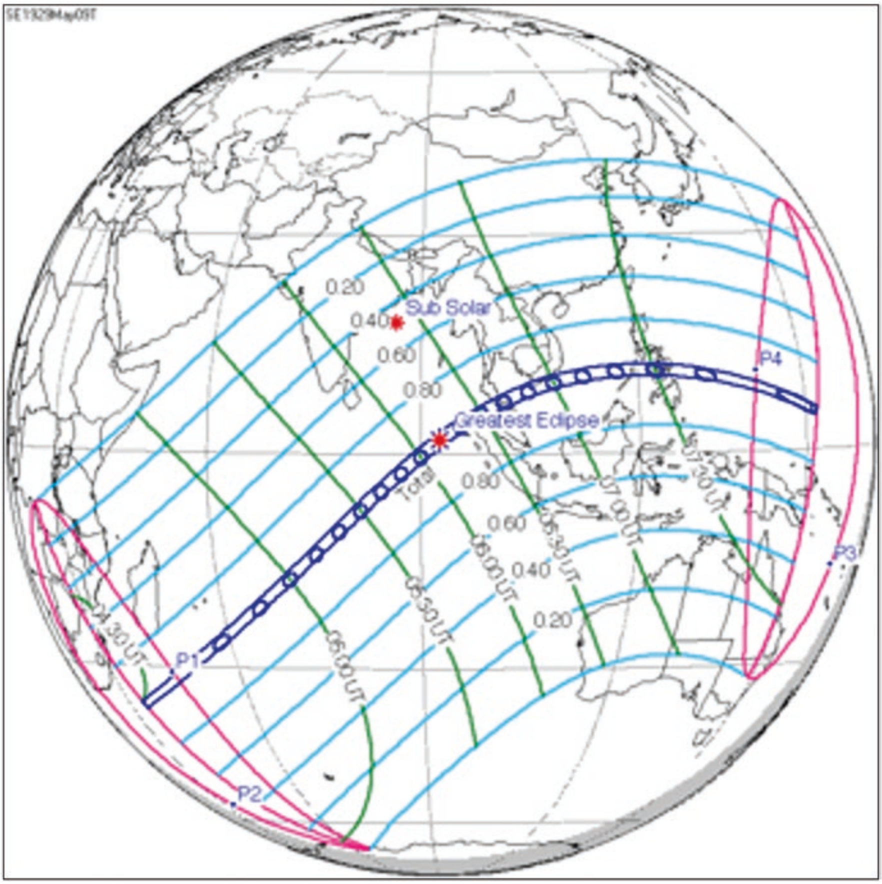


Fig. 11.1 A map showing the path of totality of the 9 May 1929 total solar eclipse (http://en.m.wikipedia.org/wiki/Solar_eclipse_of_May_9_1929).

et al., 2021). As we shall see, the British team there actually formed half of the overall British expedition that was sent out to Southeast Asia.

11.2 Planning the British Expedition

11.2.1 Research Objectives

As early as 1926 British astronomers realized the importance of the long-duration eclipse of 9 May 1929 in confirming Einstein's Theory of General Relativity. The Chairman of the Joint Permanent Eclipse Committee of the Royal Society and the Royal Astronomical Society was the Astronomer Royal, Sir Frank Dyson

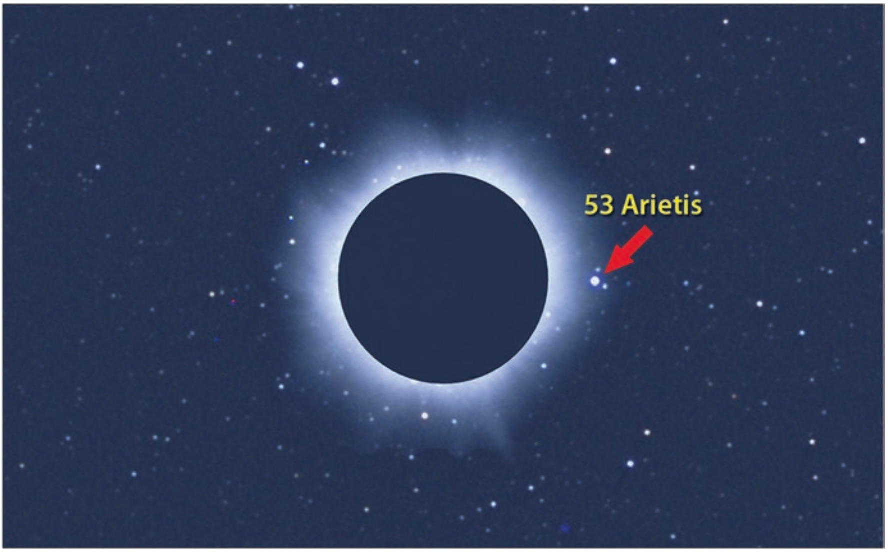


Fig. 11.2 A simulation of totality during the 9 May 1929 solar eclipse (using Starry Night Pro Plus 6.4.3) showing stars expected to be visible around the Sun. The bright star closest to the corona is 53 Arietis, which was considered an ideal target for the 'Einstein experiment'.

(1869–1939), and effectively he was in charge of the solar eclipse mission. The decision was made to send an eclipse expedition to the Malayan Peninsula, and apart from photographing the Sun during totality for the 'Einstein Experiment' (see Fig. 11.2), photographic and spectroscopic observations would be made of the corona.

11.2.2 Selecting the Eclipse Camp

Although weather conditions at the time of the eclipse were expected to be better in the Philippines than elsewhere along the path of totality, the duration of totality was shorter there and the Sun would be lower in the sky (Miller and Marriott, 1929). For these reasons, and available infrastructure in the Malayan Peninsula, the decision was made to site the British expedition in the Unfederated Malay State of Kedah, very close to the Kedah-Siam border.

Each year May was a time of generally unsettled weather, "… as it was during the intermittent period between the northeast and southwest monsoon …" (Stetson, 1929: 373). These unpredictable weather conditions motivated the British to split their party into two teams, one based in Kedah and the other in southern Siam. Both observing sites were on flat terrain near the coast rather than in the intervening mountains, and within one-day's travel of each other (Stratton, 1928). This way it was hoped that at least one of the observing sites would be greeted with clear

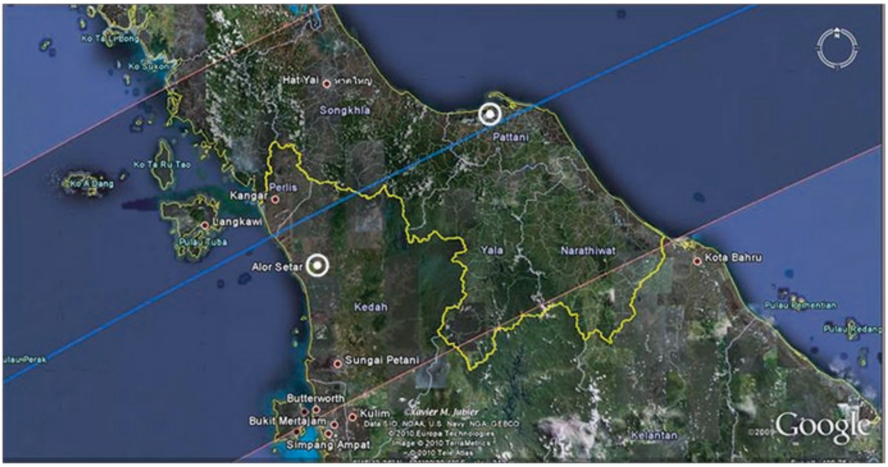


Fig. 11.3 A close-up showing the path of totality (between the two red lines), in the vicinity of the Kedah-Siam border (the yellow line). The eclipse centerline passed close to Alor Star in Kedah and Pattani in Siam, where the two components of the British expedition (shown by white bulls-eyes) were based. Map scale: as the crow flies, the distance between the eclipse camps is about 140 km (base map: Google; map modifications: Azam Noor and Wayne Orchiston).

weather on the vital day. Colonel J. Waley Cohen (d. 1948), who assisted the British solar eclipse expedition to Benkoelen in 1926, visited the area in 1928 and examined possible observing sites along the path of totality. After carefully reviewing the various options, the Eclipse Committee decided one team would be located at Alor Star in Kedah and the other at Pattani in southern Siam (see Fig. 11.3).

As we can see from Fig. 11.3, in Perlis and Kedah the path of totality extended from Kangar, and the island of Langkawi, right on the Siam border, to Butterworth and Penang Island at the extreme southern limit of the zone of totality. The largest town near the centre-line was Alor Star (now Alor Setar), and this is where the British chose to base their expedition.

Alor Star is the capital city of the state of Kedah, and by 1929 had a population of between 16,000 and 17,000 (cf. de Koninch, 1988: 159). It had developed substantially from the little village with "… long narrow muddy lanes with dirty slovenly atap houses …" (Logan, 1851: 54) of 1850 into a comfortable little town, although it was still the centre of an extensive agricultural district where the borders of 'town' and 'country' sometimes were hard to identify (Dobby, 1951). It was an administrative and service town for the district known as the 'rice-bowl' of Malaya, and was located 10 km inland from the coast. Alor Star was inhabited primarily by Malays, but following the Anglo-Siamese Treaty of 1909 the British had assumed control of the region, which "… left an imprint on Alor Setar's architectural landmarks, be they Malay, Muslim or British." (de Koninch, 1988: 150). Although still located on a flood plain at the confluence of two main rivers, by 1929 Alor Star—and indeed the whole state of Kedah—was linked by road to the rest of Malaya, and the main trunk railway from Singapore passed through the town *en route* to Siam

(Ooi, 1976: 390–391). Alor Star was no longer geographically isolated. It had all of the necessary infrastructure, and was the ideal site for the British eclipse camp. After considerable correspondence with Professor Stratton, an American eclipse expedition from Harvard University also decided to settle on Alor Star, and they and the British would share the same observing camp (Stetson, 1929: 373).

11.2.3 Selecting the British Observing Teams

The British Admiralty agreed to send Dr John Jackson from the Royal Observatory at Greenwich to conduct the 'Einstein Experiment', while the Solar Physics Observatory at Cambridge would send one of their staff members, Dr John Carroll, to carry out spectroscopic observations of the corona during totality. The Joint Permanent Eclipse Committee then decided to approach the Government Grant Committee of the Royal Society for funding to duplicate the observations. Their proposal was approved, and it was decided that Professor F.J.M. Stratton (1881–1960) from Cambridge and Mr. P.J. Melotte (1880–1961) from Greenwich also should be invited to join the expedition. They would be based in Pattani in Siam, while Drs Jackson and Carroll would go to Alor Star in Kedah.

11.2.3.1 Dr John Jackson

John Jackson (1887–1958; Fig. 11.4; Jones, 1960) was born in Paisley, Scotland on 11 February 1887. After completing secondary school he studied for an MA at the University of Glasgow, graduating in 1907. The following year he graduated with a BSc in astronomy, chemistry, mathematics and pure philosophy. He was an outstanding student, and was awarded an assortment of medals. Jackson then attended an astronomy course run by the Regius Professor of Astronomy, Ludwig Becker (1860–1947), and again he excelled. This would determine his future career, once he mastered Latin, gained entrance to Cambridge and graduated with distinction.

In 1914, at the age of 27, he was appointed Chief Assistant at the Royal Observatory, Greenwich, where the Director was the Astronomer Royal, Sir Frank Watson Dyson (1868–1939; see Fig. 10.2). Apart from routine observations with the Airy transit circle, Jackson also carried out trigonometrical survey work in France (during the war) and he analyzed and wrote up double star observations made earlier at the Observatory, and Thomas Hornsby's eighteenth century observations of Mercury. He also investigated the rotation period of Neptune. Conspicuously absent from the range of astronomy that he pursued at Greenwich was solar research, and this is reflecting in his all-too-brief sojourn in Southeast Asia in 1929, which was to be his first solar eclipse expedition. Two others came later, in 1940 and 1954.

In 1933 Jackson moved to Cape Town as His Majesty's Astronomer at the Royal Observatory, Cape of Good Hope, to replace Harold Spencer Jones (who had returned to England to take over as Astronomer Royal from Sir Frank Dyson).

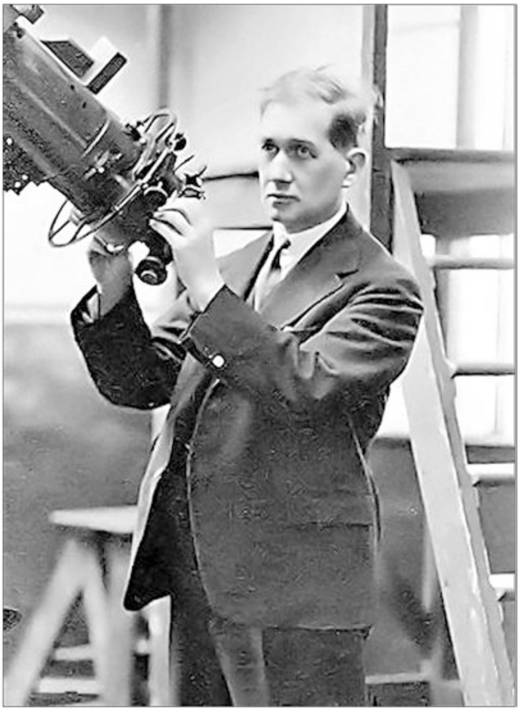


Fig. 11.4 John Jackson while Chief Assistant at the Royal Observatory, Greenwich (https://upload.wikimedia.org/wikipedia/commons/2/2a/JohnJackson%28astronomer%29.jpg).

Jackson remained at the 'Cape Observatory', mainly doing research on stellar parallaxes, until he retired in 1950 and returned to England. In this same year he received a Commander of the British Empire award and in 1953 the Gold Medal of the Royal Astronomical Society. During 1953–1955 Jackson was President of the Society, only to die three years later.

11.2.3.2 Dr John Carroll

John Anthony Carroll (1899–1974; Fig. 11.5; Sadler and Sadler, 1975) was born in England on 8 January 1899, and he worked at the Royal Aircraft Establishment at Farnborough during World War I where he "… was introduced to applied science and experimental methods … (Sadler and Sadler, 1975: 100). After the war he studied astronomy at Cambridge, then worked on spectroscopy at Caltech and Mount Wilson Observatory, and completed a PhD.

In 1924 he had been appointed Assistant to Professor Hugh Frank Newall (1857–1944), the Director of the Solar Physics Observatory at Cambridge, and one year later also became a Lecturer in Astrophysics at the University. It was while he held these two positions that he went to Kedah for the solar eclipse. This was his

Fig. 11.5 Professor John Carroll in 1930, from a photograph in the scientific instrument collection of the University of Aberdeen, donated by his daughter Mrs Heath (courtesy: University of Aberdeen).

third expedition: he also went to California in 1923 and Norway in 1927. His final expedition, to Canada in 1932, like all of the earlier ones, was clouded out. Sadly, he never got to view a total solar eclipse.

In 1930 Carroll accepted the Chair of Natural Philosophy at the University of Aberdeen. As Sadler and Sadler (1975: 101) note, this position

> … is almost unique in its scope, as it comprises both applied mathematics and experimental physics; but astronomy was then in the Department of Mathematics so that, although Carroll continued with his personal research [mainly on stellar spectroscopy] he was not free to develop a school of astrophysics. [Nevertheless] he planned the observation of spectra of Algol … [and] wrote papers on such diverse subjects as the distribution of sunspots, and a modification of Michelson's stellar interferometer. But his main interest was the design of the echelon spectrograph and its use at a total solar eclipse.

John Carroll's career took a totally new path in 1942 when he joined the British Admiralty as Assistant Director of Research, and one of his main achievements was to establish the Admiralty Computing Service. He then stayed with the Admiralty, "… in a sequence of ascending capabilities, until he retired in 1964 as Chief Scientist (Royal Navy) and a full member of the Board of Admiralty." (Sadler and Sadler, 1975: 100). Although his active career as an observational astronomer was over, he was able to pursue his astronomical interests through membership of the Joint Permanent Eclipse Committee, as the Gresham Professor of Astronomy (from

1964), and by attending astronomical and IAU meetings whenever possible. In 1953 he was knighted for his contributions to defense, becoming Sir John Carroll.

11.2.4 Instrumentation

Dr Jackson reported (Anonymous, 1929: 123) that he had three instruments:

> (1) Photographic telescope with a two-lens objective of 7 inches aperture and 21 feet focus, fed by coelostat, to test the Einstein theory; (2) Mr. Worthington's 6-inch Clark lens of 45 feet focus, also fed by coelostat, for large-scale photographs of the corona; and (3) Dallmeyer Equatorial carrying three short-focus cameras for photography of the corona through colour screens.

Note that only the first of these was to be used on the 'Einstein experiment'. The other two were for investigation of the corona, which was Dr Carroll's main interest, but his particular forté was spectroscopy, as revealed by his instruments (Anonymous, 1929: 128):

1. A three-prism spectrograph … to obtain a record of the flash spectrum on a moving film in the visible and near ultra-violet regions …
2. A grating spectrograph to record the infra-red chromospheric spectrum in the region of the ionised Calcium X lines (AA 8498, 8542, 8662) …
3. An … objective interferometer …
4. A low dispersion, large aperture spectrograph

The aim was to use the first two spectrographs to compare the calcium H, K and X lines, while the objective interferometer, an improved and enlarged version of the one designed for Norwegian 1927 eclipse, would be used to study the velocities of coronal gases. The low dispersion spectrograph was "… adapted for a photometric study of the coronal continuous spectrum over the whole visible and near infra-red regions." (ibid.)

The aforementioned instruments were constructed or renovated at the workshops of the Royal Observatory or the Solar Physics Observatory under the direction of Sir Frank Dyson and Professor Newall. All the instruments left Liverpool by ship on 16 February 1929, bound for Alor Star.

11.2.5 The British Eclipse Camp at Alor Star

Drs Jackson and Carroll and their party arrived in Alor Star on 16 March, nearly two months before the eclipse, but they needed this time because the lens of the photographic telescope (for the Einstein experiment) "… had been delivered so near the time of our departure from England that it had been impossible to test it adequately." (Anonymous, 1929: 123). However, their early arrival in Malaya was to no avail:

> We proceeded to set up the Einstein telescope as quickly as possible in the hope of photographing the eclipse field at an altitude of about 30° to 35° immediately after sunset … However, the weather was so consistently bad immediately after sunset that it was impossible to do this. Indeed, in the six weeks before the eclipse it was difficult even to get the few photographs required for focus purposes. (ibid.).

Meanwhile, erection of Dr Carroll's instruments only commenced on 28 March, and also "… proceeded under rather trying conditions … owing to rain and especially to the excessively high humidity, whereby damage to the instruments arose and photographic work was particularly difficult." (Anonymous, 1929: 128).

11.3 Eclipse Day: 9 May 1929

As Table 11.1 indicates, the eclipse would occur in the early afternoon, local time, with the Sun initially high in the sky.

Jackson could do no more than lament that

> The observations …. were almost completely spoilt by cloud. At Alor Star, in Kedah, the sky was covered throughout the day of the eclipse by high cloud through which the Sun could generally be dimly seen. The prearranged programme was carried out, but the stars in the Sun's neighbourhood did not show on the plates and the spectroscopic observations also failed. (Jackson, 1929: 225).

However he had to admit some success:

> Better success was obtained with the 6-inch lens of 45 feet focus … [loaned] by Mr. Worthington … The series of exposures from 3s to 20s were intended to show the prominences and the form of the inner corona … the five plates give excellent pictures of the brighter details. The definition was excellent, such as it often is through [thin] cloud … (ibid.).

This is well illustrated by the photograph reproduced in Fig. 11.6, which shows the inner corona and the large prominence on the eastern limb of the Sun.

Actually, Jackson had to admit that he was surprised by these results, because "At the time the plates were exposed it was not expected that they would be anything like as good as they actually turned out to be …" (Anonymous, 1929: 125). So the prominence photographs taken with the 45-ft camera were a bonus. Jackson (1929: 226) went further and measured the large filamentous prominence. It was

Table 11.1 Eclipse details for Alor Star (after Xavier M. Jubier).

Event	Time (UT)			Altitude (°)	Azimuth (°)
	h	m	s		
Start of Partial Eclipse (C1)	05	05	00.4	+78.8	011.3
Start of Total Eclipse (C2)	06	35	31.2	+67.3	300.6
Mid-eclipse	06	37	59.9	+66.8	299.9
End of Total Eclipse (C3)	06	40	28.2	+66.2	299.3
End of Partial Eclipse (C4)	08	07	11.5	+46.4	288.5

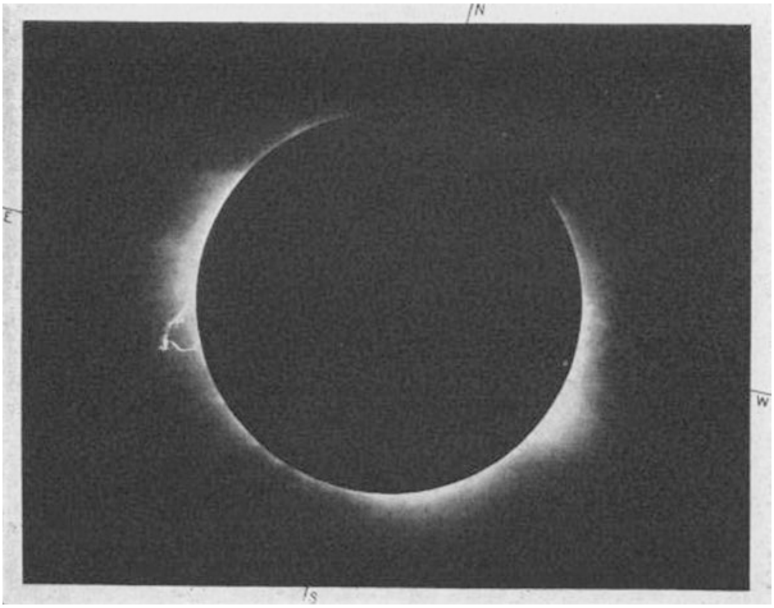


Fig. 11.6 One of the photographs of totality obtained at Alor Star using the 6-in 45-ft focal length camera on 9 May 1929 (after Jackson, 1929: facing page 225).

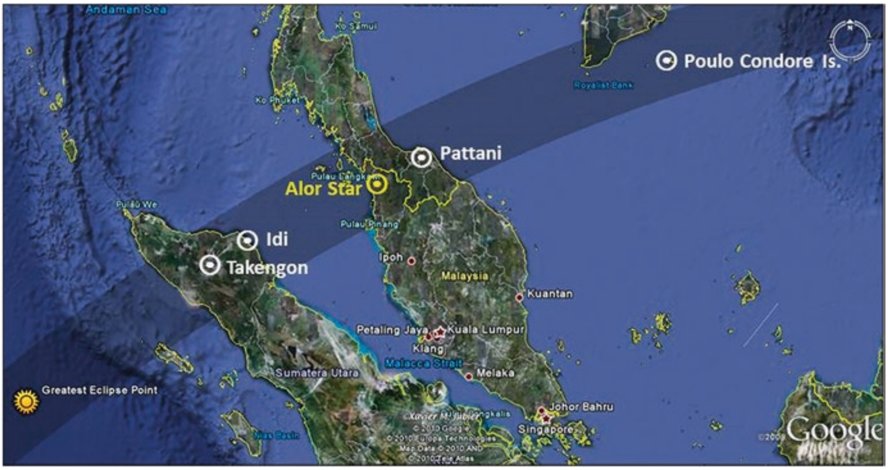


Fig. 11.7 A map showing the locations of the various Western eclipse camps in Sumatra, the Malayan Peninsula, and Indochina; missing are sites in the Philippines (base map: Google; map modifications: Azam Noor and Wayne Orchiston).

Fig. 11.8 A detailed photograph of the large prominence obtained with the 63-ft camera by the Swarthmore College eclipse team in Sumatra (after Miller and Marriott, 1929: Plate XIV).

" … 180,000 miles long and 120,000 miles high—one of the largest ever photographed … The photographs taken near the beginning and end of totality show considerable differences in the structure of this prominence." The American eclipse team from Swarthmore College located at Takengon in far northern Sumatra (see Fig. 11.7) had a long-focus 'tower camera' inspired by Lick Observatory's 'Schaeberle Camera' (see Pearson and Orchiston, 2008), and this gave a large-scale image and a detailed view of the large prominence, which we reproduce here for comparison (see Fig. 11.8).

Meanwhile, back at Alor Star, some of the small-scale photographs obtained by Jackson's team using red filters showed the corona: "There are a number of streamers shown up to a distance of fully a radius from the limb and the corona clearly is of intermediate type." (Anonymous, 1929: 126). This coronal form was anomalous, as in May 1929 the Sun was just one year past sunspot maximum, although that particular maximum had been much lower than the preceding one.

Dr Carroll also was frustrated in his attempt to carry our serious research on eclipse day. He reported that "Light clouds obscured the Sun at eclipse time so no photographs susceptible of precise measurement were obtained with any of the instruments." (Anonymous, 1929: 129). However, he did comment on one particularly pleasing aspect:

> The results obtained from the interferometer are regarded as highly profitable. The light was not strong enough to yield an image of measurable density, but there is an unmistakable impression on the plates. We are now in the position of being able to estimate accurately the exposures required for this experiment, and to feel justified in expenditure on larger and more elaborate apparatus. Previously it was entirely unknown whether it was possible to make such measurements at all. (ibid.).

The head of the American team that shared the same eclipse camp with the British also saw the eclipse in a somewhat positive light. Eclipse day

> … dawned reasonably clear, and gave fair prospects for a successful event. During the partial phase the sky thickened and the narrowing crescent was frequently obscured by clouds. A half an hour before totality it appeared we might get nothing. While darkness was falling with the approach of the moon's shadow, the clouds gradually thinned, and although a thin cirrus was overlying the sun during the total phase, the corona was plainly visible for a solar radius beyond the moon's limb. (Stetson, 1929: 374).

Stetson (1929: 375) concluded: "Considering the rather unfavorable meteorological gamble we should perhaps consider ourselves fortunate to have attained the partial success which the forbidding skies did at length allow."

11.4 Discussion

11.4.1 Pin-pointing the Alor Star Observing Site

Jackson gave the geographical co-ordinates of the Alor Star eclipse observing site as latitude 6° 8.5′ N. longitude 100° 22.4′ E., and described it as "A piece of public land outside the British Residency [which] was placed at our disposal for the erection of our instruments. The British Adviser, the Hon. T. W. Clayton, literally placed his home at the disposal of the astronomers …" (Anonymous, 1929: 127). The Harvard University eclipse team that shared the observing site with the British described it as an "… enclosure … which was just outside the walls surrounding the residence of the British Advisor for the province of Kedah." (Stetson, 1929: 373). Both accounts refer to access to the British Adviser's house and to water for processing the photographs.

The first author of this chapter was able to use this information, and archival records, to pin-point the location of the eclipse camp. He noted that the above-mentioned geographical co-ordinates were quoted in reference to Datum Kertau, which was based on the Repsold triangulation survey conducted between 1913 and 1916, and that in 1948 the Malayan Revised Triangulation (MRT) co-ordinate system was adjusted by adding 0.10″ in latitude and 3.5″ in longitude. Initial investigations then led directly to two possible locations, the College of Medical Assistants and the General Hospital. Archival records indicate that part of the General Hospital was built on the site of the British Residency, and as Fig. 11.9 indicates, there is a large area of vacant land that lies to the southeast of the Hospital. We believe that the British and American eclipse camps were located in the north-western sector of

Fig. 11.9 An aerial view of part of present-day Alor Setar showing the location of the Main Hospital (Hospital Besar), the site of the British Residency, and the College of Medical Assistants (Kolej Pembantu Perubatan). We believe the large brown-coloured compound slightly right of centre, and now associated with the Fire Station (Balai Bomba), was used by the British and American solar eclipse expeditions in 1929 (base map: Google maps; map modifications: Azam Noor).

this compound, close to the British Adviser's house and to the stream leading off the nearby river. Currently, this compound is associated with the Alor Setar Fire Station (Balai Bomba).

11.4.2 Monsoonal Weather and the 9 May 1929 Total Solar Eclipse

In northern Sumatra and the Malayan Peninsula (see Fig. 11.7) the month of May was traditionally a difficult period for astronomers as the changeable weather meant that clear skies were likely much less than 50% of the time (Stratton, 1928). In addition. topography played a key role: a coastal or near coastal site would be more likely to experience clear skies than an inland mountainous site that usually would attract clouds. We see this reflected in the unsuccessful attempts to observe the 9 May 1929 total solar eclipse listed in Table 11.2 (which is adapted and developed from Table 10 in Orchiston et al., 2019b, but with the exclusion of the Philippines).

Table 11.2 Western expeditions and the total solar eclipse of 9 May 1929.

Country	Expedition	Observing Site	Cloudy or Clear Weather	References
Dutch East Indies (Sumatra, Indonesia)	Dutch	Idi	Cloudy	Minnaert, 1931
	American	Takengon	Clear	Miller and Marriott, 1929
	German			
Kedah Unfederated Malay State (Malaysia)	American	Alor Star	Cloudy	This chapter
	British			This chapter
Siam (Thailand)	British	Pattani	Cloudy	Soonthornthum et al., 2021
	German			Soonthornthum et al., 2021
Indochina (Vietnam)	French	Poulo Condore Is.	Clear	Danjon, 1938

As outlined in this chapter and the preceding one in this book (Soonthornthum et al., 2021), cloudy weather prevailed at the near-coastal sites of Alor Star and neighbouring Pattani on the day of the eclipse. However, French astronomers led by André-Louis Danjon (1890–1967) successfully observed the eclipse from Poulo Condore Island (see Fig. 11.7) off the coast of present-day southern Vietnam (see Danjon, 1938; cf. Phạm and Lê, 2021), while—against all odds—the American team from Swarthmore College based at Takengon in northern Sumatra (Fig. 11.7), also saw the eclipse. Their success was nothing short of remarkable:

> We had not seen a clear sun for days preceding the eclipse. It was at that season of the year known as the change of the Northeast to the Southwest Monsoon. The Southwest Monsoon was to bring clear weather, and it did five days after the eclipse.
>
> The eclipse occurred at 12:47 o'clock. In the morning the sky was entirely overcast. About nine o'clock a round blue patch about 20° in diameter appeared in the southeast sky. It persisted, and seemed to drift slowly toward the completely overcast sun. At eleven o'clock one could tell where the sun was in the sky. Later it was entirely overcast again. At the time of first contact the sun was invisible, but the blue circular patch still drifted slowly on. Sometimes during the partial phase one could tell by using field glasses that the sun was eclipsed. Ten minutes before second contact we took our places at the instruments, having decided to make all exposures regardless of the clouds. At that time one could not tell with the unaided eye that the sun was in partial eclipse. Five minutes before totality it was considerably brighter, and at totality the sun was in the centre of the circular blue patch, which to the naked eye seemed perfectly clear. It remained clear during the entire period of totality, then the clear patch moved on, and half an hour after totality the sun was again obscured by clouds. (Miller and Marriott, 1929: 503–504).

During totality the Americans (and presumably the German astronomers, who also were based at Takengon) had an excellent view of the corona, which

> …was beautiful. A long, sharp coronal spike could be traced with the unaided eye to a distance of three solar diameters from the sun, and even further on the photographic plate. There were three other very long spikes. In addition the photographs showed many shorter and finer streams of normal shape. The form of the corona is … clearly not of the maximum

> type and it lacks the polar rays and long equatorial streams of the minimum type. (Miller and Marriott, 1929: 504).

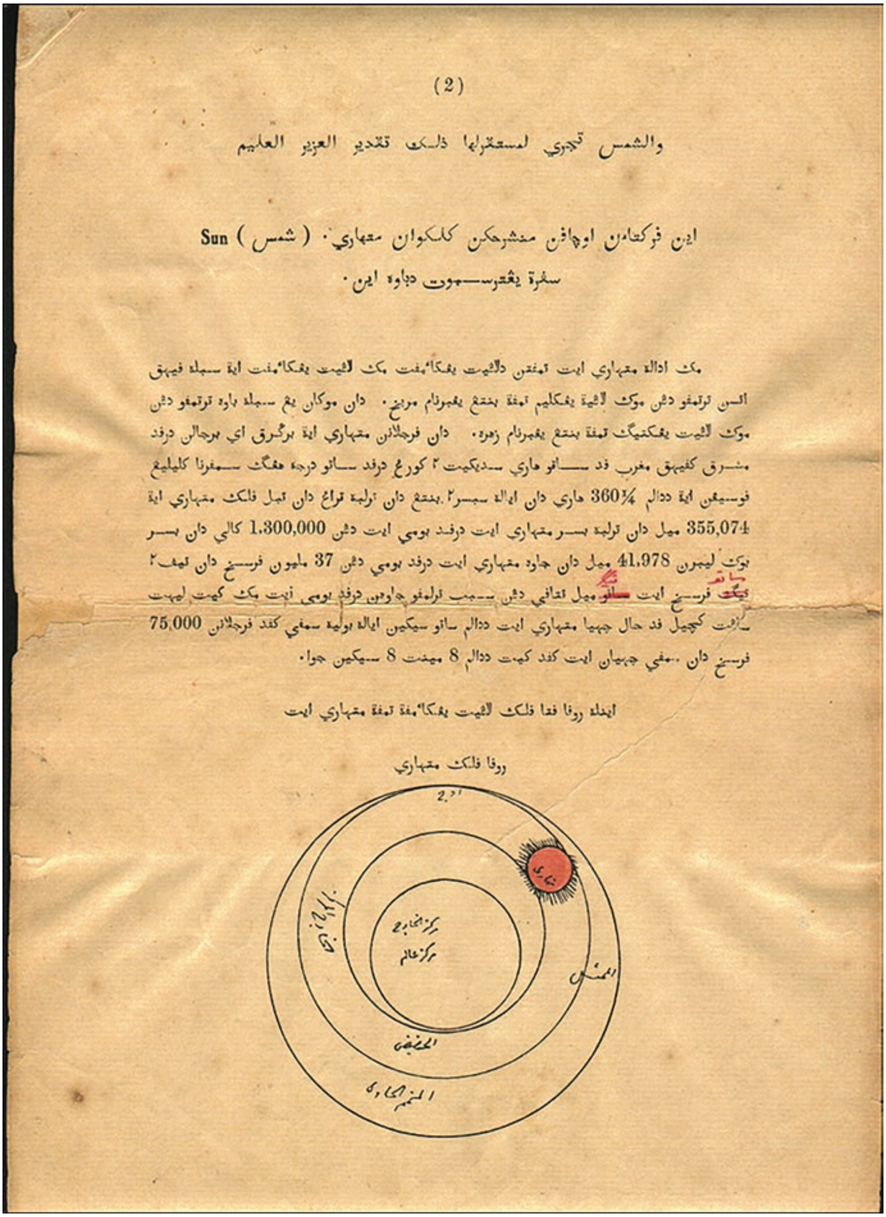
This description and the assessment of the form of the corona mirror the conclusions reached by the Alor Star astronomers on the basis of photographs of far inferior quality. Meanwhile, the Einstein experiment photographs taken through the circular blue patch at Takengon showed stars as faint as magnitude 9.2 on the best plates (ibid.).

What of the Dutch team at the coastal Sumatran site of Idi? Minnaert (1931: 151) reports that this team went to Idi "… with a view of observing the flash-spectrum and the corona and making spectrophotometric investigation. [But] Shortly before totality the sun was hidden by clouds so it was impossible to secure eclipse photographs." Nonetheless, they were able to obtain some useful research results in spite of the uncooperative sky conditions, even if the fortuitously positioned 'observing hole' seen at Takengon was not visible from the coast. This being the case, Minnaert and his team must have rued their decision to site their observing camp on the coast instead of up in the mountains to the south of Lake Tawar, which according to Stratton (1928) was their original plan.

11.4.3 Haji Wan Sulaiman and the 'Eclipse Circular'

In many parts of the world, astronomers, religious leaders and politicians have used high-profile astronomical events such as total solar eclipses and transits of Venus as vehicles to explain the scientific basis of Western astronomy to their followers or local populations and help dispel myths, legends and mysticism. For example, prior

Fig. 11.10 Haji Wan Sulaiman bin Wan Shiddiq (after *Nasihat Fasal* … (n.d.).



(2)

والشمس تجري لمستقرلها ذلك تقدير العزيز العليم

اين ڤركتاءن اوچاڤن منشرحكن كلكوان متهاري ٠ (شمس) Sun

سفرة يغترسبوت دباوه اين ٠

مك اداله متهاري ايت تمفتن دلئيهت بغكاءمنت مك لئيهت بغكاءمنت اية سبلة فيهق
السن ترتمفو دڠن موك لئيهة بغكليم تمفة بنتڠ بنمبرنام مريخ ٠ دان موكان يغ سبلة باوه ترتمفو دڠن
موك لئيهت بغكتيگ تمفة بنتڠ بنمبرنام زهره ٠ دان فرجالنن متهاري اية برگرق اي برجالن درفد
مشرق ككفيهق مغرب فد ساتو هاري سديكيت ٢ كورڠ درفد ساتو درجه هڠگ سمڤرنا كليليڠ
فوسيڠن اية ددالم 360¼ هاري دان اداله سبسر٢ بنتڠ دان ترلبه تراڠ دان تبل فلك متهاري اية
355,074 ميل دان ترلبه بسر متهاري ايت درفد بومي ايت دڠن 1,300,000 كالي دان بسر
بوك ليبرن 41,978 ميل دان جاوه متهاري ايت درفد بومي دڠن 37 مليون فرسخ دان تيف٢
تيگ فرسخ ايت ~~ساتو~~ ميل تقاني دڠن سبب ترلمفو جاوهن درفد بومي ايت مك كيهت ليهت
ساڤت كچيل فد حال جهيا متهاري ايت ددالم ساتو سيكين اياله بوليه سمڤي كفد فرجالنن 75,000
فرسخ دان سمڤي جهيان ايت كفد كيهت ددالم 8 مينت 8 سيكين جوا ٠

ايتله روفا فتا فلك لئيهت بغكاءمڠة تمفة متهاري ايت

روفا فلك متهاري

Fig. 11.11 Page 2 of the 'Eclipse Circular', which is about the Sun (after (after *Nasihat Fasal …* (n.d.).

to the 1874 transit of Venus, the Madras Observatory astronomer Chinthamani Ragoonatha Charry (1828–1880) wrote booklets in four local languages about these transits and their astronomical significance (Shylaja, 2012; Venkateswaran, 2019), while Siam's King Rama IV used the historic 1868 total solar eclipse to try and teach his court, the Royal astrologers and his subjects about Western astronomy and the actual reason for eclipses (see Soonthornthum and Orchiston, 2021).

In Malaya the distinguished writer and Kedah Islamic scholar Haji Wan Sulaiman bin Wan Shiddiq (1854–1940; Fig. 11.10; Yusof, 1991) used the 9 May 1929 eclipse to try and teach about astronomy by preparing an 'Eclipse Circular'. Although this was known to have existed back in 1929 it was only in 1992 that a copy was located by the first author of this chapter, with assistance from his friend Hilmi bin Abdul Rani. What everyone had assumed would be a scholarly pamphlet on astronomy printed by Zi United, Mercantile and Mathba'atuz Zainiyah Press in Penang (which published most of Haji Wan Sulaiman's literary works) turned out to be a 3-page general guide to the Sun and Moon (e.g. see Fig. 11.11). It was devoid of any astronomical calculations and merely provided basic commentary and Quranic verses. It did not even mention eclipses, let alone the upcoming one of 9 May 1929, so there was no attempt to dispel the prevailing view among urban and rural Malays at that time that solar eclipses took place because a dragon or a large snake was intent on devouring the Sun.

But Haji Wan Sulaiman's heart was in the right place. Apparently, he was inspired to prepare the 'Eclipse Circular' after attending an exhibition on 25 April at the Royal Theatre (Fig. 11.12) in Jalan Raja, Alor Star, and hearing Dr Jackson speak about the 1929 eclipse. While Haji Wan Sulaiman enjoyed the exhibition and

Fig. 11.12 The Royal Theatre in King's Road, Alor Setar, in 1970. The building was erected in 1920 by Y.T.M. Tunku Ibrahim, the Acting Sultan from 1914 to 1934, and originally was used as a theatre for stage performances. The building was then leased to the Shaw Brothers for 'silent movies', and it was at this time that it also featured the public exhibition about the 1929 solar eclipse (courtesy: Kedah Darul Aman State Museum).

lecture, he lamented the fact that he and the great bulk of the audience could not fully appreciate the lecture or the display because they could not understand English. Haji Wan Sulaiman was at the Royal Theatre on 25 April, and he then needed time to read up on the Sun and Moon, write the circular and distribute it to mosques prior to the 9 May eclipse, so he must have written his ‘Eclipse Circular’ at the very end of April 1929 or in the first few days of May 1929.

An inscription written in red ink on the top right corner of the first page suggested that once it was finished, Haji Wan Sulaiman sent the ‘Eclipse Circular’ to the imams of all mosques in Kedah that lay within the path of totality of the May 1929 eclipse (and perhaps even to those in neighbouring Perlis). It is not known whether the imams were able to expand on the contents of the circular and explain to their followers that noise and commotion were unlikely to drive away the evil creature intent on devouring the Sun on 9 May 1929, and that after a few minutes of totality the Sun would reappear anyway, safe and sound.

11.5 Concluding Remarks

The band of totality of the 9 May 1929 total solar eclipse crossed part of the Unfederated Malay State of Kedah on the Malayan Peninsula and eclipse expeditions from Britain and America were based in Alor Star. They shared the same observing compound that is now an area of vacant land associated with the Alor Setar Fire Station, but in 1929 was adjacent to the house of the British Adviser. Monsoonal weather conditions conspired to prevent the astronomers from carrying out their planned research programs, which focused on photographing the Sun in order to confirm Einstein’s Theory of General Relativity, and conducting spectroscopic and photometric observations of the corona. However, some observations of the corona were made through cloud, and a large prominence was seen on the eastern limb of the Sun. Cloudy skies also plagued Western eclipse teams based in nearby Pattani (southern Siam) and at Idi on the east coast of Sumatra. Successful eclipse observations in this region of Southeast Asian were only made at two sites: by French astronomers at Poulo Condore Island off present-day Vietnam, and—remarkably—at Takengon in central Sumatra, where the ‘weather gods’ smiled on the American and German expeditions and favoured them with splendid views of the eclipse through a 20° circular hole in the clouds that just happened to hover over the Sun during totality.

Finally we examined what we called Haji Wan Sulaiman’s ‘Eclipse Circular’, even though it does not even mention eclipses and is not the scholarly pamphlet replete with mathematical eclipse computations that was anticipated by all prior to the discovery of a copy in 1992. Instead, it is a 3-page ‘circular’ with basic information about the Sun and the Moon’, which Haji Wan Sulaiman hurriedly prepared at the end of April 1929 and distributed to mosques in Kedah located in the zone of totality of the eclipse. We can only hope that some imams were able to elaborate on the contents of the circular when they gave eclipse sermons and led prayers just before the 9 May 1929 eclipse. Haji Wan Sulaiman was Kedah's leading Islamic scholar at the time and we applaud his actions in this context, but we are not aware that he was familiar with the mathematical computations involved in eclipse predictions, or that he ever wrote a detailed scholarly work on astronomy. Astronomy, it would seem, was not his forté. Therefore we wonder if he only became aware of the up-coming solar eclipse when he attended the Royal Theatre exhibition and heard Dr Jackson speak on the topic.

Total solar eclipses have captured the hearts and minds of mankind for eons, and thanks to stories and reminiscences passed down to them by their parents and their grand-parents there are still many Malays living in Kedah today who view the total solar eclipse of 9 May 1929 with nostalgia. We dedicate this chapter to them and to their ancestors.

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Chapter 12
Time Signals for Mariners in SE Asia: Time Balls, Discs, Bells, Guns and Lights

Roger Kinns

12.1 Introduction

Accurate determination of longitude by a ship at sea was one of the great technical challenges of the eighteenth century. All too often, errors in navigation and inaccuracies on charts had resulted in loss of life from shipwrecks on rocks. The Longitude Prize, established in Great Britain in 1714 during the reign of Queen Anne, was designed to encourage development of solutions. The Royal Observatory at Greenwich had been founded during the reign of King Charles II specifically to improve accuracy in navigation via provision of precise astronomical observations, with initial measurements in 1676 (Howse, 1997: 45). The key was that the Earth rotated at an almost exactly constant rate, so that remote stars appeared to rotate about the axis of the Earth's rotation while the Moon revolved about the Earth and changed position relative to the stellar background. Mean time establishes noon at regular 24 hour intervals. This eliminates any daily variations caused by the Earth's elliptical path around the Sun; these variations are specified in nautical almanacs. Local mean time changes by one hour for each 15° change in longitude.

In principle, a navigator could measure the time when the Sun was at its zenith, measure the relative positions of the Moon and a chosen set of stars, and then use a nautical almanac to compute longitude relative to a prime meridian. This method of lunar distances had been recognised by European astronomers, but it required accurate predictions of the Moon's future position and invention of instruments that allowed precise angular measurements at sea that were not available in the early eighteenth century. That was the method favoured by Maskelyne (1763), using Greenwich as the location of the prime meridian. An alternative approach was to use measurement of time at that prime meridian in place of stellar observations, but clocks and watches in the eighteenth century generally had poor accuracy, made

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even poorer by the effects of seaway motion and temperature changes. John Harrison demonstrated in 1764 that sufficient accuracy was achievable and he was awarded part of the Longitude Prize. However, it was still necessary to find ways in which accurate timekeepers could be built in a reasonable time for a realistic price. There were many important contributions to the overall development (Howse, 1997: 71–81). It was not until the 1830s that chronometers, as they were by then called, became available in sufficient numbers at sufficiently low cost to be carried by all major ocean-going vessels (Rooney, 2009).

12.1.1 The Need for Time Signals in Harbour

Although chronometers were much more accurate than ordinary clocks and watches, there could be significant cumulative errors after a long period at sea. The method of lunar distances, for example, was still needed to verify the location of land-based signals that could be used to check chronometers. These land-based signals took many different forms, including discs, guns and flags, but the option preferred by the British Admiralty was a time ball, dropped at a prominent position at the same time each day within sight of ships in harbour. It had been invented by Robert Wauchope (1788–1862), a distinguished Royal Navy officer, with a first trial implementation at Portsmouth, England in 1829, followed by the first public time ball at Greenwich in 1833 (Bartky and Dick, 1981). He recommended time balls to the East India Company and to many other authorities and countries worldwide, including the USA: early time balls were introduced in Mauritius, St. Helena and the Cape of Good Hope, on the trade route between Europe, India, SE Asia and beyond (Howse, 1997: 83). The ball would usually be raised to cross-trees in two stages, so that an observer would know that a signal was imminent. The time to be recorded was the moment a gap first appeared between the top of the ball and the cross-trees, as the ball was released by triggers to descend in initial free fall. A significant exception was the first time ball at Mauritius, which preceded the Greenwich time ball by six months and was arranged to disappear at the designated time (Lloyd, 1833).

To be of value to navigators, the time had to be precise and the signal had to be repeated at regular intervals. Then, the rate at which a chronometer was gaining or losing time, as well as the absolute error on a particular day, could be determined. That calibration would be repeated at other ports. Any adjustment was deferred until return to a chronometer maker. The procedure for precise determination of longitude using a chronometer still required considerable skill and use of nautical almanacs (Greenwood, 1850). It was only in the 1930s that radio time signals and radio receivers were sufficiently widely available to make time balls and other visual signals redundant.

12.1.2 Signalling of Time for Domestic Use

Although the primary purpose of harbour signals was to provide information for mariners, they were public signals that could be used for domestic purposes. The methods by which time could be distributed inland and used for effective regulation of public clocks, businesses, railways and personal watches are outside the scope of this chapter. Time balls were installed in many inland towns and cities in Europe and North America, while time guns were often favoured by the population at large, although not always those in close proximity to a gun, who might not be within range of a visual signal. The techniques preferred in Asia need further investigation.

12.1.3 Clocks and Chronometers

The precise determination of time for signal operation required high-quality transit telescopes at an astronomical observatory and precise astronomical clocks that were regulated by star transits. They could be used to extrapolate time accurately should poor weather prevent transit observations. The best-equipped observatories had several clocks running in parallel.

Marine chronometers carried by ships at sea were relatively small, often being about 0.15m diameter, and had to tolerate the extremes of motion, humidity and temperature that would be encountered during a typical voyage. They were always expensive relative to domestic clocks and watches. They also had to be handled with care: it was regarded as bad practice to move a ship's chronometer to an office in harbour for calibration purposes. If no time ball or other visual signals were available in port, an intermediate watch would be used to relate an office time signal to the chronometer.

Large parts of SE Asia did not have local observatory facilities for determination of longitude or star transits that could be used to regulate master clocks. Often, the first accurate determinations of longitude were made in support of special expeditions to observe major astronomical events such as Transits of Venus or solar eclipses. Once the latitude and longitude had been determined for one location on land, triangulation could be used to establish the positions of other landmarks. Previously, astronomical observations might be restricted to the determination of apparent noon, using a sextant to find when the Sun was at its zenith. A nautical almanac and knowledge of the date could then be used to determine mean time noon at that location. That determination would allow setting of local clocks and watches for domestic use, but not signals at a stated Greenwich mean time. A local time accuracy of one minute might be adequate, approaching a hundred times the desired maximum error for chronometer calibration.

In the second half of the nineteenth century, undersea electric telegraphs were becoming widely available and could be used to transmit telegraph signals over large distances to check longitude at locations remote from an established observatory. It was no longer necessary for time signals to be close to an observatory. Indeed, the time ball at Deal in England had been operated using telegraph signals from London from its first use in 1855 (Howse, 1997: 102). Towards the end of the nineteenth century, undersea telegraphs allowed interconnection of countries and islands in SE Asia that had previously lacked facilities for determination of exact local time and longitude (Green, 1883).

12.1.4 Time Zones

Following the International Meridian Conference in Washington, USA in October 1884, Greenwich became the prime meridian for the whole world (see Howse, 1997: 145). Greenwich mean time had become the accepted time for the whole of Great Britain in 1848, inspired by the need to have unified railway timetables, but it was not a legal requirement until 1880 and local astronomical time could be used if preferred. Remarkably in 1868, New Zealand became the first country to adopt Greenwich mean time for the whole of the country as a legal requirement (see Kinns, 2017a: 75), whereby NZ mean time was 11 hours 30 minutes ahead of Greenwich. It was driven in New Zealand by the desire to have common opening times for public and telegraph offices. Many countries chose to use standard times that were not exactly multiples of 30 minutes from Greenwich time, but that number declined into the twentieth century, with The USA and Canada leading the way.

The time-zone system recognised that ideally local mean time should be within about 30 minutes of standard mean time, so the Earth was split into time zones at 15° intervals of longitude, each covering a one-hour range of local mean time. That was modified by the positions of coastlines and of boundaries between different countries, and by political considerations. A major deviation was in China, which elected to use the same standard time, eight hours ahead of Greenwich, for the whole of the railway system. The following extract dates from 1904 and illustrates how standard times came to be rationalised. It shows also that the same time zone was being adopted in North Borneo and Labuan (Quotation from November 1904 in United States Naval Observatory, 1906: G9).

> Gradually, and without any public notification, the standard time 8 hours fast on Greenwich has crept into use along the coast of China from Newchang, in the north, to Swatow, nearly the southernmost point; also up the Yangtsekiang as far as Hankau, and at Wei-hai-Wei and Tsingtau. It will be noted that, with the exception of Wei-hai-Wei, this territory is all non-British. There is an observatory at Hongkong, under the colonial government, in longitude $7^h\ 37^m$ east of Greenwich, and this local time is used in the colony; but it seemed good to the Hongkong Chamber of Commerce that the port, and consequently the west river ports and Canton, who use the same time, should fall into line with the rest of the country and adopt the times of the 8-hour zone. The main reason urged for the adoption was that the railway systems in China are now being developed, and that it is better that the change should be made now, before the Hongkong lines are connected with those of the rest of China … The authorities at the colonial office, having been approached by the governor of

> Hongkong, gave their consent to the change of time system, which will therefore be made. The court of directors of the British North Borneo Company, having been communicated with, expressed their willingness to join the scheme, and gave instructions for the adoption of the 8-hour zone time in British North Borneo and the island of Labuan.

The observatory at Hong Kong (the official spelling from 1926) played an important role in the accurate determinations of longitude at various locations in SE Asia, using undersea telegraphs.

There have been time zone changes to the present day, such as the use of "summer time" for part of the year, but they follow the same basic principles. Modern China continues to use a single standard time for the whole of the country, covering five time zones.

12.1.4.1 Greenwich Civil Time

Before 1925, Greenwich mean time for astronomical purposes, beginning at noon, was 12 hours different from the time used by the population at large. Confusingly, both were called GMT and they were often muddled. The decision was then made to introduce the term "Greenwich Civil Time", starting at midnight, and to use this for astronomical as well as domestic purposes (Howse, 1997: 151). This was also called Universal Time from 1928.

12.1.4.2 Worldwide Radio Time Signals

Radio time signals were available at many locations by the 1920s, with increasing power and range. There was another major step forward in 1927. The following notice was published in Singapore and typifies worldwide announcements (*The Straits Times,* 19 December 1927). It describes the signals from Rugby in England, that would allow chronometer calibration anywhere in the world. It includes restatement of a notice distributed by Reuters.

> From Dec. 19 a world-wide time signal will be transmitted from the Post Office wireless station at Rugby twice daily during the five minutes terminating at ten in the morning, and six in the evening Greenwich mean time. The transmission will be especially useful for geographers, surveyors and ships at sea. It will be effected on a wavelength of 18,740 metres …
>
> The institution of the time signal from Rugby station marks an addition to the services by which the station maintains contact with the most distant parts of the world. To ships on every sea, many of which are in the habit of receiving private and press telegrams direct from Rugby, the new time signals will provide means of checking their chronometers and should consequently prove an additional aid to navigation.

Not every ship or location had the required radio equipment and there was still a need for visual signals in harbour. Gradually, that need diminished; it had disappeared after World War II.

12.1.5 Accuracy of Longitude Measurement

The longitudes of time signal locations in official lists were usually given to an accuracy of much better than one minute of arc. This corresponds to one nautical mile at the equator or half that distance at a latitude of 60°. It takes the Earth 4 seconds to rotate by one minute of arc. Sometimes, and especially after the wide introduction of undersea telegraphs, the stated accuracy was better than one second of arc. For example, exceptional measurement accuracy was reported in the 1887 determination of the longitude of Haiphong (Dorberck, 1888). Occasionally, significant errors were found in estimates of longitude, which led to an adjustment of signal times. This happened, for example, in New Zealand in 1874 (see Kinns, 2017a: 75). This was a constant bias error, so chronometers could still be rated correctly prior to that date.

Now, geostationary satellites allow almost universal use of GPS systems that give a direct display of geographical location. Google Maps can be used to show reported locations of time signals relative to other geographical features and modern building developments.

12.1.6 Time Ball Types

High-quality photographs of time balls in SE Asia, and descriptions of the mechanisms used, have proved elusive, but time balls were widely photographed in the Antipodes and particularly fine photographs of time balls in Wellington and Auckland, New Zealand are available. Both mechanisms were of British origin.

12.1.6.1 Time Ball at Wellington, New Zealand

The cropped photograph in Fig. 12.1 shows the Wellington time ball at its second location in about 1890. The ball is in its lowered position and was raised to the cross-trees a few minutes before dropping as the signal. This illustrates the type of external arrangement that might have been used when a ball was positioned on a tower (see Kinns, 2017a). In this case, a rack and pinion mechanism was used to hoist the ball, with an air cylinder to arrest its descent.

12.1.6.2 Time Ball at Auckland, New Zealand

Other arrangements used a ball sliding down a mast, or dropped from a yard arm, with ropes and weights to arrest its descent. An arrangement of this type was used in Auckland for a short time, as shown in the cropped photograph in Fig. 12.2 dating from about 1901. The ball is in its lowered position and can be seen to run down

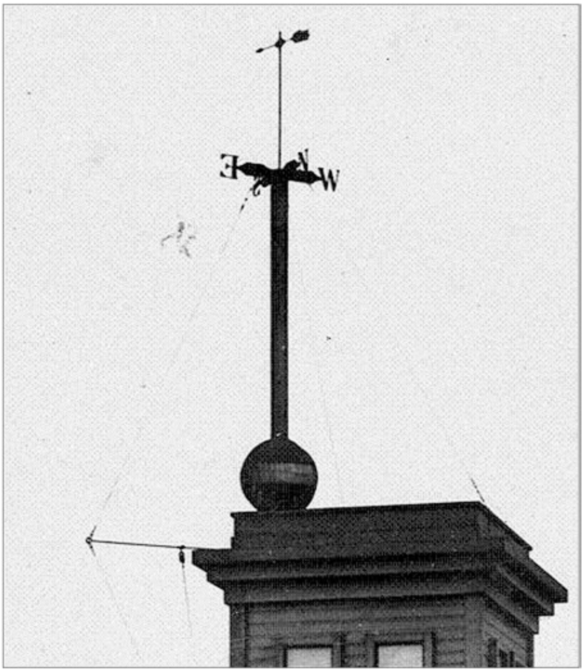


Fig. 12.1 Detail of the time ball at its second location in Wellington, NZ (Wellington City Archives 2012/2:6725).

parallel wires. It has much in common with the arrangement at Fort Canning in Singapore.

It is likely that many of the time ball mechanisms in SE Asia were also supplied from Europe.

12.2 Admiralty Lists of Time Signals

The British Admiralty produced a list of time signals for navigators of naval and commercial ships. They were not restricted to the British Empire. The first edition was published in 1880 and the fifth in 1898. Later editions were produced in the twentieth century. The transcribed entries for South East Asia in the 1880 and 1898 editions are presented in this section. The names of many countries and locations, as well as their spellings, have changed since the nineteenth century, as the result of global conflict in WWI and WWII and as former colonies of European powers achieved independence. The 1880 and 1898 spellings are retained in Tables 12.1 and 12.2 below.

The Admiralty preferred time balls, but The Netherlands used time discs in both Holland and ports in the Dutch East Indies. Only signals that were sufficiently accurate for calibration of chronometers were included in Admiralty lists. These required either accurate knowledge of longitude together with local transit telescopes, or

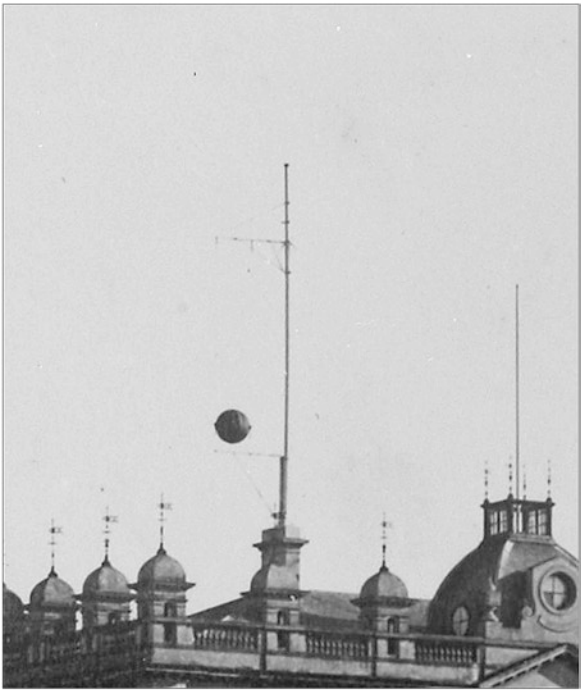


Fig. 12.2 Detail of the time ball on the Auckland Harbour Board Building (Sir George Grey Special Collections, Auckland Libraries, 4-2938).

telegraphic connections to astronomical observatories. Signals were made at a stated Greenwich mean time, corresponding to a specified local mean time. Other, less accurate, signals provided a local service.

12.3 Locations of Time Signals in SE Asia

For the purposes of the present work, SE Asia includes modern Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. Not all of these used visual time signals, although most provided radio time signals after about 1930. China (including Hong Kong), India, Japan, Korea, Sri Lanka and Taiwan are excluded from the present study. The 1880 Admiralty list included only signals in Java, while signals in Rangoon, Singapore, Manila and Haiphong were added in the 1898 list.

Time lights were used at some SE Asia locations in the twentieth century, usually being switched on a few minutes before extinction at a designated time. A sequence of flashes was used in Singapore. A more complex arrangement using a vertical array of coloured lights that were switched on at different times, appears to have been used only in New Zealand (Kinns, 2017b). Some of the most comprehensive descriptions of time signals in particular countries are contained in sailing directions issued by the United States during the twentieth century. Specific entries have been transcribed in this work.

Table 12.1 Transcription of 1880 Admiralty list of time signals: entries for SE Asia

Signal Station Latitude and Longitude	Place	Signal adopted	Situation of Time Signal	Time of Signal being made		Additional details
				Greenwich Mean Time	Local Mean Time	
Netherlands, East Indian Possessions						
	Fourth Point (Sunda Strait.)	Three Circular Discs	On a Tower, 35 yards N. by W. of Fourth Point Lighthouse. 69 feet above ground	h. m. s.	h. m. s.	Discs inclined at an angle of 45° at 5 minutes before signal.
6° 4′ 18″ S.				*16 56 30*	00 00 00	Discs placed vertical at 2 minutes before signal.
105° 52′ 30″ E.						Discs fall into a horizontal position at noon, Fourth Point mean time.
						[*Note*. - If a vessel should ask for time by means of the "International Code" of Signals, the time when the signal will be given will be hoisted on a flagstaff near the time signal tower, using the International Code.]
	Batavia	Black Circular Disc. (7 feet diamtr.)	Post on Rampart near the Boathouse. 69 feet above ground.	h. m. s.	h. m. s.	
6° 7′ 40″ S.				*16 52 47.5*	00 00 00	Disc inclined at an angle of 45° at 5 minutes before signal.
106° 48′ 7″ E.						Disc placed vertical at 2 minutes before signal.
						Disc falls into a horizontal position at noon, Batavia mean time.
						When signal fails in accuracy, a blue, white, and red (horizontal) flag is hoisted on board the gurad-ship in the Roads.
				18 00 00	1 7 12.5	
						When signal cannot be made from the shore, it is made occasionally on board the guard-ship.
						Signal repeated at $1^h\ 7^m\ 12.5^s$ p.m. Batavia mean time, which corresponds to $18^h\ 0^m\ 0^s$ a.m. Greenwich mean time. [*Note.* -Signal not made on Sundays or on *fete* days.]
	Sourabaya	Four Black Discs.	Post on Rampart, East Point of mouth of Kalimas River. 39 feet above ground.	h. m. s.	h. m. s.	Discs inclined at an angle of 45° at 5 minutes before signal. Disc placed vertical at 2 minutes before signal.
7° 12′ 10″ S.				*16 29 5.3*	00 00 00	
112° 43′ 40″ E.						Disc falls into a horizontal position at noon, Sourabaya mean time.
						[*Note.* -Signal not made on Sundays or on *fete* days.]

Table 12.2 Transcription of 1898 Admiralty list of time signals: entries for SE Asia

Signal Station Latitude and Longitude	Place	Signal adopted	Situation of Time Signal	Time of Signal being made		Additional details
				Greenwich Mean Time	Local Mean Time	
British Possessions						
	Straits Settlements, Singapore	Ball	Fort Canning flagstaff	h. m. s.	h. m. s.	Ball hoisted at $0^h\ 55^m\ 00^s$ p.m. and dropped at $1^h\ 00^m\ 00^s$ p.m. mean time of Singapore Observatory.
1° 17′ 33″ N.				*18 04 34.9*	01 00 00	103° 50′ 53″ E.
103° 50′ 53′ E.						Should signal fail, ball will be lowered 5 minutes after $1^h\ 00^m\ 00^s$ p.m., and signal again made at 2 p.m.
						Signal not made on Sundays.
						If signal cannot be made the flag W will be kept flying.
						Masters of vessels may then, by applying at the Master attendant's office, compare their chronometers with the observatory clock.
	Straits Settlements, Singapore	Ball	Pulo Brani	h. m. s.	h. m. s.	Ball hoisted at $0^h\ 55^m\ 00^s$ p.m. and dropped at $1^h\ 00^m\ 00^s$ p.m. mean time of Singapore Observatory.
1° 15′ 45″ N.				*18 04 34.9*	01 00 00	
103° 50′ 00″ E.						Should signal fail, ball will be lowered 5 minutes after $1^h\ 00^m\ 00^s$ p.m., and signal again made at $2^h\ 00^m\ 00^s$ p.m.
						Signal not made on Sundays.
						If signal cannot be made the flag W will be kept flying.

	India, Rangoon	Ball	Tower of Sailors' Home	h. m. s.	h. m. s.	Ball hoisted as preparatory at $11^h 55^m 00^s$ a.m. and dropped at noon Rangoon mean time.
16° 46′ 0″ N.				*17 35 20*	00 00 00	
96° 10′ 0″ E.						If signal fails, the ball is again dropped at $1^h 00^m 00^s$ p.m. Rangoon mean time.
						Signal not made on Sundays.
France, Tonking Possessions						
	Haifong	Ball	On mast of the Observatory East bank of the Song-tambac	h. m. s.		Ball hoisted half way up as preparatory at 10 minutes before signal.
20° 51′ 56″ N.				*13 53 20.4*	21 00 00	Ball hoisted close up at 5 minutes before signal.
106° 39′ 54″ E.						Ball dropped at $9^h 00^m 00^s$ a.m. Haifong mean time.
				13 55 20.4	21 02 00	Signal repeated at $9^h 02^m 00^s$ a.m. Haifong mean time.
Spain						
	Manila	Black Ball Also Gun*	At Meteorological Office	h. m. s.	h. m. s.	Ball hoisted close up as preparatory at 5 minutes before signal.
14° 36′ 0″ N.				*15 56 08*	00 00 00	Ball dropped at noon Manila mean time.
120° 58′ 0″ E.						Also gun fired simultaneously with drop of ball. [*Note*. - This signal is not sufficiently accurate for rating chronometers.]

(continued)

Table 12.2 (continued)

Signal Station Latitude and Longitude	Place	Signal adopted	Situation of Time Signal	Time of Signal being made		Additional details
				Greenwich Mean Time	Local Mean Time	
Netherlands, East Indian Possessions						
	Tanjong Priok (Batavia)	Four Boards	On an iron support near the entrance of the inner basin	h. m. s.	h. m. s.	Boards inclined at an angle of 45° at 5 minutes before signal. Boards placed vertical at 2 minutes before signal.
6° 5′ 48″ S.				*16 52 27.4*	00 00 00	
106° 53′ 09″ E.						Boards fall into a horizontal position at noon Tanjong Priok mean time.
				18 00 00	01 07 32.6	Signal repeated at 1^{h} 7^{m} 32.6^{s} p.m. Tanjong Priok mean time, which corresponds to 6^{h} 00^{m} 00^{s} a.m. Greenwich mean time.
						Note. -Signal not made on Sundays or holidays. Should a blue flag be hoisted, it indicates the apparatus is out of order and that no further time signals can be made on that day.
	Surabaya	Four Boards	Mast on the western Mole head of Kalimas River. 65 feet above sea. 59 feet above ground.	h. m. s.	h. m. s.	Boards inclined at an angle of 45° at 5 minutes before signal. Boards placed vertical at 2 minutes before signal.
7° 11′ 55″ S.				*16 29 2.6*	00 00 00	
112° 44′ 21″ E.						Boards fall into a horizontal position at noon Tanjong Priok mean time.
						Signal repeated at 1^{h} 7^{m} 32.6^{s} p.m. Tanjong Priok mean time, which corresponds to 6^{h} 00^{m} 00^{s} a.m. Greenwich mean time.
						[*Note.* -Signal not made on Sundays or *fête* days.]
						Should a blue flag be hoisted, it indicates the apparatus is out of order and that no further time signals can be made on that day.

The map in Fig. 12.3 shows the principal locations of time signals that have been identified in the present research. Some locations in Java and Singapore are too close together to appear separate on a small-scale map. Some had short lives and none are working in 2020. Some are additional to those in the 1880 or 1898 Admiralty lists. There were concentrations of accurate time signals in Singapore and Java, but few references to visual time signals elsewhere have been found and photographs are even scarcer. There was a notable absence of visual signals for chronometer calibration in Malaysia, Thailand and the Island of Borneo.

12.4 Indonesia

12.4.1 Time Ball at Batavia

The first known time ball in SE Asia was installed in Batavia in 1839. There is reference to a Batavia time ball by Howse (1997, 103), but he gave the date of its introduction as 1861. Its earlier existence was reported by Horsburgh (1852), who quotes from a Seaman's Guide by Lieutenant Melvill. This appears to be a reference to an 1850 publication by Dutch naval officers Lieutenant Baron Melvill of Carnbee and Lieutenant Smits (The Nautical Magazine, 1850). Melvill (1816–1856) had been attached to the hydrographical bureau at Batavia in 1839. The book has been republished by the British Library as a complete facsmile edition, confirming the quotation below (Melvill and Smits, 1850). It also confirms that there was only one time ball on Java at that time.

> **BATAVIA OBSERVATORY** is in lat. 6° 9 S′., lon. 106° 51¾′ E., by astronomical observations made by Johan Mauritz Mohr, and this longitude is considered to be very correct …
>
> Lieutenant Melvill's *Seamans Guide* gives the following information respecting the Time Ball, established at the Observatory in 1839:– "The geographic position of the Time Ball is in 6° 8′ S. and the assumed longitude 106° 52′ E., 7h. 7m. 28sec. in time … The Time Ball is hoisted every day at five minutes before noon, Batavia mean time, half-way up the pole; at two minutes to mean noon it is hoisted to the top, and precisely at Batavia mean noon it falls. For those ships that wish to rate their chronometers according to Greenwich mean time, the moment of six o'clock A.M. Greenwich mean time is indicated in the same way; the ball is hoisted half-way up at 1h. 2m. 28secs. P.M. Batavia mean time; at 1h. 5m. 28secs. to the top; and exactly at 1h. 7m. 28secs. P.M. Batavia time, which corresponds to six o'clock A.M. Greenwich mean time, it falls."

The time ball was dropped twice every day: the first drop was at noon Batavia mean time, with the second drop 1 hour, 7 minutes 28 seconds later at 6 a.m. Greenwich mean time.

There was subsequently a correction of 15½ seconds to the Greenwich mean time (Annual Report, 1876), corresponding to a revised longitude of 106° 48′ 7.5″ E.: "BATAVIA. – There is a time-ball dropped at Batavia mean noon, and also one at $1^h\ 7^m\ 12^s.5$ Batavia civil time = 18^h Greenwich mean time."

A later guide (Findlay, 1878: 684) gave the corrected longitude, but contained errors of 15½ minutes (*sic*) in the Greenwich time of the signal. The following details about the signal location correspond to those given by Melvill and Smits (1850), apart from the longitude:

> Batavia Observatory, where a time ball has been exhibited since 1839, stands East, 3133 yards from the boathouse near the river, or a little more than a mile and a half from the lighthouse on the pier-head. The geographic position of the time ball is in 6° 8′ S. and the assumed longitude 106° 48′ 7½″ E …

12.4.2 Time Ball at Surabaya

Findlay (1878, 703) made specific reference to a time ball at the Marine Establishment in Surabaya. "A time ball is in operation at the Marine Establishment, longitude 112° 43′ 30″ E." This time ball must have been replaced soon afterwards by a signal with a time disc (Admiralty list, 1880).

12.4.3 Time Discs

The 1880 Admiralty list included three entries for Indonesia and none for other countries in SE Asia. These were all in Java: at the Fourth Point (Sunda Strait), the Port of Tanjong Priok in Batavia and Surabaya. The Sunda Strait signal was not included in 1898, while there have been adjustments to the latitude and longitude of signal locations in Batavia and Surabaya that appear to be too large to be corrections to previously measured coordinates. All the entries for Java specify one or more time discs, rather than time balls.

12.4.3.1 Application of Time Discs

Eliminating the dropping mechanism for a time ball could be accomplished using a time disc. One or more round metal discs, often with lightening holes to reduce drag and inertia, rotated from the vertical position to the horizontal position at the designated time. From a distance, an observer saw the ball shape disappear and thereby received the intended time signal from the observatory. Multiple discs ensured visibility from all directions (Hite, 2014). Reduced inertia allowed each disc to be rotated quickly from the vertical to the horizontal position, reducing the time uncertainty. Significantly, the end of rotation gave the exact time, in contrast to time ball operation where separation from the cross trees gave the exact time.

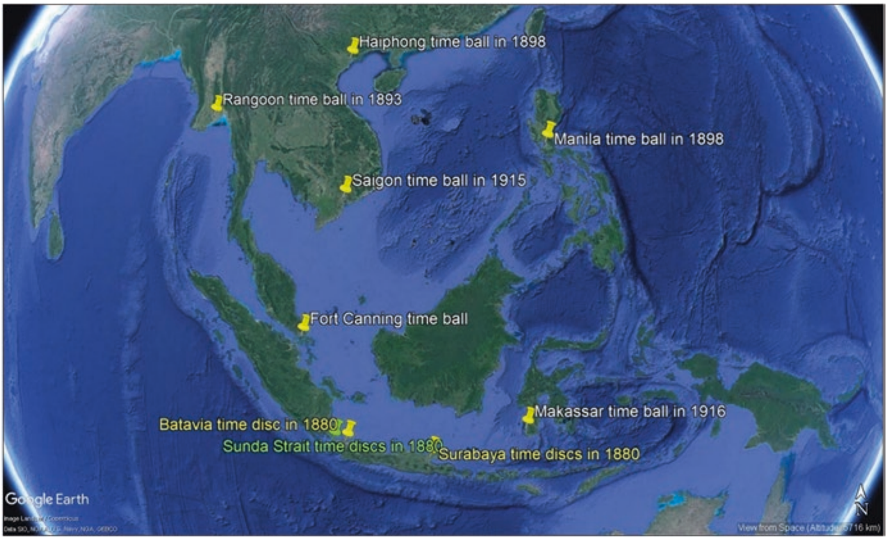


Fig. 12.3 The time signals of SE Asia (courtesy: Google Earth).

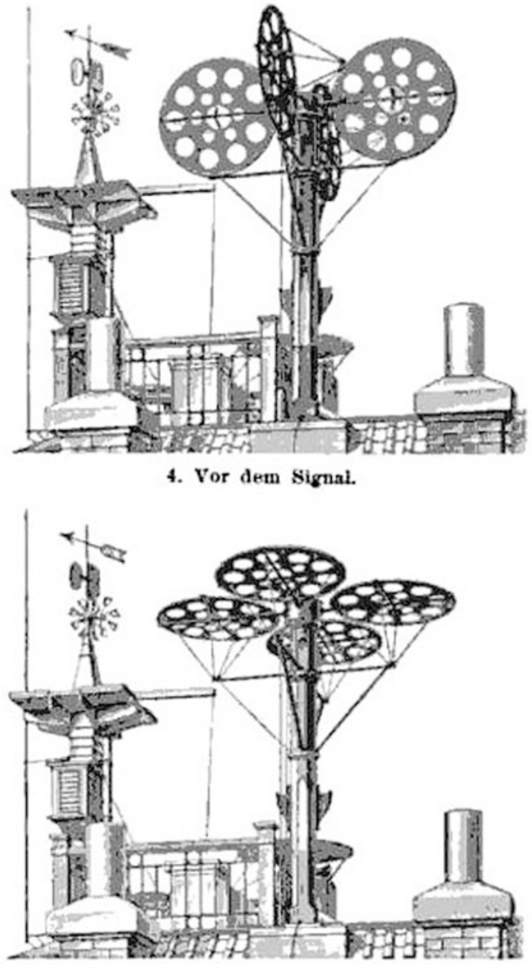
12.4.3.2 Time Discs in the Netherlands

The principal signals in Java used one or more discs instead of a time ball. This follows the practice at the principal Netherlands ports, including Rotterdam and Amsterdam. The diagram in Fig. 12.4 shows how the arrangement worked, while the photographs in Figs. 12.5 and 12.6 show the time discs at Rotterdam and Amsterdam.

12.4.3.3 Time Discs in Java

Curiously, the Admiralty changed the description of signals in Java from discs to boards between the 1880 and 1898 lists. The lists of time signals between 1898 and 1930 (page 529), all refer to the use of four boards at Tanjong Priok. The 1898 description of four boards at Surabaya had been changed to four discs by 1908 (List of Time Signals, 1908: 32). Available photographs suggest that discs were used throughout.

Local mean time noon was the time of Java signals up to at least 1908, with an additional Batavia signal at 6 a.m. Greenwich mean time. Later, a standard time was used for the whole of Java and Java standard time noon was used throughout Java as the time of the signal. In 1922, Java standard time was 7h. 19m. 14.5s. ahead of Greenwich. By 1930, it had been changed to 7h. 20m. 00s. fast on Greenwich. By 1935, it had been changed again to 7h. 30m. 00s. fast on Greenwich, corresponding to longitude 112½° E.



4. Vor dem Signal.

5. Nach dem Signal.

4 u. 5. Zeitklappen auf dem Meteorologischen Institut in Rotterdam.

Fig. 12.4 Time discs at the Rotterdam AS Meteor Institute (Kinns Collection).

Figure 12.7 shows the location of Java signals in relation to a time ball at Makassar which is described later. Note that North is to the right, so that the longitudinal locations of Java signals can be seen clearly. The Batavia and Surabaya time discs were at slightly different locations in 1898 and 1880, as well as at different locations to the earlier time balls, but the changes were too small to appear as distinct pin locations in Fig. 12.7.

Fig. 12.5 Time discs in Rotterdam (https://nl.wikipedia.org/wiki/Watertoren_(Rotterdam_Delfshaven)).

12.4.4 Time Discs at Fourth Point (Sunda Strait)

The Sunda Strait stretches in a roughly northeast/southwest orientation, with a minimum width of 24 km at its northeastern end between Cape Tua on Sumatra and Cape Pujat on Java. It is very deep at its western end, but as it narrows to the east it becomes much shallower, with a depth of only 20 m in parts of the eastern end. It is notoriously difficult to navigate because of this shallowness, very strong tidal currents and sandbanks. It had been an important shipping route for centuries, especially during the period when the Dutch East India Company used it as the gateway to the Spice Islands of Indonesia (1602–1799). The Fourth Point time signal in the 1880 Admiralty list is likely to have become superfluous by 1898 when most large ships used the Straits of Malacca.

12.4.5 Time Discs at Batavia (Tanjung Priok)

The time signal at Batavia was changed from a single large disc to four discs at a different location in the 1880s. The location changed significantly between 1880 and 1898 according to the latitude and longitude specified in the 1880 and

Fig. 12.6 Time discs in Amsterdam (courtesy: Klaus Hülse Collection).

1898 lists, as shown in Fig. 12.8. The location of the original time ball is also indicated.

Work on the Tanjung Priok Port began in May 1877 and was completed in 1886. After the inauguration of the Port in 1886, the activities of the main port of Batavia, which was originally located in Ciliwung River around the Batavia castle, were transferred to the Port of Tanjung Priok (Wikipedia). The entry in the 1880 list dates from the period of port development, while the 1898 entry is after that development. The 1880 time signal used a single disc, while four discs can be seen clearly in the second photograph.

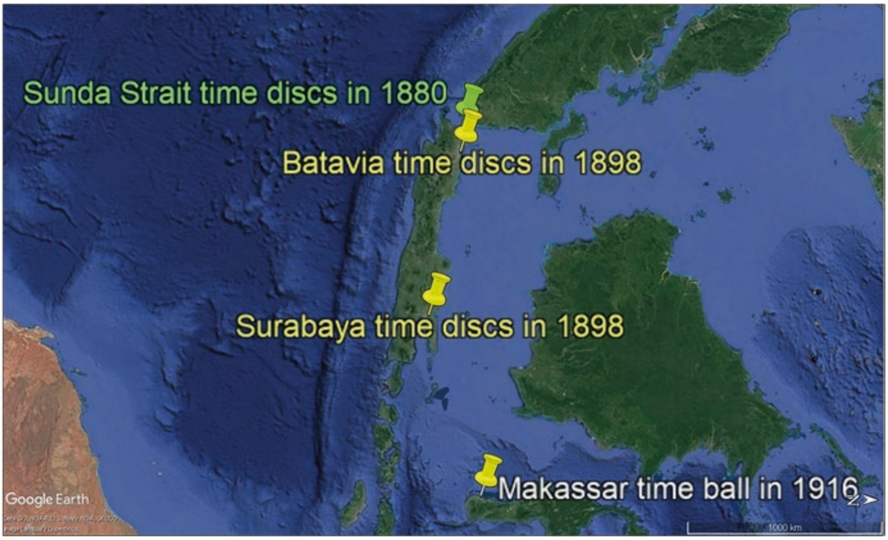


Fig. 12.7 Location of Indonesian time balls and discs, using a SN horizontal axis (courtesy: Google Earth).

Fig. 12.8 Batavia time ball and time disc locations (courtesy: Google Earth).

The photographs in Figs. 12.9 and 12.10 show the change of signal type and location between 1880 and 1898.

The following extract shows that the four discs were still in use in 1935 (Sailing Directions for Sunda Strait and NW Coast of Borneo, 1935: 137):

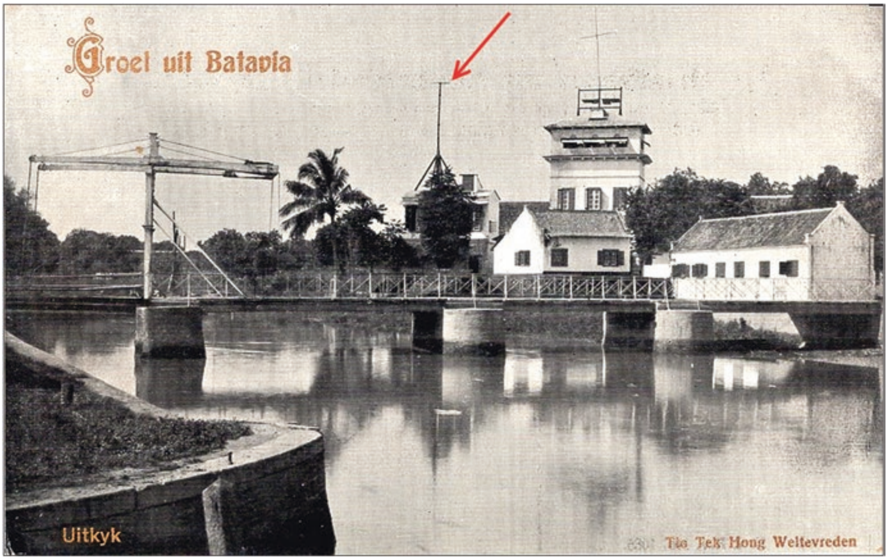


Fig. 12.9 Batavia time disc, shown arrowed, at 1880 location (courtesy: Klaus Hülse Collection).

> **Communications.** – Tanjoeng Priok, being one of the major seaports of the Far East, is a port of call for many of the principal European steamship lines and most of the oriental lines. It is connected with Batavia and the rest of Java by road, rail, telephone and telegraph. There is also a shallow canal to Batavia. For world communications see Batavia.
>
> Standard time in Java is that of the meridian 112° 30″ E.
>
> Time signals are made at the signal station, or “look-out”, on the east side of the entrance to the first inner harbor. The installation consists of an iron structure above which are four round, black, network discs. Normally, these discs lie horizontally. At 5 minutes before noon (Java time), the discs are placed at an angle of 45°; at 2 minutes before noon, they are placed vertically. At noon (Java time) the discs are turned horizontally. In the event of the discs having fallen too early or too late, the fact is indicated by hoisting a red flag with a white square, which remains hoisted until 12:55 pm., the time signals then being repeated in the same manner for 1:00 pm. A blue flag hoisted at 11:30 am., or after a faulty time signal, indicates that no further time signals will be made that day. No time signals are made on Sundays or holidays. Radio time signals are made at the Malabar station. See H. O. Publication No. 205, Radio Aids to Navigation.

12.4.6 Time Discs at Surabaya

Figure 12.11 shows the Surabaya time disc locations in 1880 and 1898. They are separated by about 1.3 km. The apparent location of the 1880 time discs in water may be due to modern relocation of piers, or to small errors in measurement of longitude.

Fig. 12.10 Time discs at Tanjung Priok after 1886 (courtesy: Klaus Hülse Collection).

The location of the signal had changed between 1880 and 1898 and had changed again by 1927 when it was moved from a mast to the top of the harbour office building, but it still used four discs.

The photograph in Fig. 12.12 shows four time discs, but its date is uncertain.

Descriptions in sailing instructions dated 1905 and 1916 (*East Indies Pilot*, Volume 1, 1916: 73) correspond to the 1898 Admiralty list and to the photograph:

> Time signals are shown from a white mast, 65 feet high, 40 feet within the western mole head of the marine basin. The apparatus consists of four round discs, which, 5 minutes before noon, are raised to an angle of 45°; placed vertically 2 minutes before; and at 0h. 0m. 00s., Central Java mean time, corresponding to 16h. 40m. 45.5s. Greenwich time, the discs are dropped horizontal. Should the signal be made too early, or too late, a red flag with white center will be hoisted on the flagstaff above the discs until 1h. 0m. 0s., when the signal will be repeated as above.

Fig. 12.11 Surabaya time disc locations in 1880 and 1898 (courtesy: Google Maps).

Fig. 12.12 Time discs in Surabaya (courtesy: Klaus Hülse Collection).

> A blue flag signals that the apparatus is out of order, and that there will be no further signal on that day.
>
> On Sundays and holidays no signals are given.

The same arrangement was specified in 1922 (Admiralty List: 449). The location had been changed by 1930 to the "Roof of harbour office, Rotterdam Quay" (Admiralty list, 1930: 529). It was also noted that "The apparatus is released by hand in preference to electricity". The location in 1935 remained the same (Sailing Directions for Celebes, Southeast Borneo, Java, 1935: 87):

> *Time Signal*. – The visual time signal located on the roof of the harbor office at the Northeast corner of Rotterdam Quay consists of four black discs which are inclined at an angle of 45° at 5 minutes before the signal; placed in a vertical position 2 minutes before the signal; and let fall to a horizontal position at noon standard time corresponding to 4h. 30m. 00s. Greenwich civil time.
>
> Should the signal fail, a red flag with white center will be hoisted and kept up until 12:55 pm, and the signal repeated at 1 pm. Standard time 1h. 0s. 0s., when the signal will be repeated as above. If the apparatus is out of order, a blue flag will be hoisted. The apparatus is released by hand. The signal is not made on Sundays or holidays.
>
> The time kept here is the same for all of Java, that of 7 hours and 30 minutes fast of Greenwich.
>
> *Time*. – Mid-Java time is used; same time used throughout Java.

12.4.7 Time Ball at Makassar

There are various notices of a time ball at Makassar, established in 1915. There is some variation in the stated latitude and longitude of the time ball, and in the described location, but the same drop time is reported in notices up to 1935.

There was a time ball at Makassar Lighthouse in 1916, as defined in the following notice. Makassar is at the SW end of Celebes Island, now South Sulawesi:

> **Time ball.** – A black ball, hoisted on the yard of a mast, 66 feet high, at Makassar Lighthouse, is dropped at 23h. 57m. 37.2s. local mean time of the meridian of Makassar Lighthouse, corresponding to 16h. 00m. 00s. Greenwich mean time. Should the signal be inaccurate, Flag W of the International Code will be shown. (*East Indies Pilot*, Volume 1, 1916: 311–312).

A black time ball at Makassar was noted in 1922 (Admiralty list, 1922: 449). The latitude and longitude were stated to be 5° 08′ 10″ S., 119° 24′ 18″ E. with a drop time of 23h. 57m. 37.25s, local standard time, corresponding to 16h. 00m. 00s. Greenwich mean time. The date of establishment of the signal was noted as 1915. The drop times are identical to those stated above and the ball height was also noted as 66 feet; the location was reported as "Mast with yard".

Fig. 12.13 Makassar Lighthouse in about 1905 (Kinns Collection).

The time ball was also noted in 1930 (Admiralty list, 1930: 529). The stated latitude and longitude were changed slightly to 5° 07′ S., 119° 24′ E., but the drop time was still 11h. 57m. 37.25s, civil standard time, corresponding to 4h. 00m. 00s. Greenwich civil time. The stated signal height remained at 66 feet, but the location was noted as "Roof of Hangar V".

The photograph in Fig. 12.13 shows Makassar Lighthouse in the early twentieth century. The lighthouse is believed to have been destroyed in about 1920. The lighthouse coordinates were 5° 08′ 2.03″S., 119° 24′ 18.32″ E. (Lightphotos, 2013).

The Makassar time ball was still operating in 1935 (Sailing Directions for Celebes, Southeast Borneo, Java, 1935: 450):

> **Time Signals–Time Ball** (*5° 07′ 12″ S., 119° 31′ 31″E.*).–The ball is hoisted 5 minutes before the signal and dropped at 11h. 57m. 37.2s, local civil time, corresponding to 4h. 00m. 00s., Greenwich civil time. Should the signal fail, flag "W" of the International Code will be displayed.

It is possible that the changes in the stated latitude and longitude between 1916 and 1935, and the location description, are corrections rather than real changes in time ball location.

12.5 Singapore

12.5.1 Time Balls at Fort Canning and Pulau Brani

There were two time balls in Singapore in 1893, one at Fort Canning and the other on the island of Pulau (often written as Pulo) Brani. The Pulau Brani time ball was moved to Mount Faber in 1905. The site of the Fort Canning time ball is celebrated using a modern representation of a ball on a vertical pole, but it is not operational. The three locations are shown in Fig. 12.14.

The 1898 Admiralty list shows that the two balls were dropped simultaneously at 1 pm, Singapore mean time, corresponding to 18h. 4m. 34.9s. Greenwich mean time. Until the 1920s, GMT for astronomical use was based on zero hours at noon, so Singapore mean time was 6h. 55m. 25.1s. fast on Greenwich. Singapore standard time was later advanced to be 7 hours ahead of Greenwich.

12.5.1.1 Greenwich Correspondence Referring to Singapore Time Balls

During 1910, there was extensive correspondence between the then Astronomer Royal (W.M.H. Christie) and the New Zealand High Commission in London about a proposed system for Wellington, NZ that would replace the installation destroyed by fire in 1909 (see Kinns, 2017a). There was related correspondence with the Admiral Superintendent at Portsmouth, England about problems with the Portsmouth

Fig. 12.14 Singapore time ball locations (courtesy: Google Earth).

time ball. The Singapore time ball apparatus was used to illustrate design characteristics and installation costs. It is clear from this correspondence that a new type of time ball apparatus had been installed at Devonport, England during 1884–1885 and that its design was adopted frequently for new installations. T. Lewis, Assistant to the Astronomer Royal, noted that "This type of installation was used at Singapore, Portsmouth, Brisbane, Cairo, Port Said, Alexandria and other locations". He also identified the suppliers for Singapore (Lewis, 1910): "The stays and hoisting gear for Singapore were made by Messrs Saxby and Farmer, 50 Victoria Street Westminster, who make Railway Signals … The other portions were made by E. Dent & Co 61 Strand, W. C."

The following statement is in a letter from the Astronomer Royal, which refers to adjustment of the trigger arrangement at Singapore (Christie, 1910):

> In the more recent form of apparatus, there are two vertical guides (wire) and when once the ball is hoisted it is held by a small rope. Everything else being loose, the ball drops about a foot before the thick rope used in hoisting comes into real action. In order to make this clear to you I enclose a drawing of the Time Ball at Singapore, which is generally similar to the one at Devonport. We should like to have this drawing back when done with …
>
> As regards the trigger apparatus, it will be well to examine whether there is loss of time between the moment of action of the armature and the release of the stirrup. If you find a considerable loss of time, it will be well to modify the trigger apparatus. In an apparatus which was submitted to us for use at Singapore the loss amounted to 0.6s, and was reduced by the makers to less than 0.2s, when the apparatus was returned to them.

Unfortunately, the Singapore time ball drawings appear to have been lost.

12.5.1.2 Time Ball Design for Singapore

There was a visit to Devonport in 1890 by Saxby & Farmer, who had been chosen as suppliers of the time ball apparatus for Singapore (Homes, 2009). The two installations in Singapore had still to be completed in March 1892, as shown in a published article that also confirms that the external arrangement was similar to the Auckland installation in Fig. 12.2 (*The Singapore Free Press and Mercantile Advertiser*, 21 March 1892):

> For the past three or four years there have been rumours of apparatus for signalling correct time to the shipping, but no decision was come to erect time balls till a couple of years ago. Now matters have so far advanced that tenders are called for by the P. W. D. for the erection of two time balls, one at Fort Canning for ships in the roads, and a second on Pulau Brani facing Tanjong Pragar, so as to be visible to all ships at the Wharves and in the New Harbour.
>
> The Observatory is the small building on the spit of land behind the Drill Hall. The chief feature in it is a massive pedestal of granite, about 4 feet high. This is to form the base for the artificial horizon, the roof being constructed so that by the removal of galvanised iron shutters, a clear view east and west can be obtained. Great care was taken in the construction of the base, it being essential that the vibration should be reduced to the minimum. The

> excavation was carried down 30 feet to the solid rock and then filled in with concrete, and so well has this answered that none but the heaviest traffic over Cavanagh Bridge in the early part of the day affects it. The observatory is to be the home of the clocks, when they are completed, which will probably not be until the end of the year, and of the transit instruments.
>
> The time ball apparatus consists of a steel mast, about 50 feet in height, duly supported by guys and an iron base. Projecting from the mast are two arms one above the other, about twenty two or three feet apart. Two strong wire ropes are stretched as guides to a time ball six feet in diameter and weighing 77 lbs.
>
> The ball is raised by a wire rope and then held in position by another single strand wire rope connected below with a magnet. When the standard clock makes connections, the ball is released by the single strand wire and falls 13ft. 6in. At that point in its fall, the main hauling rope brings into play a leaden check weight weighing 86lbs. and the last six feet of the fall is accomplished at a diminishing rate of speed, until the ball is brought up by spiral springs with a compressibility of 80 lbs. and an indiarubber cushion.

Each ball had a diameter of 6ft (1.8m) and a mass of 77lb (35 kg) with a large drop height of about 6m. It was anticipated that the balls would not be operational until at least the end of 1892. They were certainly operational during July 1893, as shown in the following announcement (*The Straits Times*, 15 July 1893):

> TIME-BALLS on Fort Canning and Pulau Brani are dropped daily (Sundays excepted) at 1 p. m. Observatory mean time. They are hoisted five minutes before 1 o'clock. When the ball drops at 1 p. m. local mean time, the corresponding Greenwich mean time is 6h. 4m. 34.95sec. a. m. Should the electricity fail, through lightning or other causes, to drop either or both of the balls, the ball that does not act will be kept up for about 5 minutes after 1 o'clock, it will then be dropped by hand and the time must not be depended on.

Announcements about the time ball drop times were published regularly in the local press, occasionally noting that there had been a temporary withdrawal of the service or a signal fault. A typical notice indicating that there had been a fault is transcribed below (*The Straits Times*, 27 July 1896):

> These Balls should fall at Fort Canning and Pulo Brani daily to indicate 1 p.m. Singapore mean time, corresponding to 6hrs. 4m. 35s. mean time at Greenwich. Yesterday, the Pulau Brani ball failed at 1 p.m. and also at 2 p.m. To-day:
>
> Fort Canning fell: correctly
>
> Pulo Brani: do.

A signal tower at Fort Canning had been erected in 1879 and served as a combined signal station and lighthouse. The time ball was installed after the two functions had been separated (*The Straits Times*, 13 April 1935). The photograph in Fig. 12.15, taken in 1902, shows the Fort Canning time ball to the left (looking at the image) of the tall signal mast at top centre, with the lighthouse to the right of the signal mast.

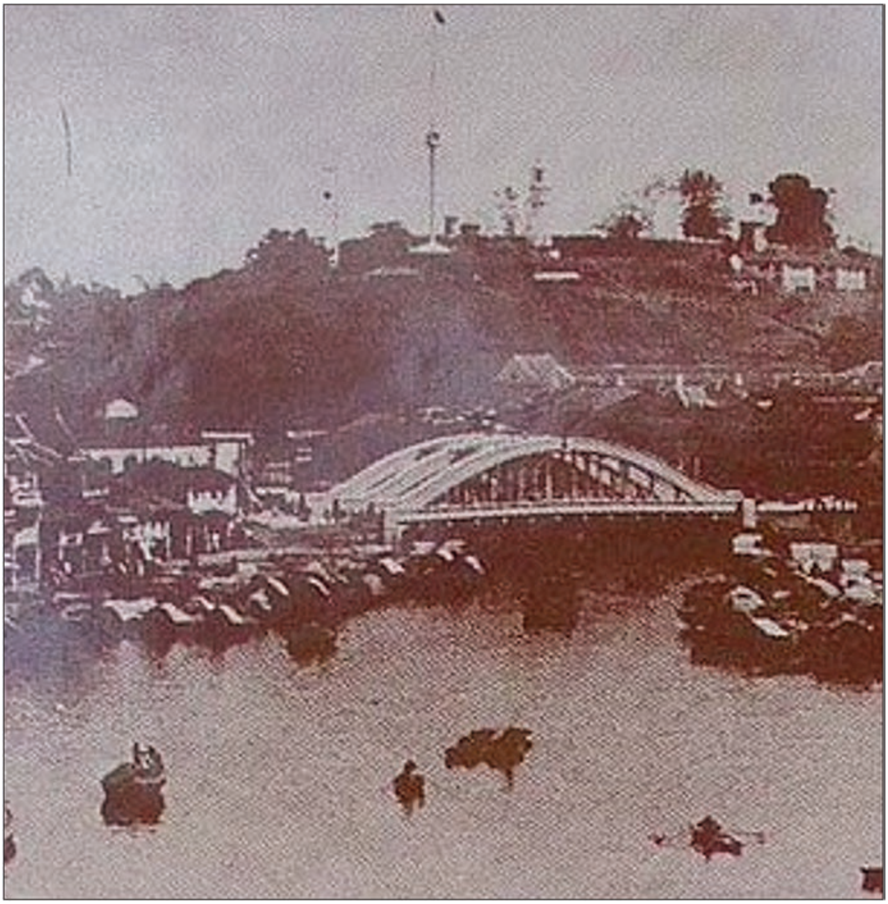


Fig. 12.15 Fort Canning viewed from the Singapore River in 1902 (courtesy: Klaus Hülse Collection).

12.5.2 Singapore Time Signals After 1905

There were several important changes to Singapore time signals in and after 1905. There were five types of signal by 1932, excluding radio time signals.

12.5.2.1 Time Balls at Fort Canning and Mount Faber

It was announced in 1905 that the Pulau Brani time ball was being moved to Mount Faber and that an electric bell would signal Greenwich mean time every hour in the Superintendent's office at Tanjong Pagar wharf (*The Straits Times,* 6 April 1905).

It was announced that Singapore standard time would be changed to 7 hours ahead of Greenwich on 1 June 1905 (*The Straits Times,* 19 May 1905): "Mount Faber time ball is now working, and drops daily at h18 m4 secs35 Greenwich mean–time. On and after 1st June it will drop at 18 hours Greenwich mean–time as already notified."

The 1908 Admiralty list (List of Time Signals, 1908: 16) gave the latitude and longitude of the Mount Faber time ball as 1° 16′ 15″ N., 103° 49′ 24″ E. The time ball was painted red. The coordinates of the Fort Canning time ball were given as 1° 17′ 33″ N., 103° 50′ 53″ E., but its colour was not stated. It was probably black. The same details were given in the 1922 Admiralty list (page 447). The colours were not stated in the 1930 list (page 529).

12.5.2.2 Time Bells

Several time bells were in use by 1927 (*The Singapore Free Press,* 23 December 1927), including the bell that had been introduced in 1905. The 1927 announcement included information about four locations of the time bells, two being designated for chronometer calibration. The announcement also included a surprising comment about the precise timing of the signals.

> Time bells now ring hourly in the Master Attendant's Offices (Register of Shipping), General Post Office, Eastern Extension Company's Office, and the Wharf Superintendent' Office, Singapore Harbour Board. Masters of ships may compare chronometers on application at either the first, or last-mentioned offices.
>
> When obtaining the time by the hourly time bells it should be noted that the Standard Solar Clock at Mount Faber Observatory, by which all time signals are controlled electrically, is kept 0.7 second fast to allow for the fall of the time balls. All bells should therefore ring 0.7 second before each hour, local standard time.

It was recognised that the time ball dropped 0.7 second after the telegraph signal to release triggers had been received. This appears to be a repetition of a previous problem (Christie, 1910). The standard clock was run 0.7 second fast to give correct ball drop times, causing the bells to ring early. This time correction was noted in the Admiralty list for 1930: 529, where it was stated to be "an allowance for time balls to be detected dropping".

12.5.2.3 Time Gun at Fort Canning

A time gun was operating at Fort Canning in January 1907, as indicated in the notice below (*The Straits Times,* 15 January 1907). Its precise date of introduction is presently uncertain:

> TIME BALLS on Fort Canning and Mount Faber drop daily at 1 p.m., Singapore standard time, corresponding to 6 a.m. Greenwich meantime.

> The time-gun is fired at 12 o'clock noon, indicating Singapore standard time, on every day excepting Sunday, when it is fired at one o'clock.

The existence of the gun was not noted in any of the Admiralty lists of time signals for 1908, 1911, 1922 or 1930, suggesting that it was not regarded by the Admiralty as suitable for chronometer calibration.

12.5.2.4 The Collapsible Arm Signal on the Post Office Building

A new type of signal using collapsible arms was erected on the Post Office building in 1930 (*The Singapore Free Press*, 4 February 1930). The signal used three feet diameter discs at the ends of four arms. These arms were extended before the discs fell towards the mast at the time of the signal. It had something in common with both a conventional time ball and the time discs used in Java. The announcement included the following statement about its operation and origin: "The discs are released by electric contact from Mt. Faber observatory, the whole apparatus having been designed and constructed in Singapore by the Colonial Engineer's Department." Figure 12.16 shows a postcard view of the GPO in 1933. The collapsed discs can be seen near the centre of the roof.

Fig. 12.16 1933 View of Singapore GPO, showing the time discs in their collapsed position (courtesy: Klaus Hülse Collection).

12.5.2.5 Time Lights on Mount Faber

Time lights were introduced on 19 October 1931 (*The Straits Times*, 16 October 1931):

> Night time signals are to be established from Monday next on the time ball mast on the south-eastern slope of Mount Faber.
>
> The signals are determined by means of three white electric lights, arranged vertically at distances of six feet apart. The signals will be flashed twice nightly at 8 p.m. and 9 p.m. and repeated in each instance 2 minutes later. The signals consist of a series of one second flashes at 10 second intervals, covering a period of 50 seconds followed by a single long flash of 10 seconds' duration, the conclusion of which denotes the actual time signal.
>
> The signals are clearly visible seaward for five miles.

The time lights followed an unusual sequence, being illuminated for one second at five 10-second intervals, followed by illumination for 10 seconds before extinction at the designated time. This was repeated, so that the signal was given at 8 p.m., 8.02 p.m., 9 p.m. and 9.02 p.m. local time.

12.5.3 Signals in 1932

By 1932, there was an extraordinary array of devices for the main island of Singapore and its surrounding smaller islands, indicating their importance for trade in SE Asia. A comprehensive description of these signals was included in sailing directions that were assembled by the United States in 1932 and published in 1933 (Sailing Directions for Malacca Strait and Sumatra, 1933: 281–282). The principal entries are reproduced in the following sections. The locations of Mount Faber, the Observatory and recommended locations for astronomical observations were described.

> **Mount Faber** is the name of a conspicuous range of hills which rise boldly near the middle of the northern shore of Keppel harbor. The direction of the range is about northwest and southeast, the highest point, 303 feet (92.4m), being towards its northwestern end. Guthrie Hill, 100 feet (30.5m) high, is isolated and conspicuous and situated about 500 yards northwest of the Victoria Dry Dock.
>
> **The Observatory** is situated about 300 yards southeastward of Mount Faber signal staff.
>
> **Observation spot.** – For the convenience of shipmasters large flat stones have been placed for astronomical observations. One of these is near the pilots' club, at the entrance to Albert Dock, and is in 1° 15′ 55″ north, 103° 50′ 41″ east.

"Visual time signals" included the time balls at Fort Canning and Mount Faber, the time gun on Mount Faber, the collapsible arm signal on the Post Office building and time bells at three locations. The time lights were included under "Night time signal":

Visual time signals. – Time balls are dropped at Fort Canning and Mount Faber Observatory daily except Sunday at 12h. 00m. 00s. Standard Time, corresponding to 7h. 00m. 00s. (*sic*) Greenwich Civil Time. A time gun is fired at Fort Canning 11h. 59m. 59s., corresponding to 6h. 59m. 59s. (*sic*) Greenwich Civil Time. On Sundays 1 hour later.

Each signal consists of a ball, hoisted as preparatory at about 55 minutes p. m., and dropped daily by electricity at 13h. 00m. 00s. time of the one hundred and fifth meridian, equivalent to 6 hours Greenwich civil time.

When the time signal ball at Fort Canning or Mount Faber fails to drop correctly the flag W will be hoisted at the time signal mast, and the ball lowered slowly by hand about 5 minutes after the signal, but it will be again hoisted at about 1 hour and 55 minutes p. m., and dropped at 14h. 00m. 00s.; should it fail a second time the flag W will be again hoisted.

Should the time ball be under repair the flag W will be kept flying until the repairs are completed.

An electric time bell for the use of shipping is fitted in the wharf superintendent's office, Tanjong Pagar, also at the office of the registry of shipping and at the master attendant's office. This time signal is in connection with the observatory standard clock, and rings automatically at every hour of Greenwich civil time. Chronometer comparisons may be obtained by applying at the above office.

A time signal is also made by black metal discs at the outer ends of four arms, placed at right angles to one another, on a steel framework structure, painted in black and white bands and surmounted by a wooden flagstaff; it is located on the post-office building. At 5 minutes before the signal, the arms are extended horizontally, and at 13h. 00m. 00s., corresponding to 6h. 00m. 00s. Greenwich civil time, dropped close in to the mast. In the case of failure the signal will be repeated at 14h. 00m. 00s. Should failure again occur, the flag W will be hoisted and kept flying until dark.

Night time signal. – A night time signal has been established on the time ball mast on the southeastern slope of Mount Faber, Singapore. The signal consists of three white electric lights arranged vertically, 6 feet apart. These lights are flashed twice each night at 20h. 00m. 00s. and 21h. 00m. 00s., local civil time, corresponding to 13h. 00m. 00s. and 14h. 00m. 00s., Greenwich civil time, and repeated in each instance 2 minutes later. The signal consists of a series of 1-second flashes at intervals of 10 seconds, covering a period of 50 seconds, followed by a single long flash of 10 seconds' duration, the conclusion of which constitutes the actual time of the signal.

The lights are flashed as follows.

FIRST SIGNAL

One-second flash at 19h. 50m. 00s.
One-second flash at 19h. 50m. 10s.
One-second flash at 19h. 50m. 20s.
One-second flash at 19h. 50m. 30s.
One-second flash at 19h. 50m. 40s.
One-second flash at 19h. 50m. 50s.
Ten-second flash from 19h. 50m. 50s. to 20h. 00m. 00s.

SECOND SIGNAL

One-second flash at 20h. 01m. 00s.

> One-second flash at 20h. 01m. 10s.
> One-second flash at 20h. 01m. 20s.
> One-second flash at 20h. 01m. 30s.
> One-second flash at 20h. 01m. 40s.
> One-second flash at 20h. 01m. 50s.
> Ten-second flash from 20h. 01m. 50s. to 20h. 02m. 00s.
>
> The signals are repeated in a similar manner from 20h. 50m. 00s. to 21h. 00m. 00s. and from 20h. 59m. 00s. to 21h. 02m.00s.

It appears that the time balls were dropped twice on weekdays in 1932, first at noon and then at 1 p.m., with the second drop as the official time signal. However, incorrect Greenwich civil time values are given in the first paragraph: they should be seven hours before the Singapore standard times. The first drop accompanied the firing of the time gun at Fort Canning, except that the gun was fired one second before noon on weekdays and one second before 1 p.m. on Sundays.

The combination of a time ball and time gun was used at other locations, including Edinburgh in Scotland, but the firing of the gun and dropping of the time ball were usually simultaneous. It was recognized in Admiralty lists that sound propagates at about 340 m/sec, so allowance had to be made for the distance of a ship from the gun if sound is used as the time signal. The remarkable 1861 arrangement at Edinburgh Castle used a controlled clock with a mechanism that compensated for the short time it would take for powder to explode after spark ignition (see Kinns, 2011); maps were issued to show the propagation delay to different locations in Edinburgh and the nearby port of Leith. The advance of one second relative to the time balls in Singapore might have been chosen to compensate for the propagation delay to dockside locations.

The signals were not reinstated after World War II, largely because radio signals were by then available universally.

12.6 Burma, now Myanmar

Burma was administered as a province of India during the period of British rule. It is now an independent country, renamed Myanmar. The capital Rangoon, on the Irrawaddy River, has long been an important trading port in SE Asia.

12.6.1 Rangoon

There are various references to an apparent time ball on the Signal Pagoda at Rangoon. However, no supporting evidence of a time signal has been found in notices prior to 1893 and it appears likely that the ball was for other signalling purposes.

12.6.1.1 Signal Pagoda

A 30 m high pagoda on Alanpya Hill is usually known in Myanmar as Alanpya Pagoda or Signal Pagoda, having been previously called McCreagh's Pagoda, Sale's Pagoda, Sandawkyo Pagoda, Gurkha Pagoda, and Tatoo Pagoda, as well as Kyaik Hapaw Cih in the Mon language. The photograph in Fig. 12.17 was taken in 1855 when the pagoda was used as a signal station.

In 1855 a British mission was sent to King Mindon Min of Burma to negotiate a settlement regarding Pegu, annexed by the British following the Second Anglo-Burmese War in 1852. Linnaeus Tripe was the official photographer on this mission. His pioneering architectural and topographical views of the country are an important photographic record.

The circular object hanging from a yard at the top of the pagoda looks like a time ball, but it seems unlikely that there would have been a local observatory or telegraphic connections that could facilitate an accurate time signal in 1855. The pagoda was used as a signal station because of the distance at which it could be seen by a ship coming up the river. It was known as Sale's Pagoda, after Sir Robert Henry Sale, who was stationed on the site with a picket during the First Anglo-Burmese War (1824–26). Sale (1782–1845) was an army officer who had served in India, and then played an active role in the capture of Rangoon. At the time of the 1855 mission's visit the administration of the rapidly growing port was not well-developed.

Fig. 12.17 1855 Photograph showing the Signal Pagoda of Rangoon (by Linnaeus Tripe, British Library on-line Gallery No. 102).

The signalling station was at the Sale Barracks and Sale's Pagoda began to be called the Signal Pagoda.

12.6.1.2 Time Ball at the Mayo Marine Institute

There is no mention of a Rangoon time signal in the 1880 Admiralty list and the first time ball appears to have been erected in 1893. The following notice is taken from the 1893 London Gazette:

> No. 549. - EAST INDIES STATION.
>
> GULF OF MATABAN. - RANGOON RIVER.
>
> *Rangoon - Time Signal Established.*
>
> The Port Commissioners of Rangoon have given notice, that on 1st October, 1893, a time signal would be established on the tower of the Mayo Sailors' Home, Rangoon. – The signal consists of a ball, which is hoisted close up as preparatory every day, except Sunday, at 11h. 55m. 0s., and dropped at noon, Rangoon mean time, equivalent to 17h. 35m. 20s. Greenwich mean time. Should the signal fail the ball will be dropped again at 1h 0m. 0s. Rangoon mean time. Approximate position, Sailors' Home Tower, lat. 16° 46′ N., long. 96° 10′ E. This Notice affects the following Admiralty Plan: – Port of Rangoon, No. 833. Also, Bay of Bengal Pilot, 1892, page 333; and List of Time Signals, 1892, page 12.

The Rangoon time ball appears in the 1898 Admiralty list. The approximate position is stated as being on the Sailors' Home Tower. An illustration of the Seamen's Home is shown in Fig. 12.18. The date is unknown, but it does not appear to have

Fig. 12.18 The Mayo Memorial Seaman's Home at Rangoon (Kinns Collection).

been a suitable building for a time ball. Later notices, giving the same latitude and longitude, indicate that the time ball was located on the nearby tower of the Mayo Marine Institute.

12.6.1.3 Time Gun at the Mayo Marine Institute

A notice in 1916 (Bay of Bengal Pilot, 1916: 358) gives the same time ball location and indicates that there was a time gun as well as a time ball at the Marine Institute. It was fired daily at noon Rangoon *standard* time, 5 minutes 20 seconds before the ball was dropped at noon Rangoon *mean* time.

> **Hospitals.** – Sailors' home. – There is a hospital to which seamen are admitted and a sailors' home.
>
> **Time Signal.** – The time signal, made from the square tower of the Mayo Marine Institute, at an elevation of 81 feet above high water, consists of a black ball, hoisted close up at 11h. 55m. 0s. every day except Sundays, is dropped at 0h. 0m. 0s. Rangoon mean time, which is equivalent to 17h. 35m. 20s. Greenwich mean time.
>
> A gun is also fired (Sundays excepted) at noon Rangoon standard time, which is 5m. 20s. before Rangoon mean time; it is situated close to the time signal. If the ball is incorrectly dropped, it will be hoisted to the masthead immediately, or if it fails to drop, it will remain at the masthead, and in either case it will be dropped at 1h. 0m. 0s. Rangoon mean time.

The briefer 1923 notice does not mention the time gun (Bay of Bengal Pilot, 1923: 364). Admiralty Lists (1922, 447 and 1930, 527) include both the time ball at the Mayo Marine Institute and the time gun, so the gun does not appear to have been discontinued in 1923. Both lists give the latitude and longitude of the time ball as 16° 45′ N., 96° 10′ E. The gun was fired at noon, standard time in 1922, but this had been changed to 1 pm by 1930.

A 1927 report shows that radio broadcasts were by then used for time signals (Port Directory of Principal Foreign Ports, 1928, Rangoon report: 723).

> *Communications*. –There is a government owned wireless station, 10-kilowatts, Marconi type, at Monkey Point, situated in latitude 16° 46′ N., longitude 96° 12′ E. Call letters VTR; wavelengths, 600 and 1200 meters; radius, 600 miles day, 1000 miles night. Handles Commercial messages. Time signals, weather bulletins and storm warnings are sent out. (Date of report, April 1927.)

It appears that the time ball, time gun and wireless signals were all available in 1927.

12.6.1.4 Time Light in Rangoon

A much later notice, issued in 1941, does not mention the time ball or time gun, which are likely to have been discontinued some years previously. Instead, there was a simple time light (Sailing Directions for the Bay of Bengal, 1941: 237).

> **Time signal.** – A time signal is made daily, except Sunday, at 1 p.m. Burma Standard Time, corresponding to 6h. 30m. Greenwich civil time, on an electric signal light rigged on the port flagstaff. The light is switched on 2 minutes before the time of signal; if the signal fails, the light will be immediately switched on for about 5 minutes. The signal will then be repeated at 2 p.m.

The time light in Rangoon was illuminated two minutes before 1 pm Burma mean time and then switched off at 1 pm. This was a daytime signal, so must have been of high intensity.

12.6.1.5 Time Gun at Moulmein

A time gun at Moulmein was noted in Admiralty Lists (1922: 447 and 1930: 527). In 1922 it was fired at noon, standard mean time, but this had been changed to 10 am by 1930. The gun location was given as 16° 29′ 00″ N. and 97° 37′ 00″ E. The Admiralty advised that the signal was “Unreliable; should not be used for rating chronometers. Not fired on Sundays”. These times were different to those used at Rangoon: the locations were separated by about 160 km, so this may have been to avoid any possibility of confusion between the two signals. The locations of the Burma signals are shown in Fig. 12.19.

Fig. 12.19 Location of the time signals in Rangoon and Moulmein (courtesy: Google Earth).

12.7 Indo-China, now Vietnam

There have been two time balls in Vietnam. The first was established in Haiphong in about 1886 and the second was established in Saigon in about 1908. The Haiphong time ball had ceased to operate by 1915. The locations of the two balls are shown in Fig. 12.20.

12.7.1 Time Ball at Haiphong

The Haiphong time ball is believed to have been established in 1886 (Hite, 2014). William Dorberck (1852–1941), then Director of Hongkong Observatory, made precise measurements of the longitude of Haiphong in 1887, using undersea telegraphy. These measurements were presented to the Royal Astronomical Society in London in March 1888 and are likely to have been made in support of a time ball at Haiphong. The paper refers to a transit instrument in Haiphong that had been installed in 1886. Dorberck's wider work as an astronomer has been described by Mackeown (2007).

The coordinates of the time ball were given as 20° 51′ 56″ N., 106° 39′ 54″ E. in the 1898 Admiralty list. Its location was at the Observatory shown in Fig. 12.21. The time ball was on top of the tower and can be seen in its lowered position within a circular fence.

The time ball appears to have been discontinued by 1904. It was not included in the 1904, 1908 and 1911 Admiralty lists and it was not mentioned in 1915 sailing

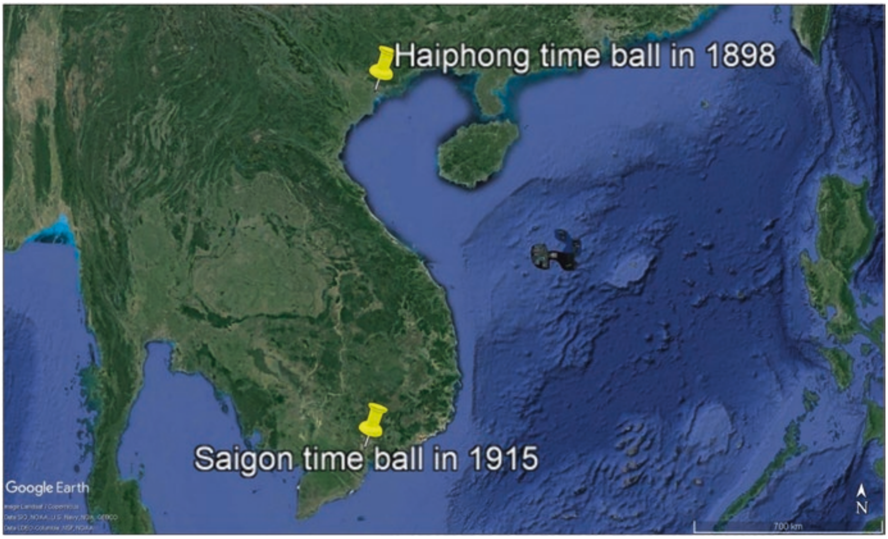


Fig. 12.20 Locations of time balls in Haiphong and Saigon (courtesy: Google Maps).

Fig. 12.21 The Observatory at Phu-Lien (Haiphong) (courtesy: Klaus Hülse Collection).

instructions (Asiatic Pilot, Volume IV, 1915: 277): "Time. – Correct time, for chronometer comparisons, may be obtained at the post office by telephone from Fu-Lien Observatory."

12.7.2 Time Ball at Saigon

The time ball at Saigon was positioned on the signal mast by the commercial harbour. It was installed in 1908, with modified drop times in 1917 (Admiralty List, 1922: 449). The following notice in 1915 shows that the ball was dropped twice daily, first at noon, Saigon mean time and then 6 minutes, 48.3 seconds later at 17h. Greenwich mean time (Asiatic Pilot, Volume IV, 1915: 207-208).

> **Time signal** (Lat. 10° 46′ 40″ N., Long. 106° 42′ 2″ E.). – A ball is dropped from the signal mast in the commercial harbour at noon, Saigon mean time, corresponding to 16h. 53m. 11.7s. Greenwich mean time. The ball is dropped a second time at 17h. 0m. 0s. Greenwich mean time, or standard time of the 105th meridian east of Greenwich.

The drop times were changed in 1917 to 15h. 00m. 00s. and 15h. 05m. 00s. Greenwich mean time. These drop times were the same in 1930, although they were then reported as 3h. 00m. 00s. and 3h. 05m. 00s. "Greenwich mean time (civil)", corresponding to 10h. 00m. 00s. and 10h. 05m. 00s. "Standard time (civil)" (Admiralty List, 1930: 531).

By 1925, radio signals were also available (Asiatic Pilot, Volume IV, 1925: 221): "**Radio**. – There is a radio station at Saigon: call letters HZA; this station sends out radio time signals on a 20,800 meter wavelength (see H. O. Pub. 205 Radio Aids to Navigation).”

The time ball was still operating in 1937, but was deemed to be for local use only. The principal time signals were then by radio (Sailing Directions for the Western Shores of the China Sea, 1937: 203):

> **Time signal. -** Standard time is that of the meridian of 105° east longitude. – A time ball for local use is dropped at 10 a. m., from the signal mast of the Bureau du Port on the northern side of the mouth of the Arroyo Chinois. The ball is dropped again 5 minutes later. Should a signal be in error, the flag W and the ball are hoisted at 10.55 a. m. and dropped at 11 a. m. For radio time signal, see H. O. Pub. 205 Radio Aids to Navigation.

The photographs in Figs. 12.22 and 12.23 (the postcard) show the Saigon time ball from river and shore directions. It was close to a tramway, as shown in the postcard that was sent in 1911.

Fig. 12.22 Saigon signal mast and time ball from the river side (Kinns Collection).

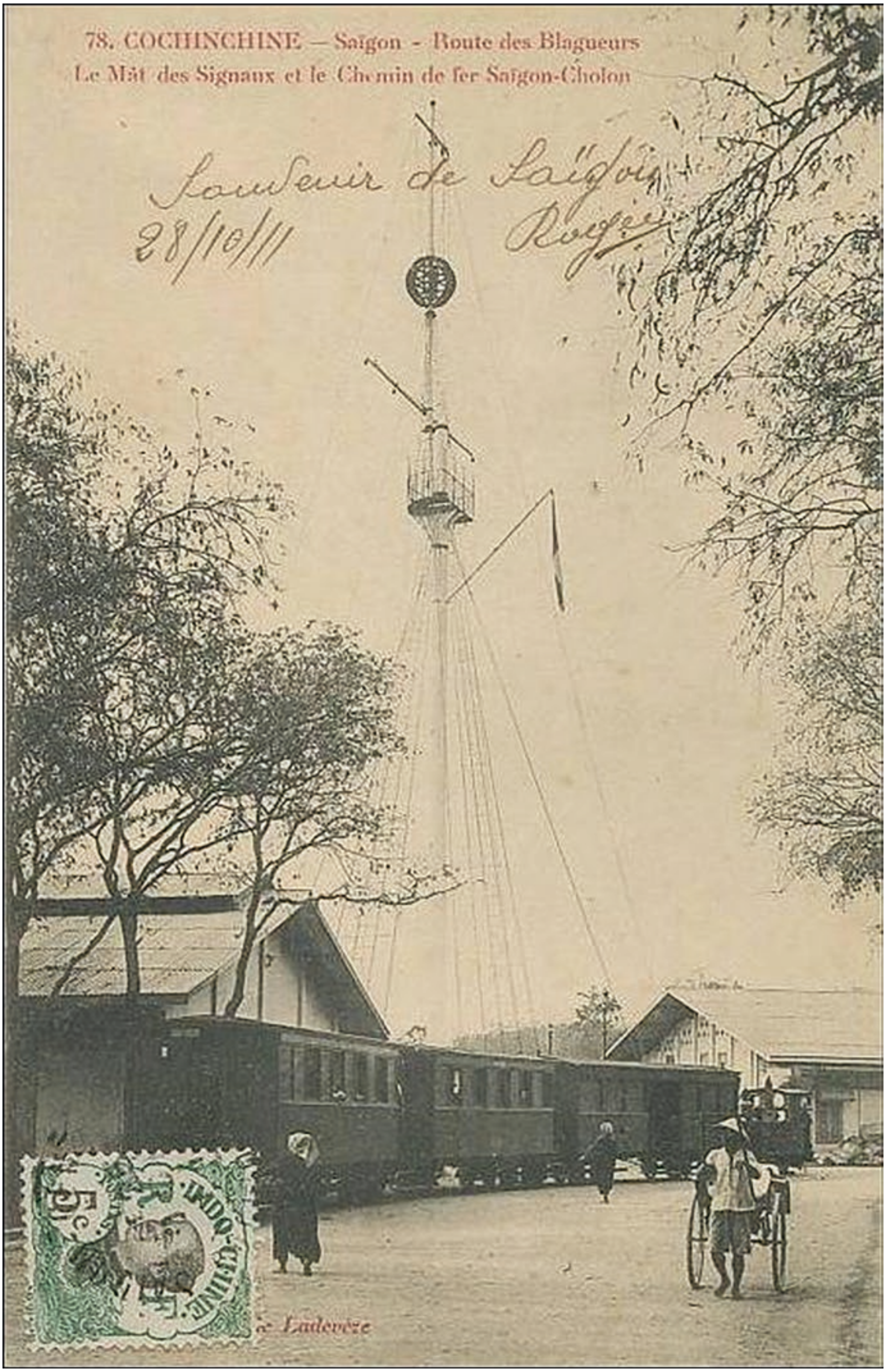


Fig. 12.23 Saigon signal mast and time ball from the shore side (Kinns Collection).

12.8 Philippines

The Observatory and time ball in Manila had been established during the period when the Philippines were administered as a Spanish colony. This period ended with the Spanish-American war in 1898, but the Observatory continued to develop its work.

12.8.1 Manila Observatory

In 1885, Manila Observatory began its time service that greatly benefited merchant shipping. A seismology section was established in 1887. In 1899, the Observatory ventured into astronomical studies. The American colonial government recognized the importance of the Observatory's work and established it as the Philippine Weather Bureau in 1901 (Manila Observatory).

12.8.2 Time Ball and Time Gun at Manila

According to the 1898 Admiralty List, there was a time ball at the Meteorological Office and also a time gun of doubtful accuracy. The time ball location was given as 14° 36′ 0″ N, 120° 58′ 0″ E.

A report in 1902 shows that the time ball and a time gun were still in operation (Gazetteer, the Philippine Islands, 1902: 184):

> … A time ball, black, which is hoisted on the roof of Manila observatory at Ermita, is dropped daily at noon, one hundred and twentieth meridian (E. lon.), standard time. It is hoisted 5 minutes before noon and in case of failure is slowly lowered 5 minutes after the signal time. A gun is also fired from the Battery of San Diego …

The following extract is taken from a 1905 report (Report of the Philippine Commission to the Secretary of War, Part 2, 1905: 392). There is no mention of a time gun.

> … As in former years, the correct time has been determined from star transits and daily telegraphed at 11. a.m. mean time of the one hundred and twentieth meridian east of Greenwich to all telegraph stations in the islands, while to shipping in port the time is signaled at 12 noon by means of the time ball. An arrangement has been made with the Daily Bulletin of Manila, according to which this paper is to be immediately informed whenever the error in dropping the ball exceeds half a second. The correction is then printed in the next edition of the paper. Thus far it happened only once.

12.8.3 Time Ball at Cavite Naval Station

In 1906, a second time ball was established at the Cavite Naval Station (Notice to Mariners, 1906). The ball was dropped at 11 a.m., an hour earlier than the time ball at the Observatory:

> **25. Luzon – West Coast – Manila Bay – Cavite – Time Ball Established**. – A time ball has been established on top of the water tower at the Naval Station, Cavite. The ball is hoisted daily, Sundays excepted, by hand at about 10.55 a.m. and dropped at 11 a.m., 120th meridian standard time (longitude east of Greenwich, equivalent to fifteen hours Greenwich mean time.
>
> In case of not falling on time the ball will be lowered slowly shortly afterward and no other signal will be made that day.

A 1923 report does not mention the ball at the Cavite Naval Station, possibly because it was not primarily for civil use (Annual Report of the Governor General, Philippine Islands, 1923: 211)

> Time signals have been sent every day of the year during 5 minutes (10h. 55m. to 11h. a.m.) from the central observatory to all telegraph stations connected with the post office of Manila. For the convenience of the city and steamers anchored in the bay the time ball is hoisted every day at 11h. 55m. a.m. and dropped automatically by the clock exactly at noon, the initial moment of descent being the exact time of 12h. At night, (9h. 55m. to 10h. p.m.) through the cooperation of the post office of Manila time signals are sent from the observatory of the Cavite-Los Banos naval radio station.

There is, however, clear reference to both the Observatory and Cavite time signals in 1931 (American Practical Navigator, Appendix IV, 1931: 334).

12.8.4 Time Ball on Engineer Island

There is reference to two time balls in a 1927 report, one at the Observatory and the other at the mouth of the Pasig River (United States Coast Pilot, 1927: 53). There is no mention of the Cavite signal:

> A time ball on the observatory at Ermita and one on the semaphore tower at the mouth of the Pasig River are hoisted five minutes before noon and dropped at noon, Philippine standard time, equivalent to $4^h\ 00^m\ 00^s$, Greenwich civil time of the same date.

The List of Time Signals (1911) and Admiralty lists (1922: 449; 1930: 531) show that three time balls were in operation for an extended period. The second ball was on the Semaphore Tower at Engineer Island, near the mouth of the Pasig River, while the third was at Cavite. The Observatory and Engineer Island time balls were dropped at noon, local standard time, while the Cavite ball was dropped at 11 a.m. Their coordinates are given in Table 12.3. The Observatory coordinates are close to those given in the 1898 Admiralty list: small changes are probably corrections to earlier measurements.

Table 12.3 Location of time balls in the Philippines

Location	Detail	Latitude	Longitude	Drop Time	
				Greenwich civil time	Philippines standard time
				h. m. s.	h. m. s.
Manila Observatory		14° 35′ 12″ N.	120° 58′ 35″ E.	04 00 00	12 00 00
Engineer Island	Semaphore Tower	14° 35′ 43″ N.	120° 57′ 21″ E.	04 00 00	12 00 00
Cavite	Water Tower, NW of Port	14° 29′ 00″ N.	120° 54′ 45″ E.	03 00 00	11 00 00

Fig. 12.24 Location of the Philippines time balls in 1922 (courtesy: Google Maps).

The three locations are shown in Fig. 12.24. The postcard image in Fig. 12.25 shows the time ball on top of the water tower at the Cavite Naval Station. The time ball service was not mentioned explicitly in a 1932 report so it may have been discontinued or reduced in status (Annual Report of the Governor General, Philippine Islands, 1932: 214):

> The time service of the weather bureau functioned efficiently during the year. The Manila Observatory devoted much attention to the accuracy of regular time signals, especially the broadcasts from the United States naval station at Cavite. These time signals are useful to other observatories and surveys not equipped with accurate instruments for observing time from the stars. Furthermore the need of accurate and reliable time signals for longitude determinations by ships at sea puts the time service of the Manila Observatory in a very responsible position. The fact that the United States Navy has been experimenting in rebroadcasts of the Manila time signals from their radio station in Honolulu shows the importance of the time service of the Manila Observatory in this part of the world.

Fig. 12.25 View showing the Cavite time ball (courtesy: Klaus Hülse Collection).

12.9 Conclusions

The work described in this chapter represents the start of a wider study into time signals in Asia during the pre-wireless era. Time signals by radio were becoming widespread in the 1920s and 1930s and some of these have been noted. Significant information about the time signals in Java, Singapore and Rangoon has been located, but photographs of the signal arrangements have proved elusive. Despite searches in sailing instructions and Admiralty lists, no information about visual time signals in Borneo and many other parts of modern Indonesia, Malaysia and Siam (now Thailand), all with extensive coastlines, has yet been found.

The earliest time ball in SE Asia was erected by the Dutch at Batavia (now Jakarta) in 1839, only six years after the first public time ball had been established at Greenwich and well before time balls were first erected in Australia and New Zealand. Time signals on Java were changed to time discs before 1880, by then the favoured signal type in the Netherlands. Other European powers continued to prefer time balls. Singapore offered a wide range of time signals by the 1930s, starting with the operation of two time balls in 1893 and including an unusual signal using discs on collapsible arms from 1930. There were also time balls at Makassar, Rangoon, Haiphong, Saigon and Manila. There were time guns at Singapore, Rangoon, Moulmein and Manila, and time light signals at Singapore and Rangoon. Some were short-lived and all were eventually superseded by wireless time signals.

It is possible that navigators relied on the comprehensive services in Singapore and Java, as well as those in India, China and Hong Kong, for chronometer calibration, and that no visual signals were needed or available in several important countries. The question then arises: how was time regulated in Thailand and elsewhere, for domestic use and internal transport regulation? Introduction of extensive railway systems was often the trigger for development of observatory facilities that enabled accurate time measurement. Later, undersea telegraph connections to remote observatories could be used. The development of time signals in SE Asia is related to technical and political changes worldwide, and to the differences between Western and Eastern cultures. Further research is needed.

The measurement of time underwent profound changes after World War II, which are outside the scope of this historical research. These changes included recognition that Earth's rate of rotation is not exactly constant and introduction of Coordinated Universal Time (UTC) for scientific purposes. The difference between UTC and GMT is constrained to be less than a second and hardly affects ordinary domestic life, but it is critical for GPS systems.

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Part III
Southeast Asian Studies: Archaeoastronomy and Ethnoastronomy

Chapter 13
An Archaeoastronomical Investigation of *Vaastu Shastra* Principles (Vedic Architecture) Implemented in the City Planning of Ancient Chiang Mai

Cherdsak Saelee, Orapin Riyaprao, Siramas Komonjinda, and Korakamon Sriboonrueang

13.1 Introduction

In many ancient kingdoms of Thailand, architectural forms including city and temple planning were influenced by Indian culture transmitted throughout the era of the Dvaravati and the Khmer Empire. The structural principles of Indian architecture propagated to Southeast Asia through migration, trade, and the missionary activities of Buddhism (*Theravada* and *Mahayana*), as well as Hinduism (*Shaivism* and *Vaishnavism*). Clear evidence of Indian influence in Thailand can be seen at the Sri Thep Ancient City (currently located in Phetchabun province), which was an ancient city during the Dvaravati era (sixth–eleventh centuries) when Buddhism and Hinduism flourished (O'Reilly, 2007).

During the thirteenth century, the most powerful king of the Khmer empire was King Jayavarman VII (CE 1181–1219) who regained the Khmer's independence from the Cham and founded Angkor Thom to be a new capital. The design of city and temple in Khmer architecture followed the knowledge of Vedic architecture named *Vaastu Shastra* as a blueprint, incorporating the belief in deities, planets of the eight directions, and buildings oriented to astronomy (Chandler, 1993). King Jayavarman VII also adopted Mahayana Buddhism instead of Hinduism, which was reflected in the infamous Bayon temple. Furthermore, he built several religious buildings resembling the Bayon art, a new art which was well-received throughout the Thai regimes in the northeast and southeast, and in central Thailand provinces

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such as Phetchaburi, Kanchanaburi, and Sukhothai. The influence of Indian architecture from central Thailand had propagated to the northern part of Thailand and reached the Lanna Kingdom when Queen Jamadevi brought nearly ten thousand followers, including monks, philosophers, and artisans from the Lavo Kingdom (Lopburi province) to found the city of Hariphunchai (now in Lamphun province). The Queen turned Hariphunchai into a resourceful city for arts and culture. Later, she founded Khelang Nakorn (Lampang province) to be another main city. The ancient Mon language was also scripted on a stone inscription during the Hariphunchai period. Thus, Queen Jamadevi can be regarded as a propagator of Indian culture from the Dvaravadi and Khmer regimes to land in the northern part of Thailand. Later, in CE 1281 the Hariphunchai Kingdom became part of the Lanna Kingdom (Ongsakul, 2005). Ancient kingdoms in the land of present-day Thailand that were ruled by the Khmer adopted Khmer city planning, with the city laid out in square or rectangular shapes, similar to the plan of Angkor Thom. Angkor Thom featured a square plan, surrounded by walls and moats, with the Prasat Bayon (temple) at the center.

During King Ramkhamhaeng's reign, Sukhothai also had the same Khmer ancient city planning features: a rectangular plan bounded by walls and moats. In the center of the city was a religious building that symbolized the center of the Universe. This differed from the previous Dvaravati Culture where the plan had an irregular shape similar to a conch (*Shanka*) or a sphere, as seen in U-thong, Lavo, Hariphunchai and Khelang Nakorn. Other examples of Khmer city plans found in Thailand are Mueng Sing and Mueng Phimai. Mueng Sing's plan is almost a square shape with Prasat Mueng Sing located at its center. Mueng Phimai has a rectangular plan enclosed by walls and moats. There was a gate on each of the four sides, and the Moon River flowed through the city from north to east. In the center was Prasat Hin Phimai (Chaturawong, 2017).

According to the *Chiang Mai Chronicle* (Wichienkaeo and Wyatt, 1995), initially King Mangrai had planned to build a city in a square shape with the sides 2000 *wa* (~ 3.2 kilometers) long, which would have been the same size as Angkor Thom. However, he was cautioned by King Ram Khamhaeng regarding homeland security, and so decided to reduce the size. Although Lanna people were migrants from southern China, there was no city planning that used Chinese *Feng Shui* principles. In general, *Feng Shui* and *Vaastu Shastra* were similar, except that the orientation of the main entrance was different (Saran and Shirodkar, 2017).

The reason for choosing *Vaastu Shastra* rather than *Feng Shui* principles could have been because India and the Lanna Kingdom were at the same latitude, and therefore the Lanna Kingdom was geographically more similar to India than to China. Also, the seasons, the monsoon directions, and religious beliefs were more similar. Furthermore, the influence of the powerful Khmer Empire propagated through Sukhothai or through Lavo to Hariphunchai could have been additional reasons for adopting *Vaastu Shastra* in Chiang Mai city planning. In this chapter, we will report on how closely Chiang Mai city planning corresponds to the *Vaastu* principle.

13.2 City Planning of Ancient Chiang Mai

Chiang Mai (the current name), the capital city of the Lanna Kingdom, was founded by King Mangrai the Great, the first Lanna king, in CE 1296. Chiang Mai was given the name *Nop Buri Sri Nakorn Ping*, and was situated in the upper northern part of Thailand between the base of Suthep Mountain and the basin on the right of the Ping River. The Lanna people inherited a fertile land capable of producing high-yield agricultural crops. They also had their own language, scripts, customs, traditions and culture. The history of the Lanna Kingdom can be divided into three periods. The first period was when Lanna was an independent state (the Mangrai Dynasty in CE 1296–1558). The second period was when Lanna was under Burmese rule, from 1558 to 1774, and the third period was when Lanna became a state of Siam (a Siamese tributary during the Chet Ton Dynasty from 1782 to 1939). In 1932, Khana Ratsadon (meaning 'People's Party') changed the system of Government in Thailand. The City Governor's position was revoked, and Chiang Mai became a province under the central administration.

Information about Chiang Mai city planning in this research was gathered from the remaining primary sources such as *Pubsa* (mulberry paper), *Bailan* (palm-leaves) and stone inscriptions. These sources were documented after the founding of the city, as described in detail in Sub-section 13.2.1. This research study is based on information that was compiled from all primary sources and published as *The Chiang Mai Chronicle* (CMC) by Wichienkaeo and Wyatt (1995) and *History of Lan Na* by Ongsakul (2005). These books provide valuable details about the city's founding, as described in Sub-sections 13.2.2 and 13.2.3. CMC is based on the Chiang Mai chronicle that translated Lanna Tham scripts from authentic palm-leaves and were corrected by Dr Hans Penth (1937–2009), and are known as 'Hans Penth version'. The original palm-leaves script had been organized into eight bundles of leaves (the maximum one with 26 sheets), each with multiple sheets that were written on both sides of the leaf. To refer to Dr Penth's collection, we write CMC-*a.bc*, where *a* indicates the bundle number (1-8), *b* is the sheet number (01-26), and *c* is the V (front) or the R (back) of the sheet. For example, the code CMC-2.13V refers to the 2nd bundle, the 13th sheet, and the front of the sheet.

13.2.1 Overview of the Historical Records

The study and writing of Lanna history started about six hundred years ago when local scholars and monks began composing chronicles on palm-leaf manuscripts. Today, the chronicles still retain a strong foothold in local popular consciousness, and they are a rich source of information for modern historians.

The Wat Phra Yean stele, inscribed in CE 1370, is considered the region's oldest stone inscription. Another stele of dynastic succession, the stone inscription in Fak

Kham script, was inscribed in 1411 and the Wat Chiang Man stele, was inscribed in 1581.

The earliest chronicles, written in the fifteenth and sixteenth centuries are now generally considered classical chronicles. Important texts from this period, including the *Mulasasana*, *Camadevivamsa* and *Jinakalamali* chronicles, became the model for all others over the following centuries.

The pioneer of the modern study of history in Thailand was Phraya Prachakitkorachak (Chaem Bunnag), who produced a renowned study of Lanna, the *Yonok Chronicle* (Ongsakul, 2005).

13.2.2 The Founding of Chiang Mai

According to the Lanna inscriptions and historical evidence, they are all in agreement that King Mangrai obeyed the auspicious time to move into the site on Thursday of the 7th Lanna lunar month (equivalent to the 5th Thai lunar month), waxing moon the 8th day, 654 *Culasakaraj* (CS) (CMC-2.10R). This was regarded as the building date of his temporary royal residence. He used his residence, which was on the northeast of the Chiang Mai City plan (today it is Wat Chiang Man), to work on the planning of the city.

According to CMC-2.10R, King Mangrai gave an order to begin plowing the site from his sleeping chamber to the northeastern corner, or the Sri Bhumi corner. Beyond the Sri Bhumi corner, there was a large lake named *Nhong Kiew* (or *Nhong Bua Jed Gor*) that connected to the Mae Kha canal. King Mangrai was very satisfied because there would be plenty of water for elephants, horses, and castles to shower and drink. He then asked carpenters to prepare wooden logs for building an elephant nursery, horse pens, observation towers, and city gates, hoping to build a grand city.

As King Mangrai and his two royal friends—King Ruang of Sukhothai (King Ram Khamhaeng) and King Ngam Muang of Phugamyao (present-day Phayao)—entered the site, they saw a large albino mouse along with its four followers ran from the temporary royal residence towards the east and then into a hole under a *Ficus lacore* tree (the same family as the Banyan tree, which was considered an auspicious tree). They were all very pleased to witness this event, and brought offerings to worship the mouse and the tree. They then designated the tree to be the city guardian, and it remained ever since (CMC-2.11V).

Afterwards, the city was planned to be 900 *wa* in width and 1000 *wa* in length (*i.e.* a rectangular shape) (CMC-2.11R). The laborers were divided into two groups. The first group, of 50,000 people, would build royal residences, royal halls, elephant nurseries and horse pens. The second group, of 40,000 people, would build the city walls by digging moats on all four sides and building up the soil to form the walls around the perimeter (CMC-2.13V).

Based on the CMC it took four years of city planning, then the groundbreaking day was the Full Moon, the 8th Lanna lunar month, 658 CS (CMC-2.13V). However, according to the Wat Chiang Man inscription (*Database of Inscriptions in Thailand*

| *Wat Chiang Man Stale*), it was the waxing moon the 8th day, the 8th *Lanna* lunar month, 658 CS. It took four months to complete the construction. Afterwards, the city hosted a festive celebration for three days and three nights with its name being given as *Nop Buri Sri Nakorn Ping*.

13.2.3 Chiang Mai City Walls and Gates

The CMC indicates that after the completion of all four city walls, five city gates were built (CMC-2.13V). However, there is no record of the name of the gate in each direction, therefore it cannot be certain whether the current names were the original names. Presently, the gate in the north is called Pratu Chang Puenk. The western gate is called Pratu Suan Dok. The eastern gate is Pratu Thapae (initially named Pratu Chiang Ruek). In the south, there are two gates: Pratu Chiang Mai (the back gate) and Pratu Suan Prung. Pratu Suan Prung, previously called *Suan Re*, was built in the reign of King Samfangkaen (the eighth King in Mangrai Dynasty, during CE 1402–1441), which implies that this gate is not one of the original gates.

Regarding a common practice when entering and exiting the city gate, Lanna kings in all reigns followed the local custom (Lawa or Lua), *i.e.*, of entering the city through the north and paying respect to the northeast. If there is a funeral, the deceased must be transported out through the south only. From the end of the Mangrai Dynasty Chiang Mai was under the Burmese rule for more than 200 years, but once Chiang Mai was recovered it was left deserted for several years.

By the time Phra Chao Kawila (the first King in the Ched Ton Dynasty during the Rattanakosin period) ruled Chiang Mai all of the city walls had deteriorated so he rebuilt them using bricks. He also built a fortress and inner-city gates. On top of the walls, bricks were laid and battlements (called *Sema*) were placed on the walls and on all four gates. The city walls as seen today were rebuilt in 1947 by the Chiang Mai Municipality in order to enhance the beauty of the city. The present walls are in the original location, but the city gates, which many people believe to be ancient, were all rebuilt.

13.3 *Vaastu Shastra* Principles

The *Vedas* are ancient sacred Hindu scriptures compiling into four resourceful collections about religious rituals and sacrifices. *Atharva Veda* (the fourth Veda) stands apart from the sacrificial theme of the other three Vedas (*Rig Veda*, *Yajur Veda,* and *Sama Veda)* in that it focuses on spells and incantations to protect human well-beings from demons or illness. It can be considered a primary source to study Vedic beliefs, philosophies and cultures. There are also several auxiliary disciplines (*Vedanga*) associated with the Vedas, and some even have applied knowledge. For example, a part of *Sthapatya Veda* called *Vaastu Shastra,* and subordinate to the

Atharva Veda, is the ancient science of designing and constructing buildings (Volwahesn, 2001).

13.3.1 Vaastu Shastra

Vaastu Shastra is a traditional Hindu system of architecture. Literally, the words mean "science of architecture". It is one of the most ancient architectural belief systems, similar to other traditional architectural sciences such as *Feng Shui* of China.

The basis for architectural design of *Vaastu Shastra* is the belief that mankind and the Universe are analogous in their structure and spirit, and that the Earth is a living organism, pulsing with life and energy. *Vaastu Shastra* principles strive to achieve optimum benefits of the *Panchbhutas* (five elements of nature), the Earth's magnetic field, and the rotational influence of the Sun, the Moon and the other surrounding planets. The goal is to attain a balanced setting for the *Vaastu-Purusha-Mandala*. Here *Vaastu* means environment, site or a building. *Purusha* is regarded as the 'man' of the Universe or the cosmic man or a creative intelligence in the Universe. *Mandala* is a geometric plan or chart representing the cosmos. In Hindu cosmology, the cosmos is usually represented by a square plan. Thus *Vaastu-Purusha-Mandala* is a metaphysical diagram of the planned site resembling the cosmos in which the *Purusha* resides. Because the Earth is essentially demarcated by sunrise and sunset, by east and west, by north and south, therefore orientation, particularly the cardinal directions, hold a significant contribution. In Fig. 13.1, the orientation principles of *Vaastu Shastra* are better understood by providing various associations to the eight cardinal directions (northeast, east, southeast, south, southwest, west, northwest and north) (Patra, 2014).

13.3.2 The Vaastu-Purusha-Mandala

Vishwakarma, the celestial architect who is regarded as the father of *Vaastu Shastra* and described the *Vaastu-Purusha-Mandala* once revealed in his treatise *Vishwakarma Prakash* a fascinating story about the origin of the *Vaastu-Purusha-Mandala*.

There was once a war between the Gods (*devtas*) and the Demons (*asuras*) that resulted in an accumulation of sweat that fell on the Earth. The accumulated sweat then transformed to a gigantic vicious being and continued to frighten both the *devtas* and the *asuras*. The *devtas*, led by Lord Shiva, and the *asuras*, led by *Andhaka*, together decided to ask Lord Brahma to tame this being. Lord Brahma laid the giant down on the earth with his head towards the northeast and feet towards the southwest. He then called this giant his mind-being and named him *Vaastu Purush*. Lord Brahma then announced that whoever reveres the *Vaastu Purush* and performs the

Fig. 13.1 The eight cardinal directions in *Vaastu Shastra*. Each direction is associated with a God or Deity of the nine planets: Sun, Moon, Mercury, Jupiter, Venus, Mars, Saturn, Rahu and Ketu. The Earth planet is said to have a presence of all five elements: earth, air, water, fire, and space. The deities associated with the directions are said to yield eternal blessings.

Vaastu Purush Pooja while constructing a temple, palace, house, pond, city *etc.* will be blessed by the *devtas*; doing the opposite will bring destruction by the *asuras*.

To ensure peace, health and prosperity, it is advisable to keep the eternal rules of the *Vaastu-Purusha-Mandala* in mind while designing any structure.

The whole *Vaastu-Purusha-Mandala* plot takes a square shape exhibiting a perfect and absolute form. The *Vaastu Purush* is the presiding lord of the whole plot. The plot can be fragmented into a square grid. There are 32 ways (Chakrabarti, 2013) of constructing *Vaastu-Purusha-Mandala* in *Vaastu Shastra.* The simplest one is conceived with a square and the largest in these characteristics is of 1024 *padas* (squares). Fig. 13.2 illustrates *mandalas* with the corresponding names of sites, starting with a 1 × 1 square site to a 9 × 9 (81) square site. The innermost square is called *Brahma* and is always occupied either by a temple or a palace. Different classes of human beings occupied different zones.

The exact size and shape of *Vaastu-Purusha-Mandala* is determined by the requirements of the building construction.

The story of *Vaastu Purush* is depicted diagrammatically in the *Vaastu-Purusha-Mandala* with specific portions allocated hierarchically to each deity based on their

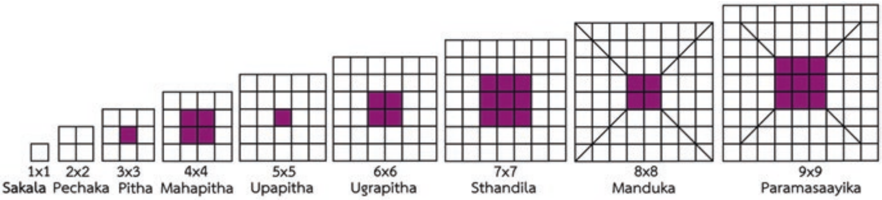


Fig. 13.2 *Vaastu-Purusha-Mandala* of various sizes from 1 × 1 to 9 × 9 square site, *Brahma* zone for each *mandala* is colored at the center.

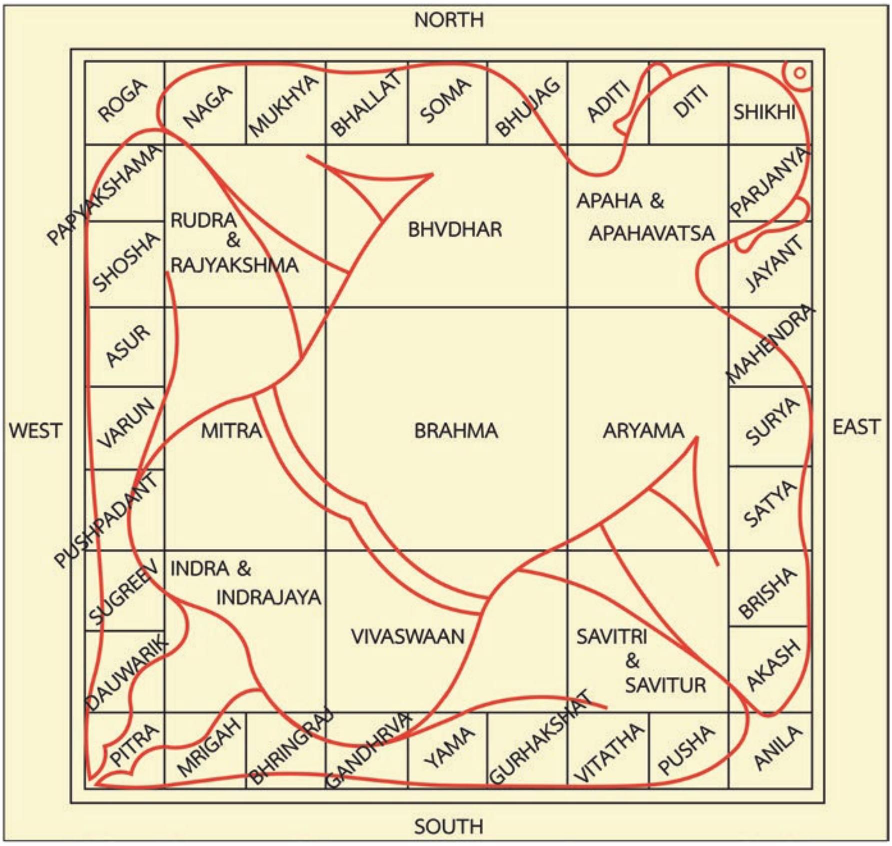


Fig. 13.3 A square plan that illustrates how the *Vaastu Purush* was pinned down by *Brahma* and 44 Gods.

attributes and powers. The division of the built-up space represents different energy fields. We call this process the *Pada Vinyasa* (modular grid). For example, for the nine-divided site in Fig. 13.3, there are a total of 45 energy fields that constitute the *Vaastu-Purusha-Mandala*. They are as follows:

(1) The Central Energy Field: *Brahma*, the Creator – *Brahma Vithi*, it is the most sacred part of the building. It contains within it, all the possibilities of creation

and existence. First the *Shilanyas* (foundation stone laying ceremony) is done and the construction of the foundation walls begins by digging the earth.

(2) The four Energy Fields next to *Brahma* – The *Deva Vithi* as *Bhudhar* (the power of manifestation), *Aryama* (the power of connection), *Vivaswaan* (the power of revolution or change), and *Mitra* (the power of inspiration and action).

(3) The eight Energy Fields in the diagonal directions, the *Manushya Vithi*.

13.3.3 Vaastu Shastra *Principles for Town Planning*

Vaastu Shastra laid strong emphasis on the selection of a proper site for establishing a new village, town or a city. A well-planned town has happy inhabitants and a healthy atmosphere, and *Vaastu Shastra* plays an important role in developing a planned town.

In planning a town, a habitation, villages, a fort, a city or any other groups of residences, the location at the starting point and the surrounding climate and soil should all be taken into consideration. The first essential of town planning is to examine the soil. An ideal town must have a green belt of forests where tall trees, plants and flowers are found in abundance. This is necessary not only from the point of view of healthy climate, but it is also conducive to the growth and maintenance of the population requiring fruits, fuel and fodder. Moreover, the natural scenery of this vegetation will add beauty and grandeur to the town.

For a town, the site should be selected on the bank of a river, seashore or lake. Trees, fruits and flowers should surround the site. The eastern side of the town should be lower, so that the Sun shines on the front doors of buildings. The site should not be selected on the western side of a mountain (Shukla, 1961: 261–267).

According to Dutt (1925: 101–102), *Vaastu Shastra* recommends five different shapes of towns: (1) square (*chanturasra*); (2) (rectangular or oblong (*ayatasra*); (3) approximately circular (*vrtta*); (4) elliptical (*vrttayata*) and (5) perfectly circular (*golavrtta*).

After the survey of the region and the selection of the site, the first thing for a town-planner is to plan out the roads and streets, lanes and by-lanes, together with the orientation of the place so as to make it a fit place for human habitation with ease and comfort, health and longevity, peace and prosperity. The layout of the roads and streets helps create inter-connection of the site, both internally and externally. The cosmic cross is used for pinpointing the roads running along the East axis to the West and the North to the South representing principal streets. Roads running along the East axis will ensure purification by the rays of the Sun from morning to evening. The North-South road will provide a perfect circulation of the air and have the benefit of a cool breeze. Furthermore, the layout of water access is an indispensable pre-requisite in town planning because water is a fundamental necessity for life. No life can subsist without a good supply of natural water.

After the selection of land as per *Vaastu*, the site is plowed on an auspicious day as fixed by astronomical observation. The pair of specific oxen used for the plowing must have white spots on their heads and knees.

The next step is to determine cardinal directions using a gnomon, which concludes with the fixing of the *Vaastu-Purusha-Mandala*. Different kinds of them were used depending upon the need.

13.3.4 Vaastu Shastra *and Ancient Town Planning*

Vaastu principles (Vedic methods) have been applied in the design and development of villages, towns and cities. Mohenjo-Daro and other outstanding Harappan cities belonging to the Indus Valley Civilization, demonstrated some of these planning concepts. The Harappan cities had a grid plan just as is recommended in the Vedic manuals. The square shape represents the heavens, with the four directions representing the cardinal directions as well as the two solstices and the equinoxes of the Sun's orbit. A late example of a city designed according to the Vedic precepts is Jaipur. Vidyadhara, who designed the plan of the city, used the *Pithapada mandala* (3 × 3) as the basis. In these nine squares that represent the Universe, the central square is assigned to the Royal Palace.

To enhance the perceived spiritual experience, Southeast Asian temples were designed first as *mandalas*—deeply spiritual symbols blending cosmological, religious and psychological motives, which together represent the microcosmic and macrocosmic levels of the Universe (Kak, 1999).

The great Hindu temple complex of Angkor Wat in Cambodia was built by King Suryavarman II who reigned between CE 1113 and 1150. The cosmological and astronomical aspects of Angkor Wat originated in the ancient Indian Vedic traditions of altar and temple design. It was found that the temple served as a practical observatory where the rising Sun was aligned on the equinox and solstice days with the western entrance of the temple. Mannika (1996) has suggested that the *Vaastu-Purusha-Mandala* at Angkor Wat forms a grid of 49, rather than the standard of 64 or 81.

In Thailand, it is evident that Vedic architectural principles were applied to Prasat Hin Phanom Rung, currently located in Buriram province, and Prasat Hin Pimai in Nakorn Ratchasima. The format of temple planning, including the statues of Devas in each direction, are clear evidence of the implementation of *Vaastu Shastra*. As for the Chiang Mai city plan, several historians and architects have agreed that it is Khmer architecture based on *Vaastu-Purusha-Mandala* (Leawrungruang, 2014; Sodabanlu, 2006) and followed an auspicious orientation, with the city regarded as a human being. However, there is no detailed comparison between the Chiang Mai city plan and *Vaastu* principles. Furthermore, there exists a trace using *Vaastu* principles in military strategy, on stone inscriptions, including Lanna talismans. The talismans (*Yantra*) might represent the *mandala* containing information about time, constellation and numbers calculated from *Suriyatra* and *Manatra* scriptures (Maison, 2019).

13.4 Comparative Study of Chiang Mai City Planning and *Vaastu* Principles

To this day, no traces of evidence or written records have been found on inscribed palm-leaves of the Lanna plans that can identify the knowledge or the textbook used in the city planning. This research study has gathered evidence from remaining ancient buildings and objects, including inscribed palm-leaves that were collected into chronicles, for example, *The Chiang Mai Chronicle* and *History of Lan Na*, containing information about the founding of the city, including customs and traditions that were passed down through generations since ancient times. We then conducted a comparative study of original scripts, or the 'root wisdom' of city planning that was extensively used between the seventh and the thirteenth centuries CE.

We find that the Chiang Mai site was chosen because it satisfied the seven good reasons (omens) described in detail in Sub-section 13.4.1. In Sub-section 13.4.2, we measure the shape of Chiang Mai city and then overlay onto it the *Vaastu-purusha-mandala* divided-sites of 8 × 8, 9 × 9, and 10 × 10 in order to determine which design matches the city plan. In Sub-section 13.4.3 we also investigate ancient Lanna norms, customs, and traditions passed down from generation to generation. Some of these practices are still applied to this day.

13.4.1 Chiang Mai Site Selection

In searching for a new site for founding a city, King Mangrai had scouted several places. He would stay at each location for three nights. Although it was suggested by CMC-2.09V that his mission was led by his visions in a dream, we rather believe that King Mangrai was in fact looking for a location that satisfied *Vaastu* principles. When he arrived at the site of present-day Chiang Mai, he did not rush to a conclusion. Instead, he spent time inspecting the topography, the climate of each season, and the local animal and plant species before he reached a decision.

According to CMC-2.12V and CMC-2.12R, King Mangrai invited King Ram Khamhaeng of Sukhothai and King Ngam Muang of Phayao to the new site and consulted with them on the suitability of the location and the city plan. Together they observed seven auspicious factors for the site, and it was only then that King Mangrai decided to establish the Lanna capital city (Chiang Mai) at this site. The seven auspicious factors (AF) were:

(1) Two white deer, a doe and her fawn, came out of the big forest in the north to live at this auspicious location, and the people worshipped them.

(2) Two white barking deer, a doe and her fawn, came to live at this auspicious location. The dogs did not bite them and fled.
(3) People saw a white rat with four attendants that came to this auspicious location.
(4) The western topography was high and sloped down towards the east.
(5) Suthep Mountain was a source of water: the Mae Kha stream flowed down from Suthep Mountain, circled the town, and then flowed towards the south (Wiang Kum Kam).
(6) There was a large water reservoir in the northeast where the animals could drink.
(7) The Ping River flowed to the east of the site for the new city.

The comparative study in Table 13.1 shows the auspicious factors that correspond to *Vaastu* principles of site selection. The reasons for choosing the Chiang Mai site consisted of considerations from geographical aspects, *e.g.*, slope, mountain, a natural water resource, fertility of the soil, all of which helped promote harmonious living for plant and animal varieties. The position and direction of the large reservoir in the northeast was also taken into consideration, including the slope topography from west to east. All seven auspicious factors satisfied the *Vaastu* principles.

For King Mangrai, and to a great extent for the two invited kings, it was vitally important that this permanent capital of the Lanna Kingdom would effectively function as a powerful defense stronghold in the north, as well as a commanding political base which would exercise a strong influence and control over other Tai states in the area. Agriculture and trade for the prosperity of the population were also a serious consideration.

In terms of agriculture and trading connections, the selected site, which had open green fields, was suitable for agriculture, and especially wet rice cultivation. The wide, long Ping River offered an excellent mode of communication for trade and for the control of other states. Indeed, the site was already connected to the ancient caravan routes through the mountains used by traders from India, Burma and Yunnan who traveled with tea horses and cattle caravans.

13.4.2 The Shape of Chiang Mai City

According to CMC-2.11R, King Mangrai ordered the construction of a perimeter wall and moat, which were laid in a rectangular shape of 900 *wa* by 1,000 *wa*. However, the actual size that we measured is in a square shape, contrary to what is recorded in the Chronicle. We assume that the reason King Mangrai did not disclose the actual size might have related to homeland security.

According to *Vaastu Shastra*, the foundation stone-laying ceremonies were done at the center of the city site and in the eight cardinal directions. The northeast direction, where the tutelary deity stays, was the most important one and had to be kept secret because the sacred ceremony could be ruined by a malevolent person.

In later years, during the reign of King Tilokkaraj (CMC-5.03V), a Burmese monk who knew of the Chiang Mai plan convinced the King to cut down the city's

Table 13.1 Comparative study of the *Chiang Mai* site selected from the seven auspicious factors and *Vaastu Shastra* principles.

Vaastu Principle	Decoding the Seven Auspicious Factors (AF)
• The first essential of town planning is to examine the soil and surrounding climate. • The town must have a green belt of forests where tall trees, plants and flowers are found in abundance. This is necessary not only from the point of view of a healthy climate.	From AF (1): the presence of deer families, which were herbivores, indicated that the soil was sufficiently fertile in this area to sustain life. From AF (2): the presence of a bloodhound coexisting with a doe implied the presence of a variety carnivorous *and* herbivorous species. The carnivores were no danger to humans, allowing humans to live safely and to have enough food to eat. From AF (3): Tai people believe that an albino mouse is an auspicious animal indicating fruitful soil and water. Furthermore, a large *ficus lacor* tree, a perennial plant, is used to indicate a yearly cycle because it grows young shoots only three days a year. The presence of large trees or a forest at the site further affirmed the suitability of the area for human habitation.
• The eastern side of the town should be lower in order for the Sun to shine on the front doors of houses and buildings • The site should not be situated on the western side of a mountain	From AF (4): the western topography was high, and sloped down towards the east. The city is on the eastern side of the mountain. Suthep Mountain, located to the west, was regarded as sacred not only by the native Lawa people, but it also was revered by the Mon as the abode of Haripunchai's legendary creator, the Sacred Rushi named Sudeva. The mountain thus ensured spiritual stability, and physical protection in the west. Furthermore, the land sloped down from the west (Suthep Mountain) towards the east (Ping River). According to *Vaastu* principles, if it rained heavily, the area would not be flooded because the rainwater would flow into the river.
• The site should be located on the bank of a river or a lake, or on the seashore	From AF (5): The forest on Suthep Mountain was fertile, and the Mountain was an important source of water. People would have plenty of water to drink and use throughout the year. They could make a living from agriculture and livestock farming. From AF (6): The Mae Kha stream cascaded down from the top of Suthep Mountain, then turned east and flowed along the south side of the auspicious area. People living in different areas would have access to fresh water. From AF (7): The Ping River flowed to the east of the Chiang Mai city site. The Ping River was also a good omen in that it flowed from Anodat Lake (Sra Anodat) in another mountain range (at Chiang Dao), and flowed constantly in the east of the city. People could drink its sacred water and use it for transportation and commerce.
• A water place should be in the northeast	From AF (6): There was a large reservoir (or lake) to the northeast of the city site where animals could drink. This reservoir could be used as a secondary water resource during the dry season. It could also be a river port used for trading with other cities to bring prosperity to Chiang Mai and its population.

guardian tree and destroy the city wall in that direction. Lanna people believed that because of this event Chiang Mai then lost its independent to Burma (CMC-5.22V).

The Chiang Mai wall therefore is not constructed in a rectangular shape of 900 *wa* by 1,000 *wa*. The wall is a square shape aligned to the cardinal directions. Since the city was built in CE 1296, the site was located on a flat area between Suthep Mountain and the Ping River. There are four corners (Jaeng) that form ramparts in the cardinal directions, and their names, latitudes, longitudes and elevations are listed below:

Jaeng Sri Bhumi in the north-east corner (18° 47′ 42.323″ N; 98° 59′ 36.773″ E; 312.2 ± 3 m)
Jaeng Katam in the south-east corner (18° 46′ 53.159″ N; 98° 59′ 33.629″ E; 312.2 ± 3 m)
Jaeng Gu Huang in the south-west corner (18° 46′ 54.449″ N; 98° 58′ 41.040″ E; 312.3 ± 3m)
Jaeng Huo Lin in the north-west corner (18° 47′ 43.971″ N; 98° 58′ 43.572″ E; 316.3 ± 3 m).

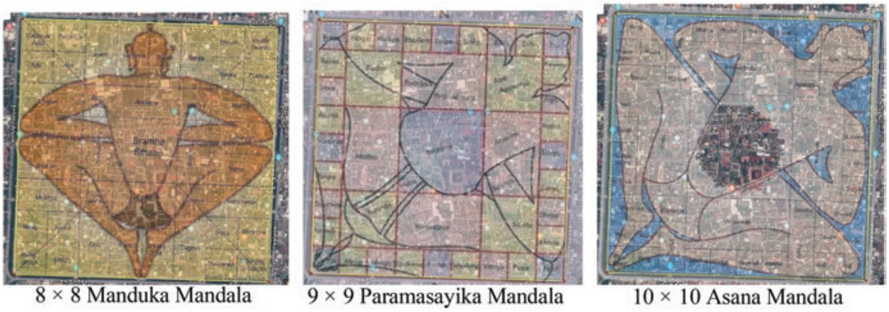
Table 13.2 shows that the length of each of the four sides of Chiang Mai city measured approximately 1.6 kilometers. Note that both rectangular and square shapes were recommended for town planning in *Vaastu Shastra*.

13.4.3 Chiang Mai Site Planning

From the actual size of a square shape, we initially assumed that the site would be either the 9 × 9 divided site called *Paramasayika Mandala* (81 squares), or the 10 × 10 divided site named *Asana Mandala* (100 squares) shown in Fig. 13.4. However, after we measured the size of the city and found that it was a square shape with walls 1.6 km × 1.6 km, then using 1-*wa* = 2 meters, the shape could also be 800-*wa* × 800-*wa*, or an 8 × 8 divided site called *Manduka Mandala* (64 square), as in Fig. 13.4.

Table 13.2 The lengths of the Chiang Mai city walls.

Source of Data	Length of each side(corner-to-corner) in km			
	east	south	west	north
Calculated using Google Map co-ordinates	1.551	1.553	1.560	1.584
Calculated using GPS data listed above	1.521	1.538	1.531	1.556
https://th.wikipedia.org/wiki/กำแพงเมืองเชียงใหม่	1.62	1.63	1.62	1.67
Thai Fine Arts Department registration no. 0003557	1.55	1.60	1.55	1.60
History of Lanna (Ongsakul, 2005)	1.6	1.6	1.6	1.6



8 × 8 Manduka Mandala 9 × 9 Paramasayika Mandala 10 × 10 Asana Mandala

Fig. 13.4 Three different types of *Vaastu-Purusha-Mandala* superimposed on the map of Chiang Mai city.

Considering that the inner-most square (the *Brahma*) should contain Wat Jai (meaning ‘heart’, present name Chai Phra Kiat), Wat Intrakhin and Wat Chedi Luang, we found that the central square with four small grids of the *Manduka Mandala* was too small to accommodate Wat Chedi Luang. We also found that the central part of the *Asana mandala* was as wide as 16 grids, which did not fit the temple periphery. We found that the *Paramasayika* contains nine grids that fit the temple periphery. Therefore, this 9 × 9 *mandala* was probably used in planning Chiang Mai, according to *Vaastu-Purusha-Mandala*.

Referring to *Vaastu Shastra*, roads running along the Eastern axis will receive purification by the Sun’s rays from morning to evening, while the North-South roads will provide perfect air circulation and the benefit of a cool breeze. Even though there is no picture of Chiang Mai city streets dated back over 700 years ago, an 1893 map of Chiang Mai (see Fig. 13.5) can still provide evidence of the road layout since the positions of several important temples are shown in the map. Considering that map instead, we find that Chiang Mai roads were laid out along East-West axis and North-South axis, in accordance with *Vaastu* principles. Note that the road layout almost exactly matches the 81 square *mandala*.

13.4.4 Comparative Study of Vaastu *Directions and Lanna Beliefs*

Vaastu Shastra is based on the beliefs that man and Universe are analogous in their structure and spirit. The story on the origin of the *Vaastu-Purusha-Mandala* implies the importance of spirit of the site (Earth) in order to create harmonious living among men, the Earth and the cosmos. The Earth is constantly moving, but the site of Chiang Mai is essentially demarcated by a set of directions, i.e., sunrise on the east, and sunset on the west. Adhering to auspicious *Vaastu* directions will ensure healthy living.

Fig. 13.5 Top: Map of Chiang Mai, year 1893 (source: National Archives of Thailand); Bottom: Layout of roads and temples that interconnected the site to the area outside (modified from Tunsuwat, 2014: 23, 44, 59). Note: *Paramasayika* (9 × 9) *mandala* represented with a yellow grid; (1) Wat Jai, (2) Wat Intrakhin, and (3) Wat Chedi Luang are located in the *Brahma* indicated as a red square; (4) Hai-ya graveyard is located; shading blocks are temple areas; the layout in 1893 is in black colour and blue indicating water, but the faded brown overlay indicates layout in the year 1978.

Lanna people also have a set of beliefs passed down through many generations. Some traditions are still in practice today. The fortification of the city of Chiang Mai has always been unique—technically, physically, and spiritually. The core concept of the fortification of Chiang Mai signified the boundary of the Auspicious City, whose fortified area, as well as the five gates, and the central spot, were believed to be blessed and protected by all of the sacred beings petitioned through the offering ceremonies made by King Mangrai himself.

In Table 13.3 we investigate auspicious *Vaastu* directions and compare them with ancient Lanna beliefs, traditions and local customs about auspicious orientation.

According to the beliefs about the directions, the Lanna King must enter the city through the north gate. Each year, Lanna people hold a ceremony at the northeast corner where they worship the city's guardian spirit. There is also an annual ceremony at the city pillar at Wat Chedi Luang to worship the founding of the city. Whenever someone dies, the body must be transported out through the south gate (the Hai-ya Cemetery is to the southwest). These customs and traditions are in accordance with *Vaastu Shastra* principle.

13.5 The Cosmological Plan of the City

King Mangrai sought an auspicious date for the city's founding using the Lanna lunar calendar, which is based on the *Culasakaraj* (CS) system. Between the eleventh and the thirteenth centuries, the Lanna Kingdom and peripheral regions adopted the Makaranta reckoning calendar from the Pagan Empire in Burma. This was a lunisolar system based on an older version of the Hindu calendar. In this calendar the months are based on lunar months, and years are based on the Indian sidereal year, with an average year length of 365.25875 days (Saelee et al., 2018). The Lanna Kingdom, however, renamed this calendar system as the CS calendar.

The start of the CS calendar is calibrated to 25 March 638 (Gregorian date), which marks the beginning of the New Year as the Sun enters the first point of *Mesha Rashi* (Aries). Most Lanna astrologers follow the CS system and have appointed the New Year's Day of each year to be the day the Sun enters *Mesha Rashi*, which is considered the auspicious day called the *Thaloeng Sok* day. The *Rashis* or astrological signs are represented by 12 equal segments of 30° each in a circle, as depicted in Fig. 13.6.

Two auspicious days were chosen by King Mangrai: one for the move-in date to the selected site described in Sub-section 13.5.1, and the other for the start of construction, as analyzed in Sub-section 13.5.2. Interpretations of the selected dates based on astronomical and astrological aspects are discussed in Sub-section 13.5.3.

Table 13.3 Similarities between *Vaastu* directions and Lanna beliefs.

According to *Vaastu* direction	Beliefs about Auspicious Orientation, Local Customs and Traditions
Center • Lord *Brahma* then ordered that whoever reveres the *Vaastu Purush* and • Performs the *Vaastu Purush Pooja* while constructing a temple, palace, house, city *etc*. will be blessed by the *devas*. • Those who do not perform the *Vaastu Purush Pooja* will be destroyed by the *asuras*.	Lanna people call the center of the city Sadue Muang (or Navel) where the Inthakhin City Pillar, Wat Inthakhin Sadue Muang, Wat Jai and Wat Chedi Luang are located. Nowadays, Chiang Mai people traditionally believe that the city's guardian spirits resides at each gate and corner, and they help maintain the city's prosperity and fertility. To this day, ceremonies are held simultaneously at these cardinal points to propitiate these spirits. The Inthakhin or Lak Mueang (City Pillar) Festival in Chiang Mai (also known as Sai Khan Dok) starts on the 12th day of the waning moon of the 6th lunar month and lasts for eight days. This is a celebration of Brahmic origin. Lanna people believe that the reason why the Lanna Kingdom lost its independence and was under the Burmese rule from the end of the Mangrai Dynasty was because King Mekhuthi (*r.* 1551–1564) did not worship the Inthakin City Pillar and abandoned the sacred celebration. The belief about the connecting power from the stones of eight directions to the center is still present to this day. Prior to any construction, there will be a foundation stone-laying ceremony. The sacred ceremony is bounded by the eight talisman stone pillars for the eight directions.
Northeast direction • The head of *Vaastu-Purusha-Mandala* lies in the northeast direction • Ruled by Lord Shiva • Planet: Jupiter	Chiang Mai has a shrine to the city's guardian spirit, Jao Luang Kam Daeng, because the local native religious beliefs were animistic. The Sri Bhumi Corner in the northeast was considered the most auspicious of the four corners, so King Mangrai began construction of the perimeter wall and accompanying moat at this corner. They were then continued clockwise to complete the whole city wall in accordance with positions of deities in *Vaastu-Purusha-Mandala*. On the anniversary of the city's founding, there is a ceremony to worship the city's guardian spirit based on the idea that a city is like a human being and needs to celebrate its birthday. This belief is similar to *Vaastu* principles that regard *Vaastu-Purush* as a cosmic man living inside the plan.
North direction • Ruled by Kubera, the God of wealth • Planet: Mercury	The Lanna King must enter the city through the north gate (Pratu Chang Puek). As mentioned in the Chronicle, King Kawila followed the ancient tradition by entering the city of Chiang Mai through the north gate. Furthermore, any inauspicious object must not be allowed through this gate (CMC-7.10R).
South direction • Ruled by Lord Yama, the God of Death. • Planet: Mars	Pratu Suan Prung, the south gate, had been used for the execution of rebels. The corpses then had to be carried out through this gate, which led to the Hai-ya Cemetery. This belief is in accordance with *Vaastu* principles that the south is ruled by the God of Death.
Southwest direction • Ruled by Lord Pitra – Niruthi ancestor • Planet: Rahu	The Hai-ya Cemetery was located to the southwest of the city. This direction is an inauspicious direction where Lord Rahu rules based on *Vaastu* principle. Historically, this corner was used to detain and to punish the third Prince of King Manrai who planned to overthrown King Sanphu (the third King of the Mangrai Dynasty) until he passed away. The soldier who guarded the Prince's jail cell was praised for his duty, and later the wall corner was named. Jeang Gu Huang (CMC-3.07V).

13.5.1 The Auspicious Time for Occupying the Site

Referring to the Chronicle, King Mangrai chose an auspicious time at 4:24 a.m. on the Thaloeng Sok day to move into his new settlement (*Chaiyabhumi*) on Thursday, the 8th day of the waxing moon of the 7th Lanna lunar month in 654 CS or Taosee (Dragon) year, which corresponds to 3 April 1292 (Gregorian date). The Moon was in *Punarvasu Nakshatra* (see Fig. 13.6 the inner circle number 7, which is known as *Rerk* 7).

On the *Thaloeng Sok* day, the Sun moved from *Meena Rashi* (Pisces) into *Mesha Rashi* (Aries). At the selected auspicious time, the Pisces constellation was appearing on the eastern horizon. To precisely illustrate the sky phenomenon at that time, a star map generated by *Stellarium* is shown in Fig. 13.7. This map shows the Sun in Pisces which is slightly different from the Indian astrological calculation due to the equal division of *Rashi*. The map also shows the Moon in Gemini, and Pisces ascendant as stated in the Chronicle.

13.5.2 The Auspicious Time for Starting Construction

Another important date listed on the stele at Wat Chiang Man in Fig. 13.8 is the starting date of construction, which was in the year 658 CS or Rawaisan (Monkey) year, on the 8th day of the waxing moon of the 8th Lanna lunar month at an early hour. This date corresponds to 4 a.m. on 19 April 1296 (Gregorian date).

Based on the Lanna lunar calendar, the construction starting date and time were calculated using the position of the Sun and the Moon that reached the auspicious ceremony time. The Moon was in the *Punarvasu Nakshatra* with Pisces ascendant (*Meena Rashi Lagna*).

The planetary positions specified in the inscription in Fig. 13.8 are as follows: Saturn in *Vrishah* (Taurus), Mercury in *Mesha* (Aries), Venus in *Meena* (Pisces), Mars in *Kumbha* (Aquarius) and Jupiter in *Dhanu* (Sagittarius). They coincide with the star map shown in Fig. 13.9. This implies that during that period there was knowledge of how to calculate planetary positions with respect to the zodiac signs. This was probably through Hindu astrology, which used sidereal zodiac signs.

13.5.3 Interpretation and Discussion

The two selected auspicious dates were related to cosmological phenomena such as the Moon in *Punarvasu Nakshatra* and the Sun in *Mesha Rashi* at the time Pisces was ascending (*Meena Rashi Lagna*). It can be noted that most of the planets, except Jupiter and Mars, were aligned in zodiac signs that were close to the zodiac sign of the Sun (*Meena*, *Mesha* and *Vrishabha*). Moreover, the *Thaloeng Sok* day, believed

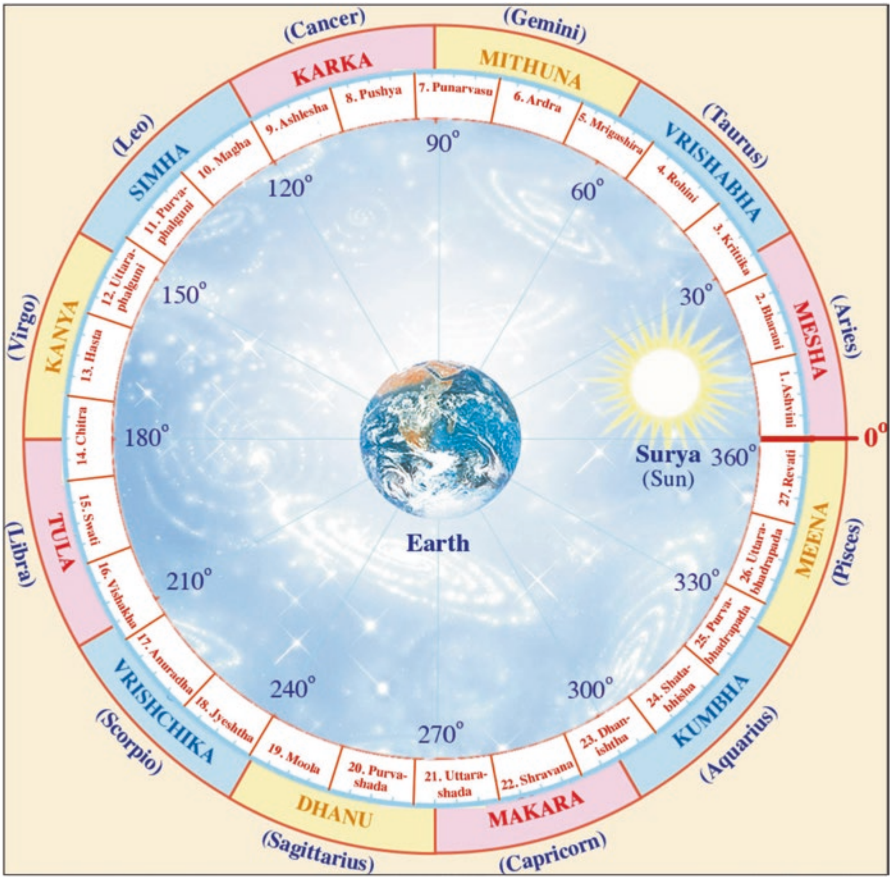


Fig. 13.6 The sidereal zodiac chart of Vedic astrology showing the 12 Signs of the Zodiac or *Rashis* (the outer circle) and the 27 lunar mansions or *Nakshatras* (inner circle) (modified from https://www.maharishijyotishprogram.eu/images/predictions-nakshatras.jpg, retrieved February 10, 2020).

to be associated with the vernal equinox, was probably also considered an auspicious date for a new start.

Further discussion on the equinox will be given in Sub-section 13.5.3.1, and astrological aspects on *Punarvasu Nakshatra* and *Meena Rashi Lagna* will be presented in Sub-section 13.5.3.2.

Fig. 13.7 A star map, generated by *Stellarium* (https://stellarium-web.org/), shows the location of the Sun, the Moon and other planets appearing in the different zodiac constellations observed at Wat Chiang Man on 3 April 1292 at 4:24 a.m. The Pisces constellation rising on the eastern horizon can be seen on the right in the stripped area and marked by the letter ‘E’.

Fig. 13.8 The date and time scripted on the stele of Wat Chiang Man. Right: the whole stele. Left: an enlargement of the portion in the red box and in reversed color for clarity (https://db.sac.or.th/inscriptions/uploads/images/20160205143618GRq3.jpg, retrieved February 10, 2020).

13.5.3.1 Astronomical Aspect

According to *Vaastu* principles, the site would be plowed on an auspicious day determined by astronomical observation of a pair of specific oxen having white spots on their heads and knees. However, there is no record of the observation of these two stars in either the *Chiang Mai* Chronicle or the *Wat Chiang Man* stele.

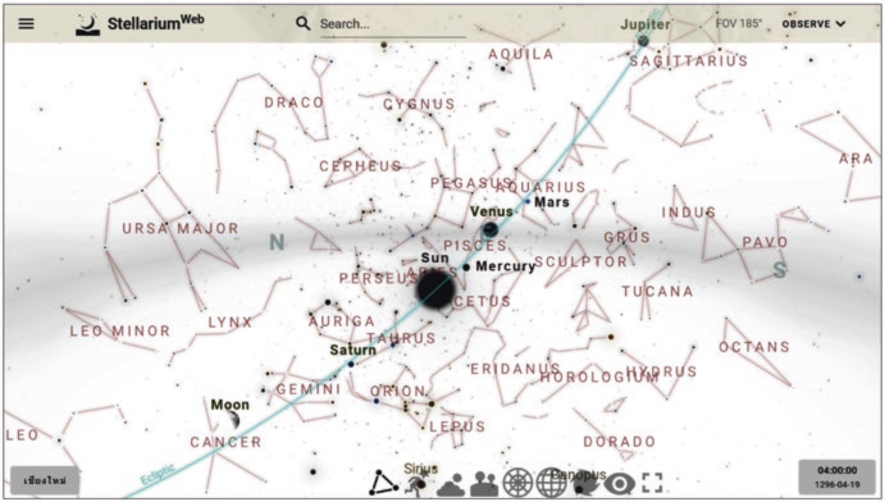


Fig. 13.9 A star map, generated by *Stellarium* (https://stellarium-web.org/), showing the locations of the Sun, the Moon and planets appearing in the different zodiac constellations as observed from Wat Chiang Man on 19 April 1296 at 4:00 a.m. In the east is the constellation Pisces and Venus were rising above the horizon, shown as the stripped area marked by the letters 'N', 'E' and 'S'.

It can be assumed that Vedic astronomy would have related the rising and setting locations of various stars to the seasons, to the solstices and to the equinoxes. Therefore, it is possible that Aldebaran (or *Rohinī* in Sanskrit) and the Pleiades (*Kritikkā* in Sanskrit) might rise in the east at the vernal equinox during Harappan times (3000 to 2000 BCE) as the word *'rohinī'* literally means 'rising'. During the Vedic period, the vernal equinox was in Taurus, and it might be considered the beginning of the New Year.

However, the precession of the equinoxes and the difference length between the sidereal and the tropical year were unobserved by ancient people. For naked-eye observers, the shift of the constellations relative to the equinoxes only became apparent over centuries.

For example, Mohenjo-Daro in Pakistan, an important archaeological site during the Vedic and Harrappan periods, exhibited slight divergence of 1–2° clockwise in its axes relative to the cardinal directions. Furthermore, slight differences in the orientations of the various buildings at Mohenjo-Daro indicates that different construction periods were used with the same traditional sighting points that shifted over this interval due to precession of the equinoxes (Kenoyer, 1998).

At another historical site, the fourteenth century Vidyashankar temple at Sringeri, Shylaja (2007) discovered that only two pillars are now aligned with the direction of the rising Sun at winter and summer solstices, whereas the others are no longer orientated to their correct zodiacal signs. The signs shift with respect to the constellations by 1° in about 72 years due to the precession.

Although during a period of CE 1292–1296, Pisces (Meena *Rashi*) rose in the east on the vernal equinox, Lanna astronomers instead used the Thaloeng Sok day, the day the Sun entered Mesha *Rashi*, as New Year's Day.

13.5.3.2 Astrological Aspects

According to Vedic astrology, the symbol of Pisces is two fish. It is worthwhile considering the significance of this sign when humanity is at the threshold of a new beginning and a new cycle. Pisces is feminine, watery, and common, which is related to the preservation principle. Jupiter is a ruler of Pisces. As an ascendant Lord, it will encourage individuals to grow and prosper in this world. The Hindu, Christian, Pagan and many other regions have shown much reverence for fish. It is one of Lord Vishnu's incarnations known as Matsyavatar. It was this god who taught mankind to build houses and cultivate land. Ancient Brahmans and the Babylonians also connected fish to their Messiah. Pisces is indeed an auspicious sign with an auspicious beginning (Shah, 2020).

It is interesting to note that King Mangrai chose *Punarvasu* for the auspicious time of both events. *Punarvasu* is the birth *Nakshatra* of Lord Rama, the eternal-incarnation of God (Lord Vishnu) on Earth. He is the central figure of the ancient Hindu *Ramayana* epic, that has long-established deep cultural bonds between India and Thailand since the sixth century CE. He is considered a supreme being who fulfilled all his moral obligations. King Ram Khamhaeng of Sukhothai and all the kings of the current Chakri Dynasty of Thailand are often referred to as Rama. Even Ayuttaya, a prosperous kingdom that existed for over four centuries, was named after Ayodhya, Lord Rama's birthplace. Therefore, it is possible that King Mangrai might have been influenced by the ideology of Lord Rama to choose *Panarvasu*. As the star *Punarvasu* was in the ascendant, the five planets (Sun, Mars, Jupiter, Venus and Saturn) were in their respective exaltation positions. *Punarvasu* is known as the *Nakshatra* of renewal, repetition, and repeating patterns. Pisces ascendant and the *Punarvasu Nakshatra* were also chosen for auspicious events in Bangkok, and in other cities and temples. It would be interesting to investigate their popularity for auspicious times in the future.

13.6 Concluding Remarks

We find that the Chiang Mai city planners had seven good reasons (omens) for choosing the location for the new capital city of the Lanna Kingdom when King Mangrai explored the site. The reasons included topographical aspects (*e.g.*, flat land, a mountain, a river and a stream), natural water resources and the fertility of the soil, all of which would help promote harmony between the humans and local plant and animal varieties. The position and direction of the large lake in the north-east was also taken into consideration. Furthermore, King Mangai ordered that city construction would start from the Sri Bhumi corner. Besides the seven good omens, we also investigated ancient Lanna norms, customs and traditions that were passed from generation to generation. Some practices are still applied to this day.

The results of this investigation suggest that the planning of Chiang Mai city was influenced by *Vaastu Shastra* (an ancient Hindu architectural knowledge base), combined with traditional concepts and beliefs, indigenous Khmer knowledge and technology, Vedic cosmological concepts, and possibly ideas held by the King of Sukhothai.

The city might have been designed using a *mandala* of be 9 × 9 divided sites (81 squares) in the *Paramasayika* design. This has a symbolized human figure with the face and the stomach touching the ground lying with his head facing the northeast corner and his legs at the southwest corner. The form was to represent a human living in complete harmony with nature. The city planning thus symbolized a peaceful and a prosperous person.

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Chapter 14
Astronomical Aspects of the Prambanan Temple in Central Java, Indonesia

Sitti Attari Khairunnisa, Taufiq Hidayat, Wayne Orchiston, and Nok Nikeu

14.1 Introduction

The appearance of the Sun, the Moon, stars and planets are well known to have played important roles in our daily lives for thousands of years. People observed the movements of these celestial bodies for time-keeping, to identify the changing seasons, to decide when to plant their crops, to make calendars, to navigate across the oceans, and so on. Ancient cultures also identified celestial objects as a symbolic form of deities according to their religious beliefs, including the Hindu people of India. This was shown by the discovery of various astronomical aspects of several ancient Hindu structures (Chakrabarti, 2013; Shylaja, 2016). In other words, the role of astronomy in Hindu architecture has been widely recognized.

Outside India, numerical and astronomical analyses by Stencel et al. (1976) of Angkor Wat, the famous Hindu temple in Cambodia, revealed the importance of the calendar, the Sun and the Moon, from its structure and reliefs. It is assumed that similar astronomical aspects that have been found in Angkor Wat also exist in the Prambanan Temple, the largest Hindu temple complex in Indonesia. Jordaan (1996) stated that this temple was precisely oriented towards the cardinal points, and there are studies regarding the 24 male deities as the guardians of the compass points (*lokapāla*) reliefs on Prambanan by Tonnet (1908), Soehamir (1948), Van

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Lohuizen-de Leeuw (1955), Jordaan (1996) and Acri and Jordaan (2012). This orientation and relief show that the architect of Prambanan Temple had detailed knowledge of the cardinal directions. With this background, we will search for the astronomical aspects of the Prambanan temple complex.

In this chapter, we focus on the architectural structure and location of the temple. First, we will examine the orientation of the temple by photographing the temple relative to the Sun and the Moon, and then we made a map by utilizing a theodolite to confirm the orientation of the temple. Second, we will analyze the *mandala* of the Prambanan Temple, which is the basic concept of Hindu structures. The construction date and function of the temple can be inferred from *vastupurusamandala*. Considering the lack of available inscriptions or writing about the construction phase of the Prambanan Temple, the analysis is performed using the rules of Hindu temple construction in India. Eventually, we will seek the possibility of alignments with the most important celestial bodies in Hinduism, the Sun and the Moon. Astronomical alignments can be measured by observing the structure and orientation of the temple, as well as measuring the azimuth and altitude of the temple (Ruggles, 2005). In the following section, first we will describe the structure of the Prambanan temple complex, and then we will explain in more detail the methods used for this research.

14.2 An Overview of Prambanan

The Prambanan Temple is the largest Hindu temple complex in Indonesia dedicated to Śiva, one of the Trimūrti (see Fig. 14.1). This temple is located in Central Java and registered as a UNESCO world heritage monument. Based on its original plan, this complex consists of more than 250 large and small temples (Jordaan, 1996). Local people refer to the Prambanan Temple as 'Candi Prambanan' or 'Candi Loro Jonggrang', where in Indonesia the term 'Candi' means ancient Hindu or Buddhist temple. There is no information about the exact date when construction commencement, but according to a Śivagrha inscription, the temple was inaugurated around the ninth century (De Casparis, 1956). Jordaan (1996) has conducted a thorough study of the Prambanan Temple, and as stated by him, what makes it unique is the distribution of large and small temples over three areas separated by walls (see the map of the Prambanan Temple on Fig. 14.1 in Jordaan, 1996).

The central area of the complex (we also called this the first area) has the form of a raised terrace. This area is surrounded by a massive square wall that has four gateways in each side and has a size of 110 × 110 m^2. There are 16 temples with various dimensions located in this area. Three of them are dedicated to the Trimūrti, the divine trio, consisting of Brahmā (south), Śiva (center) and Viṣṇu (north). These temples are in a line and located in the west side of the first area and facing east. From the size of its temple, the structure, and the central location, it can be concluded that the Śiva temple is the main temple of Prambanan. Unlike the Brahmā and the Viṣṇu temples, the Śiva temple has four separate chambers which are

Fig. 14.1 The Prambanan Temple complex (source: Archaeological Department for the Preservation of Cultural Heritage of Yogyakarta, 2001).

connected by a passageway. A statue of Śiva Mahadeva stands in the main chamber located in the central, Agastya or Śiva Guru on the south, Gaṇeśa on the west, and Durgā (also known as Loro Jonggrang) on the north. Facing these temples, there are three smaller temples, called B / Hamsa (south), Nandi (central) and A / Garuda (north). Besides these six temples, there are two Apit temples located near the north and south entrance, and eight small buildings called Kelir and Patok located just inside the wall.

The second area of the complex is larger than the first one (222 × 222 m^2). This area is also surrounded by a square wall but, unfortunately, only incomplete remnants remain. This area consists of 224 small shrines called Pervara that were arranged in parallel into four descending tiers that face the back of the first area. To date only four Pervaras have been successfully restored. However, from their remains it is clear that all Pervaras were the same size and had similar design and decoration. In the third area, we cannot find any foundations, but it was reported that some remnants of the third wall used to be visible at the beginning of the nineteenth century. Although the third wall (390 × 390 m^2) also was a square shape, it was not parallel with the first and the second walls. It is assumed that this area was used as the accommodation of priests, temple servants and pilgrims (Jordaan, 1996).

14.3 The Field Survey

14.3.1 The Orientation of Prambanan

According to Jordaan (1996), Prambanan is precisely oriented to the cardinal points. To confirm this statement, we did a field survey at Prambanan by observing and taking photographs of the temple with respect to the Sun when the equinox occurred. Such observations in Prambanan were performed three times during our study, on 21 March 2013, 21 September 2013, and 20 March 2014. While the first and the third observations were conducted when the vernal equinox occurred, the second visit to Prambanan unfortunately did not exactly coincide with the autumnal equinox. Nevertheless, the most precise image that shows the orientation of the temple with respect to the Sun was taken during the sunset on 21 March 2013 at the western chamber of the Śiva temple facing west (see Fig. 14.2).

This photograph shows a wooden bar that we put on the middle of the chamber entrance acting as a *gnomon* or a sundial, which then formed a straight line projection towards the bar and had exactly a perpendicular shadow with respect to the entrance. From this picture, we could confirm that Prambanan is precisely oriented towards the cardinal points. From the orientation of the temple, there is no doubt that the architect of this temple had a qualified knowledge in astronomy. They must have been observing the Sun continuously so that the accurate position of the cardinal directions could be determined.

14.3.2 Geographic Coordinates of Prambanan

In addition to photographing the temple, we also collaborated with geodetic engineering students from Gadjah Mada University to make a map of the first area by utilizing a Nikon DTM-352 theodolite and a hand-held Garmin GPSMAP 76CSx. This map should provide essential data to search for astronomical alignments in the architecture. Measurements of the positions from six temples (Śiva, Brahmā, Viṣṇu, Nandi, A and B) and the wall that surrounded them, along with four entrances were performed on 21 September 2013. The results are presented in Table 14.1 with a systematic error of no more than 1″.

From Table 14.1, we could confirm that the three temples dedicated to the Trimūrti (Brahmā, Śiva, Viṣṇu) have the same longitude co-ordinate as well as the three temples located across from each one of them (A, Nandi, B). These Trimūrti temples also have the same latitude coordinate with their 'companion' temples, e.g., Brahmā and B (Hamsa), Śiva and Nandi, Viṣṇu and A (Garuda). Because of its role as the main temple of the complex, we select the Śiva position as Prambanan's geographic coordinate, i.e., $\theta = 7° 45' 7.3''$ S and $\lambda = 110° 29' 28''$ E.

Fig. 14.2 A wooden bar as a sundial placed in the middle of the western chamber entrance of Śiva temple to verify the orientation of the temple.

14.4 *Vaastu Shastra* Principles and the *Vaastu-Purusha-Mandala*

It has been mentioned by Hapsoro (1986) that a Hindu temple is a sacred building and was built primarily for religious purposes. The basis for the architectural design

> … is the belief that mankind and the Universe are analogous in their structure and spirit, and that the Earth is a living organism, pulsing with life and energy. *Vaastu Shastra* principles strive to achieve optimum benefits of the *Panchbhutas* (five elements of nature), the Earth's magnetic field, and the rotational influence of the Sun, the Moon and the other surrounding planets. The goal is to attain a balanced setting for the *Vaastu-Purusha-Mandala.* Here

Table 14.1 Measured co-ordinates for six temples and the wall in the first area.

Location	Latitude (south)			Longitude (east)		
	°	′	″	°	′	″
Brahmā Temple	7	45	8.8	110	29	28.0
Śiva Temple	7	45	7.3	110	29	28.0
Viṣṇu Temple	7	45	6.0	110	29	28.0
A (Garuda) Temple	7	45	6.0	110	29	30.0
Nandi Temple	7	45	7.3	110	29	30.0
B (Hamsa) Temple	7	45	8.8	110	29	30.0
The Southeast Corner	7	45	9.3	110	29	30.7
The Southern Entrance	7	45	9.3	110	29	28.9
The Southwest Corner	7	45	9.3	110	29	27.1
The Western Entrance	7	45	7.4	110	29	27.1
The Northwestern Corner	7	45	5.7	110	29	27.1
The North Entrance	7	45	5.7	110	29	28.9
The Northeast Corner	7	45	5.7	110	29	30.7
The Eastern Entrance	7	45	5.7	110	29	30.7

> *Vaastu* means environment, site or a building. *Purusha* is regarded as the ‘man’ of the Universe or the cosmic man or a creative intelligence in the Universe. *Mandala* is a geometric plan or chart representing the cosmos. In Hindu cosmology, the cosmos is usually represented by a square plan. Thus *Vaastu-Purusha-Mandala* is a metaphysical diagram of the planned site resembling the cosmos in which the *Purusha* resides. Because the Earth is essentially demarcated by sunrise and sunset, by east and west, by north and south, therefore orientation, particularly the cardinal directions, hold a significant contribution … To ensure peace, health and prosperity, it is advisable to keep the eternal rules of the *Vaastu-Purusha-Mandala* in mind while designing any structure. (Saelee et al., 2021: 466–467).

Therefore, to be a success a temple must fulfill specific requirements and procedures, including architectural rules. As we have seen, one of the most important fundamental concepts of Hindu architecture is called *Vaastu-Purusha-Mandala*, or *mandala* for short. The definition of this concept is described by Kramrisch (1946):

> Vastu here is the extent of Existence in its ordered state and is beheld in the likeness of the Purusa. Purusa, Cosmic Man, the origin and source of Existence, is its instrumental or efficient cause and causes it to be of His substance as its material cause. Mandala denotes any closed polygon.

The essential form of the *mandala* is a square, which is made from circles. According to the Hindu people of India, the form of a square is sacred, perfect, and is the symbolic form of the Universe. A temple built on the ground above the *mandala* represents a microcosmic event. This event will be complete if the *mandala* is oriented towards the Sun, especially when the Sun and the Moon are united at New Moon (Hapsoro, 1986; Kramrisch, 1946). In other words, the *mandala* set up should be arranged during a solar eclipse. This means that those two celestial bodies have the most influence on Hindu architecture, especially for temples.

By knowing the guidelines of the *mandala* set up as explained by Kramrisch (1946) and Acharya (1980), and then by conducting some astronomical calculations and combining the results with existing historical data, Hapsoro (1986) was able to determine the dates for the establishment of several temples in Central Java, including Prambanan. The instruction on how to make the *mandala* is described below (after Raz, 1834) and illustrated graphically in Fig. 14.3:

On a smooth level ground a gnomon is erected.

Around this a circle is drawn with a cord of twice the height of the gnomon.

Points are marked on the circumference where the shadow of the gnomon projects, both in the forenoon and the afternoon, that is at any given hour after sun-rise, and at the same time before sun-set, and between these points a straight line is drawn so as to join them.

The point marked by the morning shadow will show the east, and that marked by the evening shadow the west.

Then, from each of these two points, and with a radius equal to the distance between them, describe two more circles cutting each other, between which draw a straight line, which will point to the south and north.

Again, from the southern and northern points, which touch the circumference of the inner circle respectively, and with the same radius, describe two more circles, and the points of intersection on the two other sides will indicate the east and west.

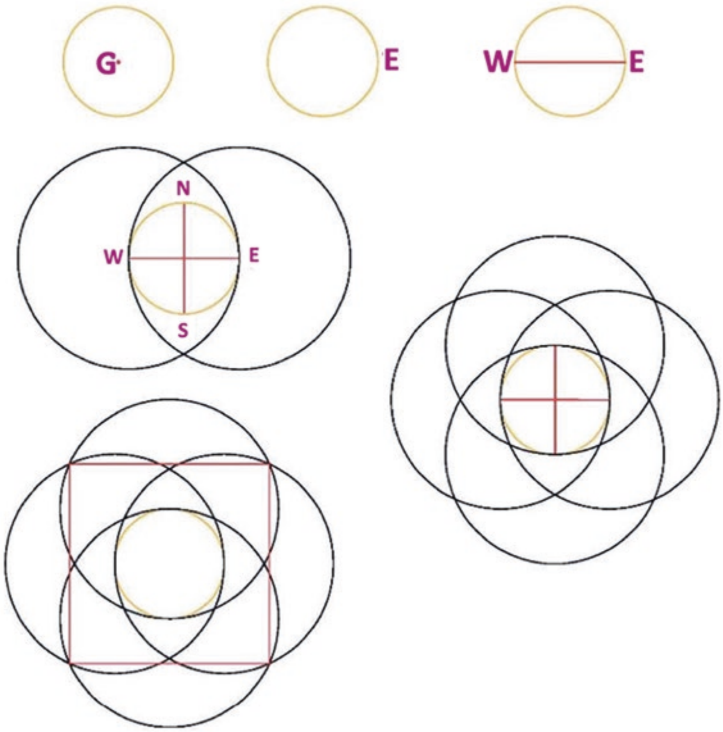

Fig. 14.3 The guideline of *mandala* set up.

From the description above, it is not surprising if Prambanan has walls with a square shape surrounding each one of the areas, as well as its orientation towards the cardinal points. To make it even clearer, we made a *mandala* with the procedure described above and enlarged it until it has the same size as the first area on the plan of Prambanan. Then, we did an overlay on the plan shown by Fig. 14.4 that we made by utilizing the contour map from the Archaeological Department for the Preservation of Cultural Heritage of Yogyakarta. There is an interesting feature in Fig. 14.4, namely that the mid-point of the first area of Prambanan is not located in the middle of the stairs on the Śiva temple, but instead, it is located just next to the stairs. Although Śiva is not exactly located in the middle of the first area, we are going to use Śiva's coordinate as the coordinate of Prambanan for calculation purposes because of its role. So here we can conclude that the *mandala* was the fundamental concept in the construction of Prambanan.

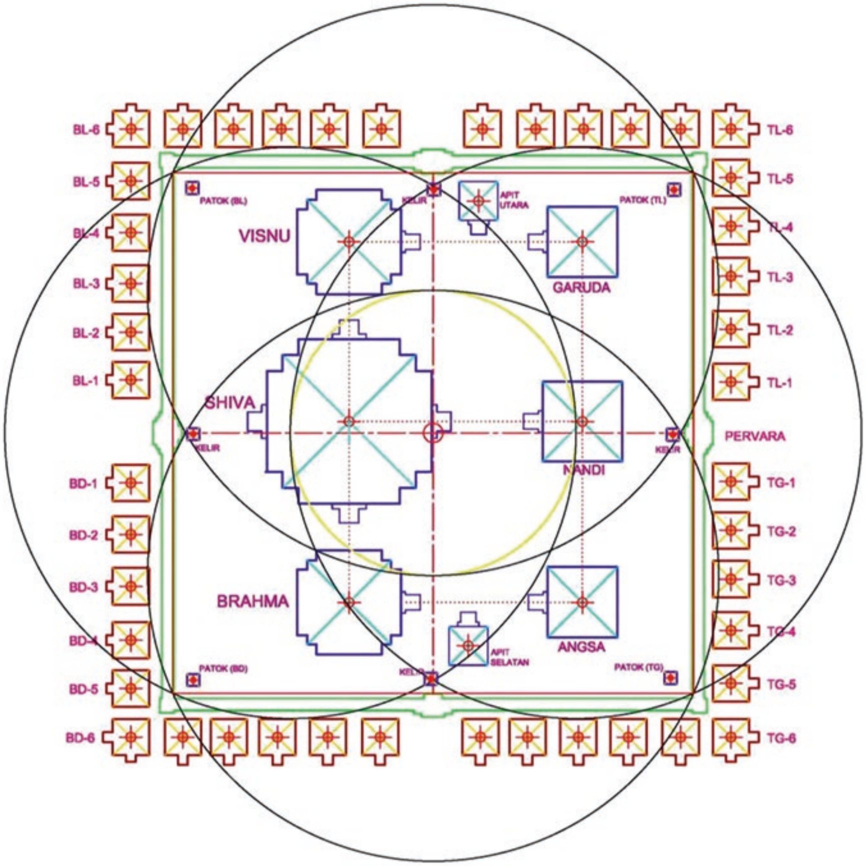

Fig. 14.4 The *Mandala* and the plan of Prambanan.

14.4.1 The Date of Establishment of Prambanan

In this Section, we are going to determine the construction date of Prambanan by adapting the method outlined by Hapsoro (1986). Instead of calculating the estimated declination of the Sun at the time of the construction, we use the longitude and latitude co-ordinates of Prambanan, and the azimuth and altitude of the Sun. As stated before, we use Śiva's coordinate as the co-ordinates of Prambanan, and we could find the approximate value for azimuth and altitude from the *mandala's* instruction. It is said that the *mandala* can be determined from the morning and the afternoon shadow, this means that the azimuth angle would be 90° (forenoon) or 270° (afternoon). As for the altitude, because the shadow of the gnomon will have the radius twice as the length of the gnomon, the altitude should be $\alpha = 26° \ 33' \ 54.18''$.

To determine a suitable date, we input the data to several astronomical web-based programs, i.e., *Accurate Times, JPL DE406* and NASA's *Moon Phase Predictions* to obtain Sun and Moon ephemerides. According to the *Shivagrha* inscription, Prambanan was inaugurated on 12 November 856 (De Casparis, 1956; Hapsoro, 1986). Hence, we select the range of available data from CE 800 until 860, while at the same time the Moon was in its first phase. We obtained 16 possible dates and compared them with the historical data described by Hapsoro (1986). Here, we may conclude that the most feasible date for construction of Prambanan to have begun was CE 27 September 846.

Our results differ from the result obtained by Hapsoro (CE 838). This could be due to the different calculation methods, or the less accurate ephemerides of the Sun and the Moon that were available at the time of Hapsoro's work. In our study, we included corrections for the effects of precession, nutation, refraction and parallax, so the result derived from our computation should be more precise.

14.5 The Function of the Prambanan Temple Complex

Due to the lack of information about the construction of Prambanan, we do not know for whom the temple was built. Therefore, we propose a hypothesis about the purpose of Prambanan by examining the type of *mandala* from the distribution of Pervara temples on its original plan (see Fig. 14.5). But first, we will explain the type of *mandala*.

There are 32 types of *mandala* diagrams, from one square (1 × 1) to a square with 1024 (32 × 32) subdivisions. However, the two main types are the *mandala* of 64 (8 × 8) and 81 (9 × 9) squares. The *mandala* of 64 and 81 squares are also known as *Manduka* and *Paramasayika*, respectively. The difference between these types is explained by Kramrisch (1946):

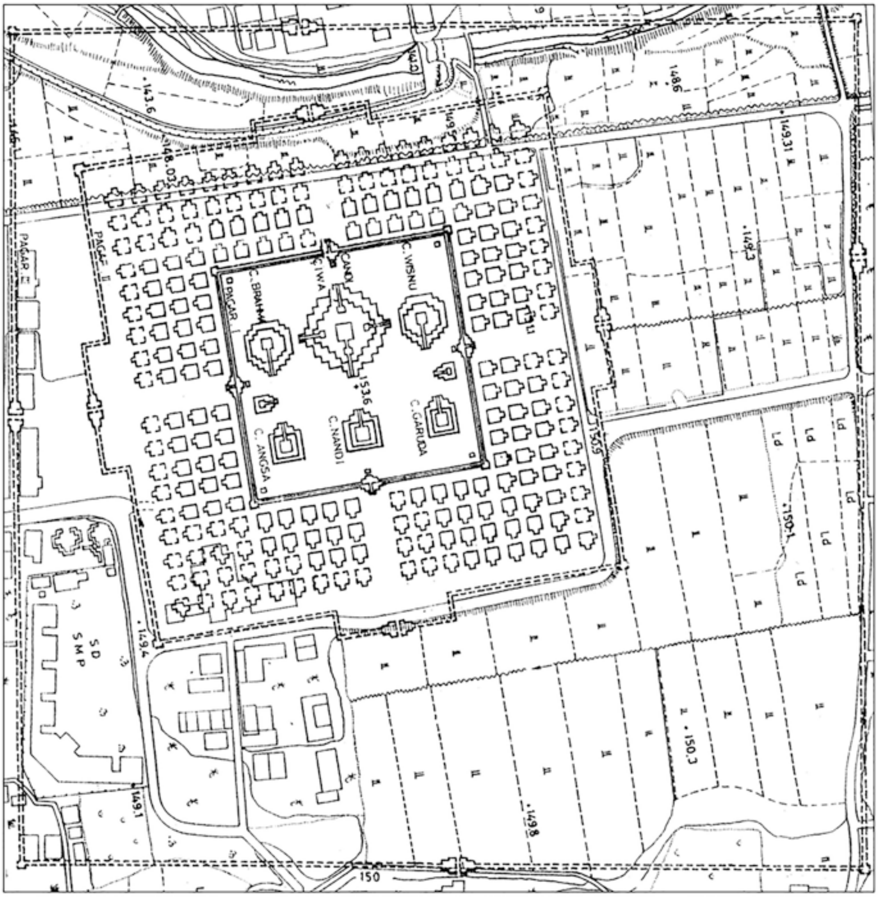

Fig. 14.5 The plan of Prambanan with respect to the third area (source: Archaeological Department for the Preservation of Cultural Heritage of Yogyakarta).

> … but it is obvious that the Vastu of 64 squares is meant for the construction of shrines and for worship by Brahmānas, and the Vastu of 81 squares is for the construction of other buildings and for worship on behalf of kings (Ksatriyas); or that the diagram of 64 squares and also of 81 squares are fit for temples, but the first is for worship by Brahmānas, the sacerdotal power, and the second for worship on behalf of the temporal power (Ksatra).

From the statement above, we know that the purpose and function of the temple can be inferred from the type of *mandala*. There are two ways to see the distribution of Pervara as a big picture. First, these temples are arranged into four concentric squares, and the numbers of temples from the inner to the outer row are 44, 52, 60 and 68 respectively. Second, Pervara can be seen as four groups, and each of them consists of 56 temples. If we look more closely at one of them, we know that the number of temples in the outer row is 9 for each of the groups. Thus, we propose an hypothesis that the type of *mandala* in Prambanan is the *mandala* of 81 (9 × 9) squares, known as *Paramasayika*. In other words, Prambanan was built for worship on behalf of Kings.

14.6 The Astronomical Alignments Hypothesis

It is obvious that the Sun and the Moon play a major role in the construction of *mandala* (Hapsoro, 1986; Kramrisch, 1946). Aside from its function as a place of worship, it could be possible that Prambanan was also used as a site for solar or lunar observations. Therefore, we will examine the possibility of astronomical alignments in Prambanan by using the following equation:

$$\sin\delta = \sin\phi \sin \mathrm{h} + \cos\phi \cos \mathrm{h} \cos \mathrm{A} \tag{1}$$

where δ is declination, ϕ is observer's latitude, *h* is elevation or altitude and A is azimuth. This method was adopted by Stencel et al. (1976) who applied it successfully to Angkor Wat:

> … we computed the apparent alt-azimuth orientation of one point as seen from the other, and further related the sighting line to a particular celestial declination.

In order to perform this calculation, we utilized the co-ordinates of the Prambanan Temple that we obtained from the field survey (see Table 14.1), the dimensional data of the temple, the laser scanned data and a contour map of Prambanan, which was provided by the Archaeological Department for the Preservation of Cultural Heritage of Yogyakarta. The observer's latitude at various positions within the temple is relatively the same because the main focus of this work is the first and the inner row of the second area of the complex. Therefore, we chose the latitude coordinate of Śiva (7° 45′ 7.3″) as the input data for ϕ. There is no significant error in the result caused by this input. As for the altitude (*h*) and azimuth (A), we used the dimensional data of the temple (Table 14.2), the laser scanning image, a contour map, as well as the plan of Prambanan (see Fig. 14.6) that we made using a CAD (Computer-Aided Design) program as the primary source.

We computed more than 200 declinations and determined for the solar equinoxes and solstices (0° and ±23.5°), as well as declination extremes of the Moon (±5°,

Table 14.2 The dimensions of the temples at Prambanan (from Archaeological Department for the Preservation of Cultural Heritage of Yogyakarta).

	Dimension (m)		
Temple	Length	Width	Height
Śiva	34	34	47
Brahmā	20	20	37
Viṣṇu	20	20	37
Nandi	15	15	25
B (Hamsa)	13	13	22
A (Garuda)	13	13	22
Apit	6	6	16
Kelir	1.55	1.55	4.1
Patok	1.55	1.55	4.1
Pervara	6	6	14

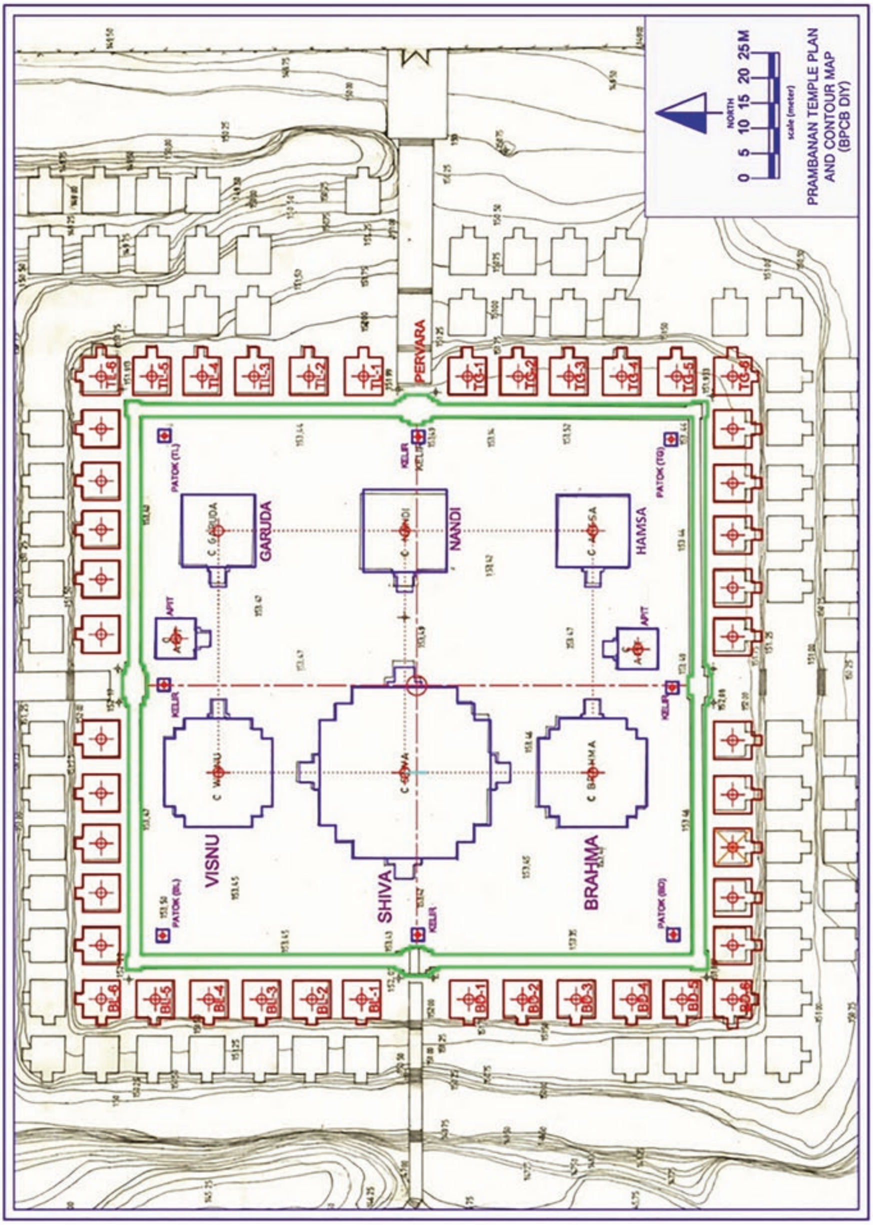

Fig. 14.6 The plan of Prambanan based on the contour map from the Archaeological Department for the Preservation of Cultural Heritage of Yogyakarta.

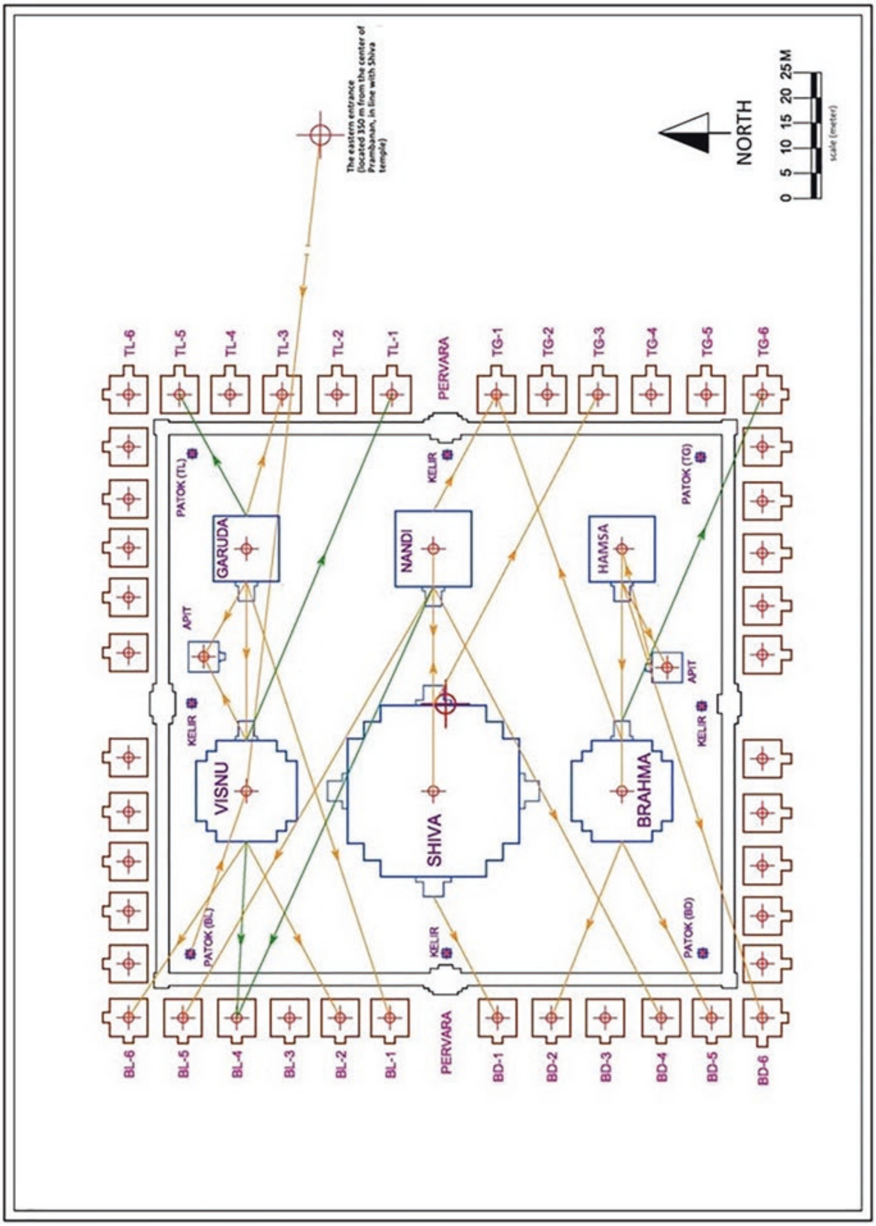

Fig. 14.7 Possible lunar (yellow) and solar (green) alignments at Prambanan.

Table 14.3 Possible solar and lunar alignments at Prambanan.

No	Observer's location	Temple observed	Declination (°)
1	The eastern entrance (350 m from the midpoint of the first area)	Viṣṇu	+5.08
2	Apit – South (ground level)	B (Hamsa)	+5.15
3	Śiva (ground level)	Nandi	−5.24
4	Viṣṇu (passageway of Viṣṇu, 4 m from the ground level)	Apit (North)	+18.23
5	Nandi (passageway of Nandi, 4 m from the ground level)	Śiva	−5.63
6	B / Hamsa (passageway of Hamsa, 3 m from the ground level)	Brahmā	−4.96
7		Apit (South)	−28.02
8	A / Garuda (passageway of Garuda, 3 m from the ground level)	Viṣṇu	−4.95
9		Apit (North)	+18.48
10	Patok – Northwest (ground level)	Viṣṇu	−18.69
Temple observed: the inner row of Pervara			
11	Śiva (ground level)	Southwest-1 (BD-1)	−28.32
12	Śiva (entrance of Śiva, 5 m from the ground level)	Southeast-3 (TG-3)	−28.31
13	Brahmā (ground level)	Southeast-6 (TG-6)	−24.11
14	Brahmā (passageway of Brahmā, 4 m from the ground level)	Southwest (BD-2)	+19.01
15		Southwest-5 (BD-5)	−27.83
16		Southeast-1 (TG-1)	+18.56
17	Viṣṇu (ground level)	Northwest-4 (BL-4)	+0.21
18		Northwest-6 (BL-6)	+29.03
19	Viṣṇu (passageway of Viṣṇu, 4 m from the ground level)	Northeast-1 (TL-1)	−23.38
20		Northwest-2 (BL-2)	−28.86
21	Nandi (passageway of Nandi, 4 m from the ground level)	Southeast-1 (TG-1)	−29.13
22		Northwest-4 (BL-4)	+23.50
23		Northwest-5 (BL-5)	+29.08
24		Southwest-4 (BD-4)	−28.42

(continued)

Table 14.3 (continued)

No	Observer's location	Temple observed	Declination (°)
25	A / Garuda (passageway of Garuda, 3 m from the ground level)	Northeast-3 (TL-3)	−17.99
26		Northeast-5 (TL-5)	+23.69
27		Northwest-1 (BL-1)	−18.95
28	B / Hamsa (passageway of Hamsa, 3 m from the ground level)	Southwest-6 (BD-6)	−18.57

±18.5° and ±28.5°). The estimated value for the error is ±0.5°, which includes uncertainty about the dimension data of the temple, the distance between two points, the ephemeris of the Sun and the Moon at epoch CE 846, and also the geological aspect of the site. The results are presented in Table 14.3 and shown in Fig. 14.7.

We can see from the results that 23 of 28 alignments possibly refer to the Moon. Most of these alignments use Pervara as the points observed, and this also applies to the solar alignments. This may indicate that the Pervara layout as a concentric square is useful for making observations of the Sun and the Moon. Hence, we propose a hypothesis that apart from its main function as a place for Hindu worship, Prambanan may also have been a lunar observing site.

14.7 Concluding Remarks

The results from the present study of the Prambanan Temple can be are summarized as follows:

(1) There is no doubt that the architect of Prambanan Temple integrated astronomy into its architecture. This is shown by the orientation of the temple towards the cardinal points, which utilizes *vastupurusamandala* as the fundamental concept of the temple.
(2) We could estimate the date of the temple based on a calculation that we derived from the *mandala* set up, when compared with the historical literature. We conclude that the possible date when construction of Prambanan commenced was CE 27 September 846.
(3) The type of *mandala* not only allowed us to determine the construction date, but also the purpose of the temple. By examining the Pervara temples, we propose that Prambanan was built as a place of worship on behalf of kings (Ksatriya).
(4) The Sun and the Moon play an important role in the construction of the *mandala*. Therefore, we searched for possible lunar and solar alignments. We found that Prambanan has 23 lunar alignments and five solar alignments, most of which used Pervara as their observing points. We propose that apart from its religious purpose Prambanan was built as a lunar observing site.

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Chapter 15
Astronomical Knowledge and Practices of the *Orang Asli* of Malaysia

Nurul Fatini Jaafar and Ahmad Hakimi Khairuddin

15.1 Introduction

The indigenous peoples in Peninsular Malaysia are referred to as 'aborigines' or *orang asli* (literally 'original people', in Bahasa Melayu). Article 160(2) of the Federal Constitution defines 'aborigines' as an aborigine on the Malay Peninsula (West Malaysia), while in Sabah and Sarawak, they are called 'natives' as defined by Article 161A(6) (a) & (b) of the Federal Constitution (Nordin, 2018). For administrative purposes, the Malaysian Government categorized 18 culturally distinct *orang asli* groups into three main categories: *negritos/semang, senoi*, and aboriginal/*proto-Malays* (Endicott, 2016). Some examples of Malaysian *orang asli* encountered in the course of our research are shown below in Table 15.1.

At a superficial level, Malaysia's *negritos* (Fig. 15.1) appear to be physically and genetically related to other Southeast Asian *negrito* groups found in the Philippines and southern Thailand, and on the Andaman Islands in the Indian Ocean off the coast of Myanmar (Macaulay et al., 2005). Researchers believe that all of these *negrito* groups carry 'relict' evidence of the first anatomically modern *Homo sapiens* population that dispersed along the coasts of East Africa, the Arabian Peninsula, India and Southeast Asia to Sahul (New Guinea and Australia) between 100,000 and 70,000 years ago (Stoneking and Delfin, 2010).

In Malaysia, there are many issues regarding the official status of the *orang asli*, especially in terms of development (Dentan et al., 1997) and customary land rights (Nicholas et al., 2010). The classification of the different ethnic groups has been formalized but is still being fine-tuned. In the case of *orang asli*, many perceive them as representing a single homogenous group (based on informal interviews and readings on digital media).

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Fig. 15.1 Examples of Malaysian negritos (photographs: Nurul Fatini Jaafar).

In this chapter, we include two different tables showing the different ethnic classifications so that the reader can distinguish the similarities and differences between the various classes. Table 15.1 shows the traditional trilateral categories of *semang*, *senoi* and *proto-Malay* (Carey, 1976), while Table 15.2 is based on linguistic categories developed by Benjamin (1973) and by Omar et al. (2018). The former traditional grouping is flawed and inaccurate since the characteristics between the different ethnic groups in terms of cultural and physiological aspects are obscure. For Table 15.2, we maintain the 18 known groups as per the old-style classification, with the addition of further subgroups as suggested by Benjamin, such as the Mintil, the Sabum, the Semnam and the Temok.

15.2 Research Objectives

This chapter is based on the findings of our preliminary study in identifying the traditional astronomical knowledge among the *orang asli*. We focus only on celestial objects such as stars, asterisms, planets, comets, meteors, and on the basis of what has been reported by previous researchers excluding the Sun and the Moon (with the notable exception of lunar phases). We include the findings from our own fieldwork and from reports of previous researchers.

Out of the five publications that have reported astronomical knowledge among the *orang asli*, we found two publications that incorporate evidence of ecological adaptation with astronomical knowledge. The most recent is a compilation of oral traditions (stories, legends and myths) by Nicholas (2018) on various themes, one of which is the ‘Sun and Moon’. Nicholas argues that the ecological system does

Fig. 15.2 A map showing the geographical distribution of *negrito*/*semang*, *senoi* and aboriginal/*proto-Malay* ethnic groups found in the Malay Peninsula (http://egagah.blogspot.my/2011/06/malaysian-orang-asli-in-dire-straits.html).

Table 15.1 Traditional *orang asli* classification by groups and sub-groups.

Ethnic group	Sub-group
Semang	Jahai
	Batek
	Mendrik
	Lanoh
	Kensiu
	Kintak
Senoi	Semai
	Temiar
	Jah Hut
	Mah Meri
	Semoq Beri
	Che Wong
Proto-Malay	Jakun
	Temuan
	Semelai
	Orang Kuala
	Orang Seletar
	Orang Kanak

Table 15.2 Modified *orang asli* linguistic subgrouping.

Ethnic group	Language family	Linguistic class
Che Wong	Austroasiatic	Northern Aslian
Batek		
Mendrik		
Jahai		
Kensiu		
Kintak		
Jah Hut		Central Aslian
Semai		
Temiar		
Lanoh		
Mah Meri		Southern Aslian
Semoq Beri		
Semelai		
Jakun	Austronesia	Malayic Orang Asli
Temuan		
Kanak		
Seletar		
Duano/Orang Kuala		Non-Malayic Orang Asli

affect the *orang asli* prospects of gazing at the night sky. People in coastal areas are believed to have a better chance of clearly observing the distant horizon than inland groups living near large lakes surrounded by misty forests, hills, predators and overcast skies that do not allow for a clear view of the distant horizon. Nicholas also mentions that the "… *orang asli* seem not to have used the 'rising' of stellar constellations such as the Pleiades … as an indicator of the time to begin preparing farm fields for planting." This suggests that *orang asli* farmers were not dependant on astronomical indicators for their planting activities.

Another work written by Rambo (1980) discussed the environmental knowledge and adaptation of the *orang asli* in relation to animals, plants, stones, stars and astronomical phenomena. With regards to the stars, he commented that the forest dwellers, and specifically the Jahai, did not have assigned names for the various asterisms, and even their word for a 'star' was a loan word. The reason that Rambo gives for this is the presence of the tree canopy, which blocked off the view of the night sky.

Both of these publications associate these *orang asli* living in the forests with an absence of knowledge of astronomy. These communities only refer to dominant objects and phenomena, such as the Sun, the Moon, lunar phases and eclipses. Rambo also noted that agriculturally oriented *orang asli* groups took particular notice of the changes in the phases of the Moon.

Hence, the purpose of this chapter is to: (1) see if this statement about the local ecological niche of the *orang asli* having an influence on astronomical knowledge is supported by our own research findings; and (2) to provide a preliminary analysis of the linkages between local ecological niches and astronomical bodies.

15.3 The Origins of the Name *Orang Asli*

Many different names have been given to the *orang asli*. According to Manickam (2015), among the earliest writings were those of William Marsden (1754–1836) and John Leyden (1775–1811) in 1811. They recorded names such as Samang, Bila and Dayak referring to the 'black mountain tribes' of the Malay peninsula. Later, in 1818, Thomas Stamford Raffles (1781–1826) also recorded tribe names according to their localities: Semang, Caffries and Orang Udai for people living in the hills, Orang Benua for groups on the plains, and a specific tribe residing in Melaka called Jokong. Even more names come later including the Sakai, Jakun, Biduanda, Pangan and Orang Jinak (literally 'tame men'). The various locations mentioned in this chapter are, for the most part, shown in Fig. 15.3.

As stated by Carey (1976), the Malaysian Government introduced the term *orang asli* in the early 1960s to fight against communist ideology. *Orang asli* who were originally referred to as Sakai during the colonial period felt mortified by this term, which for them was a derogatory name. The left-wing nationalists had coined a more deferential term, *orang asal*, meaning the original inhabitants. To counter this,

Fig. 15.3 The states in Peninsular Malaysia, and localities mentioned in this chapter (map: Nurul Fatini Jaafar).

the Malaysian Government officially introduced the *'orang asli'* terminology, where *asli* means natural, genuine or original.

However, the terms *asli* and *asal* were not first introduced in the 1960s. We find it interesting that Za'ba (i.e. Tan Sri Zainal Abidin bin Ahmad, 1895–1973), a prolific Malay writer in 1920s, had already referred to the indigenous peoples as '*bangsa bangsa asli*' (original races), while Munshi Abdullah (i.e. Abdullah bin Abdul al Kadir, 1796–1854), who was regarded as the father of modern Malay literature, introduced the term '*orang asal*' in his 1840s' work entitled *Hikayat Abdullah* (*Tales of Abdullah*) (Manickam, 2015).

According to Omar et al. (2018), the nomenclature that has been assigned to the various *orang asli* ethnic groups has come about possibly due to recognition of their habitat (local ecological system) which is either coastal or inland. She also argues that "… a clear-cut division of the sea and the land Orang Asli is not tenable … in the process of history whereby a land tribe, wholly or partially may turn into Orang Laut, or vice versa." Therefore, it is important to look at the origins of the name of a particular *orang asli* group as well as their endogenous tribal names to reconstruct their historical ecological adaptation.

15.4 Our Findings from the Literature

Among the many scholarly works written on the *orang asli*, we have so far discovered five that mentioned astronomical objects. The first is a book written by the British anthropologists Walter William Skeat (1866–1953) and Charles Otto Blagden (1864–1949) and published in 1906 as a result of the University of Cambridge Expedition to the North-Eastern Malay States and Upper Perak in 1899–1900. In the supplementary section of the *Pagan Races of the Malay Peninsula, First Volume*, we can find a list of terminologies in many indigenous dialects, including astronomical objects such as the Sun, the Moon, stars, planets and comets. To be in line with the objectives of this paper, in Table 15.3 we only list the indigenous words referring to a 'star' (*bintang*, in Malay).

Readers should note that neither of the authors of this chapter has been formally trained in linguistics. However, based on the variety of words presented in the table above, we have sorted them out into eight different groups according to similar sounds:

(1) *chun-dan*
(2) *lang-ēr*
(3) *tĕ-nûrr*
(4) *pĕr-lâu-i*, *perlauī*, *pĕ-lau-i*, *pĕrlohi*, *pĕrloí?*, *perlôi*, *pĕrlōy*, *perloi*, *pĕluih*, *pĕlo-i*, *puloe*, *puloi*, *paloy*, *paloye*
(5) *jelā̆t*
(6) *sea*, *chiang*, *cheong*, *chéong*, *cheóng*, *chēöng*, *chĕóng*
(7) *binten*, *binteng*, *bnting*, *binting*, *benting*, *bintang*, *bntg*, *bintañ*, *bintàk*
(8) *pĕnabor*

Words like *perloi* and *bintang* are still used by different *orang asli* groups today. We suspect that words like *chun-dan*, *lang-ēr*, *tĕ-nûrr* and *chiang* were the original words for star before the adoption of intra-groups word took place. Nevertheless, we leave it to the linguists to do further research on this matter.

The record by Skeat and Blagden (1906) also revealed that the Semangs perceived every object (other than the Moon) in the night sky as a star. The Semang Paya, or swamp Semangs who live in Ulu Kerian, a locality on the Perak-Kedah border, and also the Semang Bukit (the hill Semangs) of Bukit Berambar in North

Table 15.3 Terms for a 'star' used by different Malaysian ethnic groups (after Skeat and Blagden, 1906).

Indigenous term	Indigenous group and description
chun-dan	Semang of Ulu Siong, near Bukit Sabelah, Kedah
lang-ēr	Semang of the northern portion of the Plus River valley, North Perak
tě-nûrr	Sakai of the Central Group, precise locality undefined, but no doubt collected in Ulu Pahang
pěr-lâu-i	
perlauī	Orang Tanjong (men of the river reaches) of the Ulu Langat district, South Selangor; Blandas (= Belandas) of Kuala Langat district
pě-lau-i	Sakai of the Central Group, precise locality undefined, but no doubt collected in Ulu Pahang
pěrlohi	Sakai of the Chenderiang River district, Perak
pěrloí? (*berloí*)	Sakai (Senoi) of Ulu Gedang, in the mountains two days' journey from Bidor, South Perak
perlôi	The likely dialect is Sakai from the neighbourhood of Blanja, Perak
pěrlōy; *pěrlōí*	Sakai of the Ulu Kampar, Perak, but also spoken in Ulu Pulai, Ulu Gopeng and the hills around Batu Gajah
perloi	Sakai, known to local Malays as Orang Darat (up-country men); collected near Jeram Star and Tanjong Gahai, Ulu Jelai mukim, Ulu Pahang
pěluih (*pluih*)	Semang Paya (swamp Semangs) or low-country Semangs of Ulu Kerian, Perak-Kedah border
pělo-i (*pöloī*)	Sakai of the Kerbu (or Korbu) River valley, Perak
puloe (*poolo-e*)	Semang, locality undefined, but probably in Kenering, North Perak
puloi	Orang Benua (but the list is a jumble of Semang from the north of the Peninsula, Besisi probably from Sungai Ujong, Jakun probably from Bukit Panchor, Malacca and perhaps Belandas from the same neighbourhood as Besisi)
paloy	Sakai of Kerbu (or Korbu) River valley, Perak
paloye	
jelā̆t (*djelā̆t*)	Semang (but really a northern Sakai dialect) of Kuala Kenering, collected at Kamnugie-Ongbal, North Perak
sea	Sakai of Selangor, locality undefined, probably Kuala Lumpor or Klang district
chiang	Jokang (= Jakun) of the neighbourhood of Malacca, probably lived at least 10 miles away from Malacca town)
cheong	
chéong	
cheóng	Jakun of Malacca territory, collected from Jakuns near Jasin
chēöng (*chaüng*)	Orang Benua (but the list is a jumble of Semang from the north of the Peninsula, Besisi probably from Sungai Ujong, Jakun probably from Bukit Panchor, Malacca and perhaps Belandas from the same neighbourhood as Besisi)
chěóng	Jakun of Malacca territory, collected from Jakuns near Jasin
binten	Semang of Ijoh (or Ijok), North-west Perak
binteng	Orang Laut (men of the sea) of Singkep, Lingga Archipelago (south of Singapore); Semang of Ulu Siong, near Bukit Sabelah, Kedah; Semang of the northern portion of the Plus River valley, North Perak; Semang of Ulu Selama (or Selamar), North-west Perak

(continued)

Table 15.3 (continued)

Indigenous term	Indigenous group and description
bnting	Semang of Bukit Berambar, North Perak (the locality has not been identified, it cannot be Berumban or Berembun)
binting	Semang of Mt. Jerai (Kedah Peak), Kedah; Semang of Ian (Yan, at the foot of Mt. Jerai), Kedah; Semang of Juru (the mountains of Jooroo) behind Province Wellesley (as bounded in 1824)
benting	Semang of Ian (Yan, at the foot of Mt. Jerai), Kedah; Semang of Juru (the mountains of Jooroo) behind Province Wellesley (as bounded in 1824)
bintang	Semang of Ian (Yan, at the foot of Mt. Jerai), Kedah; Semang (speaking a Sakai dialect) of (North) Perak, probably of the neighbourhood of Kenderong; Semang of Kenering, Perak (printed as Perak Semang), really a northern Sakai dialect; Orang Benua (but the list incorporates Semang from the north of the Peninsula, Besisi probably from Sungai Ujong, Jakun probably from Bukit Panchor, Malacca and perhaps Belandas from the same neighbourhood as Besisi); Besisi of Malacca territory, collected from aborigines in the mukims of Bukit Senggeh and Sebatu, the latter being recent emigrants from Sepang, Kuala Langat district, South Selangor while the former originally from Sungai Ujong; Mantra (= Mentera) of Malacca territory, collected mainly at Bukit Senggeh, Malacca
bntg	Semang Paya (swamp Semangs) or low-country Semangs of Ulu Kerian, Perak-Kedah border
bintañ	Sakai of the Sungai Raya River valley, Kinta district, Perak
bintàk	Soman (= Semang), a mixed Negrito tribe speaking a Sakai dialect, of the Sungai Piah River valley, North Perak
pěnabor (*pinabor*)	Pantang Kapur of Johor Jakuns (the same on the Sedili, Endau and Batu Pahat River; apparently, therefore, covering Central Johor

Table 15.4 Astronomical objects in the Semang and Malay languages (after Skeat and Blagden, 1906).

Ethnic name	Indigenous term	Malay term	Astronomical object
Semang Bukit	*pěluih timor* (*plu timur*)	*bintang timur* (*bintang* = star, *timur* = east)	Morning star; planet Venus
Semang Paya	*pěluih barah* (*pluih barh*)	*bintang barat* (*barat* = west)	Evening star; planet Venus
	it pěluih (*ait pluih*)	*tahi bintang* (*tahi* = faeces)	Shooting star; meteor
	pěluih chub (*pluih chub*)	bintang berjalan (*berjalan* = wandering)	Planets
	pěluih kětika (*pluih ketik*)	*bintang ketika* (*ketika* = temporal)	Seasonal stars; Pleiades
	pěluih hīte' (*pluih hiti'*)	*bintang berekor* (*berekor* = tailed)	Comet

Perak had ideas about planets, globular clusters, meteors and comets. We notice that the meanings of all these objects are very similar in the Malay language. We argue that these terms may have been shared among the Semangs and the Malays. However, there is a possibility that a Malay translator's bias could have imposed his worldview upon the collected data. Table 15.4 contains a list of the astronomical terms for the aforementioned objects found in the *Pagan Races* book.

The second source is from Josephine Stephenson's Honours Thesis on the ethno-ecology of the Temuans in Kampung Paya Lebar, Hulu Langat, Selangor in 1977. According to Rambo (1980), Stephenson recorded several asterisms from these people. However, she remarks that only a few informants in the village were knowledgeable about astronomy. Among the asterisms recorded were *bintang lunga* (the Pleiades) which indicated the fruit season, *bintang lerek* (Orion's Belt) and *bintang labor* (whose appearance promised pleasant weather). There was also a record of *bintang timur*. In order to look for specific definitions, we have interviewed the most senior elders and community leader in the same village. However, the 40-year time gap since Stephenson's field research and this current study has altered the socio-economic landscape of the community from a traditional lifestyle to a modern one. They have forgotten their knowledge about stars, although still following social customs with reference to the phases of the Moon. In personal communications with some *orang asli* friends, we found that *lunga* means 'loosen', and *lerek* means 'to move steadily and continuously', and also referred to a type of fruit that ripens in March following the durian season. We suspect that *bintang labor* carries the same denotation as *bintang temabor* (Wilkinson, 1901) and *bintang terambor* (Clifford and Swettenham, 1894), which means 'besprinkled', 'scattered' and 'dispersed' stars. Zain (2013), like Wilkinson, uses *bintang temabor* for the Milky Way.

The third source of the information comes from Endicott (1979). He mentions the Batek folk-tale of the Moon being married to a star named *bintang jong*. He believes that the Batek Dè' of Kelantan refer to Polaris as *bintang jong*, the north star. Clifford and Swettenham (1894) also record the same star name among the Malays, and we also found the same name used among the Semelais in Tasik Bera (Lake Bera), Pahang. However, the term *jong* in Batik is a loan-word from the Malay language, which carries the meaning of a sailing vessel-junk, while, in the Semelai language it means foot.

The fourth source of astronomical information (Ahmad, 2014) talks about the stars known to the Orang Seletar in Pasir Gudang, Johor. The Orang Seletar is one of the various tribes living along the coast and on the islands of the Riau-Lingga Archipelago, as well as in the east coast of Sumatera (Andaya, 2017). They are labelled as *suku* (tribe) Orang Laut meaning sea peoples. Orang Seletar however can only be found in the waters of southern Peninsular Malaysia and Singapore within the Straits of Melaka. According to Winstedt (1935), in 1553 João de Barros (1496–1570) and in 1600 Emamuel Godinho de Eredia (1563–1623) were among the first Portuguese to use the term *Cellates* or *Saletes* to refer to a 'race of fishermen' before the founding of Melaka. This word as well as the term 'Seletar' might have originated from the Malay word *selat* meaning 'straits'. Orang Seletar described ways to predict the weather using knowledge of Orion which they called *bintang balatek*. They believed that the rising of *bintang balatek* brought strong winds and rough seas. *Balatek* in Malay refers to a spring spear trap named *belantik*. Knowledge of *bintang belantik* is well spread across the two-thirds of the Malay Archipelago (see Jaafar, 2016).

Since the Seletar are a group of sea dwellers specifically adapted to mangrove swamps, this particular group does not quite come within the objectives of this paper. However, we have included them as a reference for the coastal peoples, so that they can be compared with land-based peoples. It is interesting to note that they used the *bintang balatek*, which is a spring spear trap that is similar to those used by land-base peoples. It will be informative for us to find out about other stars or asterisms that they used that can be identified with a coastal or marine ecological adaptation.

The fifth source of information is a compilation of oral traditions by Nicholas (2018). However, this compilation does not specify individual stars or asterisms (as mentioned in Section 15.2 earlier).

15.5 Our Findings from Field Investigations

Ethnoastronomical field research for this chapter was first conducted in April 2014. Since then, we have been working with the Jahai of RPS Banun, Hulu Perak; the Semai of Sungai Koyan, Kuala Lipis, Pahang; the Mah Meri of Sungai Kurau, Pulau Carey, Selangor; the Temuan of Kampung Paya Lebar, Kuala Langat and Kampung Pulau Kempas, Hulu Langat in Selangor as well as Kampung Tohor, Jelebu in Negeri Sembilan; and Semelai of Kampung Lubuk Perah and Pos Iskandar, Bera, Pahang. Most of the data were gathered during short field visits where the researcher went to stay with the informants between three to five days during each visit, and this continued through many visits. For the Semelais, in 2018 we conducted a full ethnographical study within six months. The aforementioned locations are shown in Fig. 15.3.

Since this is a preliminary study, we might not have gathered sufficient data since we were not able to confirm that we have met all of the persons who possess such information. However, most of the ethnic groups are aware of the western (*bintang barat*) and eastern stars (*bintang timur*) (i.e. Venus) and used these stars to denote the cardinal directions. Only the Temuans and the Semelais have given different names to this ‘star’. Venus in Temuan is called *bintang tembaga*, the copper star. The Semelais also use the same name, but they also referred to it as *bintang padoman*, the guiding star.

We also found out about additional asterisms from our Temuan informants in Kuala Langat and Jelebu: *bintang layang petek*, the kite star (Crux); *bintang naga*, the dragon star (Milky Way); *bintang tiga*, the three stars (Orion’s Belt); *bintang tujuh*, the seven stars (Pleiades) and *bintang pecah dua*, the splitting stars (unknown location). When we asked for additional identifying explanation, our informants refused to answer because of their belief in certain taboos. We argue that the names for Orion's Belt and the Pleiades as collected by Stephenson differ from what we have gathered because we accessed differing territorial Temuan bands, either upstream (Hulu Langat and Jelebu) or downstream (Kuala Langat).

From fieldwork carried out in the Bera district of Pahang, we discovered seven more star names among the Semelais. The Semelais reside in villages located in the wetlands surrounding the lake and river of Bera. Tasik Bera is Malaysia's largest natural freshwater lake system. Not far from here is Tasik Chini, home of the Jakuns. Unlike the Temuans of Hulu Langat who cultivate wetland paddy, the Semelais practise shifting crop cultivation involving rice, tapioca, sugarcane and vegetables. Other than *bintang jong* and *bintang tembaga*, they also have names for other stars such as *bintang peyh*, the spring spear trap star (Orion); *bintang jekat*, the wild boar's jaw (Taurus); *bintang keran cong*, the mouse-deer's dung (Pleiades); *bintang tukul*, the hammer star (Big Dipper); and *denai*, the animal's trail (Milky Way).

15.6 Discussion and Concluding Remarks

In response to Nicholas (2018) and Rambo (1980), the data gathered for this chapter strongly suggests that forest or lake localities do not necessarily impinge on the astronomical knowledge of the different *orang asli* groups. The ethnic group's habitat, whether inland or near the sea, also does not prevent the members of a group from gazing at the sky and developing a systematic knowledge of astronomy.

The meaning behind each astronomical object's name symbolizes the relationship between humans, animals, plants and weather within specific seasonal windows. For example, the rising of *bintang peyh*, *bintang jekat* and *bintang keran cong* marked the arrival of *periantan penungguyan* (waiting season) among the Semelais. During this period according to Salleh (2008) and Sapura (2010), the farmers will guard their growing paddy crop for almost three months before the harvesting takes place. In the meantime, the Semelais will use this time to set up traps (*peyh*) for the mouse deer (*cong*) and roe deer, which they know become more active at this time as a result of the mating season (Salleh, 1974).

On the basis of data gathered thus far, we can question whether the *proto-Malay* ethnic groups have a complex knowledge system of the sky, or whether this knowledge is only evident among the people who practise paddy planting. It would also be interesting to confirm whether such knowledge is the result of the *orang asli's* affinity with the Malays. The names of stars among the *semang* who once lived near coastal areas and later on were forced into the interiors (and therefore did not require astronomical information in order to live in inland areas), might be the root cause why such traditional knowledge has disappeared. However, other factors, such as the changing landscape and migration, could have triggered changes in the traditional socio-cultural and socio-economic adaptations among the *orang asli*, especially the coastal Mah Meri and Orang Laut. The building of ports, light pollution, and the introduction of modern fishing technology, has no doubt taken its toll on the traditional body of astronomical knowledge.

All these corresponding factors are parallel to knowledge learning and reproduction. Most informants whom we interviewed have learned by listening to elders in a casual way. Only families who practised certain activities such as fishing and paddy planting possessed the skills required to identify stars scientifically. Even so, compared to knowledge of plants, animals, taboos and illnesses, it is not compulsory to learn about or memorize astronomical knowledge, maybe because the traditional practitioners can refer to or fall back on other ecological markers available in the landscape.

To sum up, based upon the preliminary evidence and analysis, we argue that astronomical knowledge does not play a critical role in the survival of the *orang asli* who live in the rainforests of Peninsular Malaysia. However, this does not mean that the *orang asli* are not accomplished and have not adapted well to their surroundings. The limited astronomical data we gathered suggests that the *orang asli* are not dependent on such knowledge for their survival, even though they have extensive knowledge of and ideas about the Sun and the Moon in their cosmological beliefs.

A.L. Kroeber (1939: 205) once mentioned that

> … on the one hand culture can be understood primarily only in terms of cultural factors, but that on the other hand no culture is wholly intelligible without reference to the noncultural or so-called environmental factors with which it is in relation and which condition it.

We agree that all human beings interact with the world around them, including the sky, and thus have formed a holistic relationship between the entities in their ecosystems (see Khairuddin, 2007). Nevertheless, their ways of adaptation in different environments only provide a limited sense of the people themselves and their knowledge of the local ecological system, which in turn allows us to generate only a very limited reconstruction of their knowledge system as an archival heritage of the past times (see Khairuddin, 2012). Despite the various assumptions and hypotheses, the gathered evidence is still far from complete. Therefore, lots more compilations and analyses need to be done in order to construct a more coherent picture.

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Chapter 16
The Linkage Between Asterisms and Local Ecological Systems Among the Austronesian Speakers of Southeast Asia

Ahmad Hakimi Khairuddin and Nurul Fatini Jaafar

16.1 Introduction

This paper is divided into four parts. The first section provides a brief introduction to the Austronesian-speaking people of Southeast Asia; the second section introduces the discipline of Cultural Anthropology and a particular conceptual framework that can explain the diversity of recognized constellation patterns among the afore-mentioned Austronesian-speakers; the third section presents data collected thus far, which have been arranged according to the conceptual framework introduced in the previous section; and the final section presents some discussion and initial conclusions arising from the information presented in the earlier sections.

16.1.1 The Austronesians

The word "Austronesia" comes from the Latin word *Austr-* meaning the southern, and Greek word *nēsos* means islands (*The New Penguin English Dictionary*, 2000). 'Austronesia' normally refers to the area encompassed by the people who speak Austronesian languages. It covers half of the globe (see Fig. 16.1), starting from Madagascar in the west, Formosa (Taiwan) and Hawaii in the North, Aotearoa/New Zealand in the south and reaching Rapa Nui/Easter Island in the east (Klamer, 2019). Austronesian is actually a linguistic term that refers to a language group. Previously, the term Malayo-Polynesia was used (Omar, 2015). According to Collins (2017), the idea that Austronesian was linked to other Asian language families such as Austronesian with Old Chinese (the Sino-Austronesian hypothesis) and

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Fig. 16.1 Geographical distribution of Austronesian speakers (adapted from Klamer, 2019).

connecting Austronesian to Austro-Asiatic languages (the Austric hypothesis) has been under discussion for many years.

This paper focuses primarily on the Malay Archipelago of Southeast Asia, which is also known as Maritime Southeast Asia (Bellwood, 1997). Even though this area is less than an eighth of the entire area of the Austronesian region, it still covers a group of over 25,000 islands in Southern Myanmar, Southern Thailand, Malaysia, Singapore, Indonesia, Brunei and the Philippines. Due to its location and population, we can consider Southeast Asia as the core area of the Austronesian-speakers.

From the traditional standpoint of historical linguistics, the home of the Austronesian languages is the island of Taiwan which is formerly known as Formosa (Bellwood, 1997). It was suggested that the migration of Neolithic people out of the area of the Yangtze River Delta to Taiwan occurred around 6,000 years ago (Khairuddin, 2005). More recently, as a result of the Human Genome Project, genetic studies suggests that the earliest modern humans, *Homo sapiens* first arrived at Southeast Asia around 50,000 years ago from Africa (most probably via the Indian sub-continent) (Oppenheimer, 2012). However, there are some who suggest a much earlier period between 60–120,000 years ago (see discussion in Khairuddin, 2013a). The last remnants of the *Homo erectus* on Java became extinct around 100,000 years ago (Widianto, 2009) and thus would not have met the *Homo sapiens* when they migrated into Southeast Asia some 50,000 years later. This first group of anatomically modern humans of Southeast Asia were the fore-fathers of the present-day indigenous inhabitants of Southeast Asia, Melanesia, and Australia. There is a great deal of variety among this group of people in terms of their cultures and local ecological adaptations. The latest group of present-day indigenous inhabitants of Southeast Asia are either Austronesian-speakers or Austro-Asiatic speakers. This suggests that the earliest human group in this area were probably Austric speakers.

The arrival of the modern humans in Southeast Asia occurred during the late Pleistocene era (Khairuddin, 2013a) when sea-levels varied considerably as the Earth experienced differing degrees of glaciations. At times of ultra-low sea level, around 50,000 and 18,000 years ago the seas were as much as 125m below their present level. As a result, large areas of land that now are under the sea were exposed, and many present-day islands were connected to form a large land-mass. Geographically, the Malay Archipelago once comprised a large land-mass called Sundaland (Bellwood, 1997). Peninsular Malaysia, Sumatra, Java, Borneo, Sulawesi and some of the islands in the Philippines were all connected.

The fluctuations in sea-level have been reconstructed for SE Asia, but they only play an important role in this chapter with the final rise in sea-level at the end of the last glaciation. This event occurred well after the first modern humans came into Southeast Asia about 50,000 years ago. Global warming and the rising in sea-level as a result of the thawing of glaciers the occurred at the end of Ice Age marked the beginning of the Holocene around 10,000 years ago.

The sea-level rose from about 125 metres below the present level, reaching current shorelines around SE Asia about 6,000 years ago, in the process flooding Sundaland (Bellwood, 1997). The rising seas probably devastated many communities and the submerging of the previously habited low-lying locations forced the movement of people into decreasing land masses at higher elevations. At the same time, the rising seas physically separated groups of people that had once lived together. It created a new condition that allowed for the diversification of cultures, which was sometimes linked to ecological adaptations to new environments. This probably started the process that ultimately resulted in the rise of the Austronesian-speakers maritime cultures (Khairuddin, 2011, 2012).

There is some genetic evidence, supported by archaeological records, to suggest that there also was an outward migration of Austronesian-speaking people from the Sunda landmass area in various directions: northwards to the Philippines and even Taiwan; eastwards towards the Pacific islands; and westwards to Madagascar. All this outward migration seems to have happened sometime after the submerging of the Sunda landmass, and most probably before 1,000 BCE. For further discussions, see Baer (2011) and Bellwood (2017).

16.2 Conceptual Approach

The specific school of thought used in this discussion is the American School of Cultural Anthropology, specifically known as the Boasian School of Historical Particularism.

Three basic concepts normally associated with Cultural Anthropology, though not adhered to strictly by some, are Cultural Relativism, the Holistic Approach, and the Emic Perspective (Khairuddin, 2007). Simply put, cultural relativism considers each culture as a separate entity with its own set or system of values and norms. When we assume that our value system is universal and evaluate everybody's actions using our own cultural values, that is against the idea of cultural relativism and is specifically labelled as ethnocentric.

A holistic approach today is assumed to be when we do multi-disciplinary research in order to get all the different ‘sides’ of the story. In actuality, it means looking at culture as one whole entity with no sub-divisions such as religion, family, politic, society, and economy. This approach is similar to that of the Gestalt Philosophy in Psychology.

An emic perspective tries to describe everything from the point of view of the culture in question and its people. This perspective demands the usage of measurements (when required) that are specific and relevant to the culture under investigation.

All three basic concepts work together to embody an approach that, at first glance, is unscientific since it is very difficult to make generalizations or propose theories, which is the ultimate goal of science. Measuring culture is still the holy grail in Cultural Anthropology.

16.3 An Operational Definition and Conceptual Framework

The Human Genome Project strongly suggests that all human beings today belong to one species, *Homo sapiens*, and thus are basically the same physically (Oppenheimer, 2011). Cultural Anthropologists believe that the diversity of human beings that we see in the world today is a result of their differing cultures and environments.

The working definition of ‘culture’ that is used in this chapter is a system/body of knowledge or human operating system that allows humans to interact with other humans, with local ecological systems, and with supernatural beings (Khairuddin and Ahmad, 2012).

For the purposes of this chapter, the explanation for the diversity of cultures is because human beings use culture as a means of adapting themselves to different local ecological systems. Humans extend the cultural knowledge onto the tangible world that surrounds them. Following from this, there is a strong possibility that the division and naming of the stellar constellations could be a manifestation of their cultural knowledge.

16.4 Our Study Objective

Based on published anthropological, archaeological and linguistic data and on our field observations we found that the *orang asli* (most of whom speak Austro-Asiatic Aslian languages) had an inland ecological lifestyle while Malay Austronesian-speakers mainly were adapted to coastal environments.

These Southeast Asian speakers of non-identical language families normally have one of four main economic lifestyles. There are nomadic hunter-gatherers, semi-nomadic slash-and-burn horticulturists, nomadic to semi-nomadic fishermen, and sedentary rice agriculturalists (Bellwood, 1997; Khairuddin, 2011, 2012, 2013a).

These ecological adaptations and economic lifestyles were probably influenced by either the changing environment (for e.g. the changing sea-levels, extreme weather), dispersion and movements of the various groups of people, and the wide diversity of local ecological systems. All these three factors created conditions that are very difficult to trace and to monitor.

From the previous section, we have argued that the division and naming of asterisms was a manifestation of mankind's cultural knowledge. Therefore, asterisms can be inferred as markers of the past. The past gives us the meanings and the functions of the asterisms, a limited sense of the people and their knowledge of the local ecological system in which they live, and at the same time, also allows us a limited reconstruction of earlier times.

On that account, in this chapter we will try to place each local asterism that can be associated with any particular group of Austronesian speakers within its correct local ecological system and specific economic lifestyle. We will also attempt to reconstruct part of the history of the people in question, based upon our current understanding of their own local system of asterisms.

16.5 The Data Collected Thus Far

The data for this study were gathered from several different sources. Since 2016, a literature survey has been carried out for Peninsular Malaysia, the Philippines, Borneo and other islands of Indonesia (including Oceania), while a series of anthropological field visits has been conducted since 2015 focusing mainly on the Malay Peninsula. Some of the places visited include Pulau Langkawi, Kuala Muda, and Sik in Kedah, as well as Perlis and Seberang Perai. During this fieldwork, key informants were identified, and then, interviewed. The information gathered was then verified through further interviews with the various key informants. Additionally, the method of participant observation was also utilized in order to obtain additional information that was not gathered through the initial interviews. The participant observation method was performed during our stay in Bera, Pahang.

To our surprise, we found that some ethnic groups had kindred views and even similar names for certain asterisms. The Sections below will list the asterisms that are related to our investigation.

16.6 Symbolic Interpretation

16.6.1 Asterisms and the Hunter-Gatherer Theme

In this Subsection, the discussion is about asterisms that can be linked to a hunting-gathering society. The hunter- gatherers would have certain stars named after specific activities associated with a hunting and gathering lifestyle. At the same time, this lifestyle is normally associated with an inland ecological adaptation. However, some gathering activities might also occur in coastal areas.

The most recorded asterism is a ‘spear trap’ for hunting animals that range in size from a porcupine to an elephant. The second most recorded asterism is called ‘the jaw of a wild boar’.

The people of Kedah (Jaafar and Khairuddin, 2021) and Orang Seletar (Ahmad, 2014) in the Malay Peninsula called the spear trap *belantik* and *balatek*. Other ethnic groups in the islands of the Philippines recognized this same asterism as *balatik*, *bayatik*, *belatik*, *gendaw balatik*, *batik* or *binawagan magsasawad* (Ambrosio, 2005, 2010) while to the Meratus Dayak of Borneo the spear trap asterism is *baur bilah* (Ammarell and Tsing, 2015). The story of *belantik* is related to its neighbouring star clusters—that is, the Hyades and Pleiades clusters in the constellation of Taurus. According to the Dayak’s story as recorded by Gene Ammarell, a wild boar had eaten one of the seven stars of *karantika* (the Pleiades). Therefore, a warrior set up a trap to hunt down the wild boar. He managed to spear the wild boar. When the wild boar became rotten, a swarm of flies started to surround it. The Dayak people refer to the ‘rotten jaw of the wild boar’ (the Hyades) as *ra’ang bayi*, while ethnic groups in the Philippines called it *baka* (Tiruray, Maguindanao) or *sangat at bjak* (Palawan) (Ambrosio, 2005; Ammarell and Tsing, 2015; Schlegel, 1987). For those particular groups in the Philippines where the Pleiades is seen as ‘flies swarming around the rotten wild boar’, it is called *langaw* in Maguindanao and *kufukufu* in Tiruray (Ambrosio, 2005; Schlegel, 1987). From the point of view of the Dayaks, because the wild boar had stolen one of the stars in the Pleiades, only six out of seven stars can be seen nowadays by the naked eye. The Semelai—one of the sub-ethnic of the Proto-Malay indigenous group of Peninsular Malaysia—and the Tempasuk Dusun of Sabah also have similar images of the spear trap and wild boar’s jaw. They refer to each them as *peyh* and *jekat*, and *ginamak* and *roh* respectively (Evans, 1953; Jaafar and Khairuddin, 2018).

16.6.2 Asterisms and the Slash-and-Burn Horticulture Theme

The second type of community discussed is the slash-and-burn horticulturalists. Slash-and-burn horticulture is basically a modified hunting-gathering lifestyle that has been forced onto the people as a result of encroaching populations. The horticulture is however not a sedentary lifestyle, even though it is basically an inland adaptation. There is still some form of hunting and gathering that supplements the main horticulture practices.

There is no direct evidence for the linking of slash-and-burn horticulture with the identification and naming of local asterisms. However, ethnographic data collected during our fieldwork shows evidence for this type of horticulture in certain groups. These horticultural groups have a vague recollection of their hunting and gathering past. However, we still have an imperfect understanding of related asterisms that can be expected with this horticultural lifestyle.

16.6.3 Asterisms and the Sedentary Agriculture Theme

The third group under discussion is the sedentary agriculturalists. The wet rice agricultural lifestyle seen in Southeast Asia today is an import from elsewhere (see discussions in Hill, 2012). The archaeological evidence for a local sedentary agricultural development is poor. It would be interesting to trace the movement of the sedentary agricultural knowledge projected on the asterisms throughout the various peoples of Southeast Asia.

For the ethnic groups of Java, Sunda, Bugis and Makassar the star pattern in the region of Orion is envisioned as a ‘field plough’. It is known as *waluku* or *weluku* among the Javanese (Ammarell, 2016; Ammarell and Tsing, 2015), *beluku* by the Sundanese, *rakkalaé* by the Buginese and *pajjékoé* by the Macassans (Ammarell, 1999). Interestingly, the elders of Northern Thailand—the predecessors of the Lanna Kingdom—also refer to Orion as the plough star (interviews carried out during May 2019 UNESCO-ITCA Ethnoastronomy Workshop). But for the people in Ireland and United Kingdom, the plough represents the constellation of Ursa Major. The annual movements of the stars in *waluku* have been used traditionally to mark events in the cultivation calendar (Ammarell, 1988). When they see the celestial plough rising in the east at dawn in an upright position, it means the plough must be used and it is time to start planting the fields. In contrast, when the plough is seen low in the west in the upside-down position, it means the end of harvesting season (Ammarell and Tsing, 2015).

Other stars or asterisms that portray a sedentary lifestyle are based on the stories of *wulanjar ngirim* (α and β Centauri) and *gubug penceng* (the Southern Cross) of the Javanese, and *balué sallatang* (α and β Centauri) and *bola képpang* (the Southern Cross) of the Buginese (Ammarell, 1999, 2016). These two stories that revolve around “a woman with a carpenter and his inclined hut” might be of riverine water dwellings related to sedentary agriculture.

16.6.4 Asterisms and the Fishing Theme

The last community discussed is the fishermen who practise a water-based ecological adaptation. There are many different local ecological systems for the so-called fishing adaptation, and each local system involves different geographical areas and fishing technologies. There are at least riverine, lake, estuary, mangrove swamp, sandy beach areas, rocky coasts and deep-sea ecological systems to consider. An initial way of identifying the various local ecological systems is to identify the various species of animals and the ecological systems to which they belong to. At the same time, the different tools used or technologies can also help to identify the specific local ecological systems.

According to Ammarell (1999), the Buginese seafaring community of Sulawesi used strategies well adapted to their maritime environment to travel on the sea and safely reach their destinations. In finding directions, they used knowledge of the Sun, the Moon, the stars, ocean swells, and wind; while to find land, they gathered information by observing birds, cloud formations, water coloration and drifting objects. Some groups of people also focussed on the three stars in the belt of Orion to get their bearings and to locate the four main cardinal directions. The Orang Seletar of the Aboriginal Proto-Malay (Ahmad, 2014) and other ethnic groups such as the Kedahans and the Buginese recognized this particular asterism as *bintang tiga*, *tiga beradik* or *tanra tellue* (meaning the three stars, three siblings or sign of three).

Stars of the Southern Cross (known in the West as the constellation Crux) and two brightest stars in Centaurus (α and β Centauri) were well-known to the Austronesians as markers of the southerly direction. Based on its many names and shapes, we suggest that the idea of a 'kite' (*langlayangan* to the Sundanese) can be related to coastal areas, while 'sting-ray' (*pari* in Kedah, or *pai* in Sasak), 'pufferfish' (*bunta* in Tawi-tawi/Sama; *buntal in* Palawan), 'fish-spear' (*tampulung* in Palawan; *tohok* in Peninsular Malaysia; *salanaqan ja* in Palawan; *sahapang* in Tawi-tawi/Sama/Jama Mapun) and 'fisherman' (*anak datu* in Tawi-tawi/Sama/Jama Mapun) might be associated with coastal environments (Ambrosio, 2005, 2010; Jaafar, 2016).

Stories about stingrays also appeared among the Titan speakers of Manus, Admiralty Islands in Papua New Guinea. The 'stingray' (*pei*) represents Scorpius, and it is associated with the 'shark' (*peo*) that is made up of stars in Sagittarius (Hoeppe, 2000). Amusingly this story is similar to that of the Buginese and the neigbouring Mandar people of Indonesia (Ammarell, 1999; Rasyid et al., 2021). The story about the stingray and shark also appeared in an Australian Aboriginal narrative.

In order to carry out fishing activities and to travel between places in areas surrounded by seas and ocean, boats play a most important role in subsistence fishing and inter-island shipping and trade. The Buginese and Macassan are famous for ship-building and seafaring. The Maguindanao and the Palawanese from the Philippines, and also the Kedahan of Peninsular Malaysia, saw the Big Dipper as a 'rowboat' named *biduk* (Ambrosio, 2005, 2010; Jaafar, 2016). The Buginese, however, portrayed it as *baggo* or *lambo*, which means a larger size sailing ship (Ammarell, 1999). Rowboat can be associated with coastal areas while larger-size ships might be related to deep-sea maritime transportation. The indigenous groups of Batek Negrito and the Semelai Proto-Malay also portray the Big Dipper as a sailing vessel named *jong* (Endicott, 1979; Jaafar and Khairuddin, 2018). The Lanna people of northern Thailand also see a similar vessel to a *jong*, but they refer it to Sirius, Procyon and a combination of stars in Gemini.

16.7 Data Analysis and Discussion

The first *Homo sapiens* who migrated into Southeast Asia must have been nomadic hunters and gatherers. From this initial hunting and gathering phase, we can probably deduce that this lifestyle was clearly the base culture which all of the other ethnic groups in southeast Asia started from. The clearest cultural knowledge that can be associated with this phase is the 'spear trap' and 'wild boar's jaw' asterisms.

The change from a fully-nomadic hunter-gatherer lifestyle to a semi-sedentary slash-and-burn horticultural lifestyle is a change that is less clearly evident. At the same time, the newer lifestyle is still partly dependent upon the spoils of the earlier hunting and gathering lifestyle. The less than perfect recollection of the *ginamak* asterism by the horticulturalists of Tempasuk Dusun in Sabah and the *peyh* star asterism that belongs to the Semelai Proto-Malay in Bera (Pahang) might be indirect evidence of this changing lifestyle. However, we must bear in mind that the Dusun people are Austronesians while the Semelai are Austro-Asiatic speakers. The similarities between the Semelai and some Austronesian speakers point towards a common history among the associated groups, while the dissimilarities could reflect the subsequent parting of the original groups that later developed separately.

Evidence for the sedentary agriculture lifestyle is strongly suggested by the 'plough' asterism. Characters such as 'a woman with a carpenter and his inclined hut' might also suggest a lifestyle in a riparian ecosystem that is related to sedentary agricultural living. However, this type of lifestyle is probably an import from elsewhere since there is no conclusive archaeological evidence for a local development (Bulbeck, 2016; Khairuddin, 2013b). Lack of animals and tools associated with this lifestyle in the depiction of asterisms also suggests that this was not an old or a major local adaptation.

As for the fishing lifestyle, the numerous fishing adaptations coincide with distinct local ecologies. This is manifested by a number of fish species and tools/equipment such as the kite and the spear that are associated with this lifestyle. The similarities of 'shark and stingray' between Bugis and Titan, and the 'jong' star among the Batek, Semelai and Lanna people also indicate mutual connections between these groups in the past, before they dispersed—probably due to environmental changes and other factors. This hypothetical finding therefore supports the

Austric Hypothesis, which proposes that the Austronesian and Austro-Asiatic speakers might have evolved from the same ancestral language family.

16.8 Concluding Remarks

We can see from the information presented above, together with the various assumptions and hypotheses, that the gathered evidence is far from complete. However, there is a possibility that the cultural remnants allow a limited reconstruction of the past times including the history of the people in question, based upon their current understanding of their own local constellation systems. However, more fieldwork and analysis needs to be done in order to construct a more coherent picture. It should be noted that this chapter and an earlier paper by Orchiston and Orchiston (2017) suggest a new paradigm for further research in the field of ethnoastronomy.

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Chapter 17
Folk Astronomy of the Northern West Coast of Peninsula Malaysia

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17.1 Introduction

In spite of being inhabited by the Austronesian's Malay-subgroup, Peninsula Malaysia is also occupied by the Aslian speakers of the Austro-Asiatic Mon-Khmer subfamily (see Benjamin, 1973). The former is typically associated with a coastal or sea-based cultural adaptation, whereas the latter group is linked with an interior land-based adaptation (Higham, 1996; Khairuddin, 2012; Mees, 1967). The state of Kedah which is located in the northwest coast of Peninsula Malaysia (see Fig. 17.1), at the border of Malaysia and Thailand is home to both Austronesian- and Austro-Asiatic-speaking peoples. Meanwhile Peninsular Malaysian localities mentioned in the text are shown in Fig. 17.2

The Austronesian language family is the most widespread language in the world in that it is distributed more than half way around the globe. It extends from Madagascar in the west to Easter Island in the east, crossing Formosa (Taiwan) in the north to New Zealand in the south (Omar, 2015). Bellwood (2006) and others have hypothesized that Austronesian-speaking peoples entered island SE Asia from Taiwan via the Philippines about 4000 years ago and they spread in two directions: eastwards through the north-eastern islands of Indonesia and the out into the Pacific (eventually becoming the Polynesians) and southward through Sulawesi and then eastwards along the Lesser Sunda Islands and westwards into Bali, Java, Sumatra and Borneo. It was Austronesian speakers from the Borneo region who are thought to have voyaged to Madagascar and settled there (Cox et al., 2012; Crowther et al., 2016). Within about one thousand years of the Austronesian settlement of island SE Asia people from mainland SE Asia speaking Austro-Asiatic languages moved down into island SE Asia via the Malayan Peninsula, and spread along the Greater and Lesser Sunda Islands, where they abandoned their original languages and

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Fig. 17.1 A map showing Malaysian and neighbouring localities mentioned in this chapter (map: Hakimi Khairuddin).

adopted the Austronesian languages of those already living in this region. People in this latest major wave of immigrants are thought to be the ancestors of the present-day populations of Malaysia and Indonesia.

The Austronesian and Austro-Asiatic populations brought pottery-making with them and they were the first farmers of Island SE Asia. Before their arrival, island SE Asian was occupied by Australo-Melanesian hunter-gatherers, who had arrived 70,000–60,000 years ago and witnessed major changes in the environment, especially during the last glaciation when sea levels varied enormously and at times areas that are now under the ocean were dry land (referred to as Sundaland). The final rise in sea level between 18,000 and 6,000 years ago caused flooding of Sundaland, and the many scattered islands that now make up the Philippines and Indonesia were formed. Meanwhile, *negrito* populations comprising remnants of the original Australo-Melanesian population have survived through to the present day on some of the islands in the Philippines and in mountainous inland areas of the Malayan Peninsula (Jaafar and Khairuddin, 2021; Orchiston et al., 2021).

In the course of our ethoastronomical research we came across various asterisms that portray both seafaring cultures and land-based lifestyles (Jaafar, 2016). We also found that some ethnic groups who speak very different Austronesian dialects and were separated by thousands of kilometres had kindred views and used similar names for specific asterisms (see Jaafar and Khairuddin, 2021). This may support the idea that the ancestral occupants of island SE Asian spoke a common language (see Higham, 1996; Khairuddin, 2012; Mees, 1967), but this needs further research.

17.2 Theoretical and Conceptual Frameworks

Asterisms are groupings of stars seen in the night sky. Just like a Roschach ink blot test an asterism may not represent any actual shape or form. Instead, the creativity of the human mind ‘imagines’ and projects the shapes of various objects onto the

Fig. 17.2 A map of peninsular Malaysian states and localities mentioned in this chapter (map: Nurul Fatini Jaafar).

stars in the night sky. This means that the shapes and forms that are projected on the sky arise from minds that are influenced by cultural knowledge.

The working definition for ‘culture’ that is used in this paper follows Khairuddin (2007):

A system of knowledge or human operating system that enables humans to interact with:

(1) *other humans;*
(2) *the natural world, or local ecological systems around them; and*
(3) *invisible supernatural beings.*

Unlike other animals, human beings use cultural knowledge as a mechanism to adapt themselves to various local ecological niches. Their knowledge about a particular ecological niche increases with the amount of time they spend living in that particular environment. This knowledge is integrated into their understanding of the world around them.

Following upon this, humans project the cultural meaning from their system of knowledge onto the physical world around them. Therefore, the identification and naming of asterisms above them could be a reflection of their own cultural knowledge, which includes their own particular economic lifestyles. The various asterism shapes that are shared by a group of people shows that they have a common cultural tradition.

Unlike the asterisms project carried out by the first author of this chapter back in 2016, this chapter tries to interpolate local economic knowledge from the identification of asterisms. This idea is derived from our belief that asterisms are associated with the different economic lifestyles of ethnic groups. Groups that reside in specific local ecological niches develop their own celestial knowledge. Unique identifiers, such as the identification of asterisms and their naming, as used in this chapter, can be considered as markers that categorize the economic lifestyles of the various groups.

Geographically, Sundaland is a biogeographical region of the present-day Thai-Malaysian Peninsula, Sumatra, Borneo, Java, and other small groups such as the Riau and Lingga Islands that were joined together during the late Pliocene and early Pleistocene era as a result of local low sea-levels (Bellwood, 2017). During the Last Glacial Maximum when sea-levels were at their lowest, Sundaland was an even larger exposed landmass. Oppenheimer (1998) suggested that Sundaland was home to a large number of species that occupied different ecological niches. Actually, the low sea-levels allowed for a gradual change in temperature as we go up in elevation; once the sea-levels rose again, this created a more abrupt change in temperature i.e. compressing the different climates into smaller areas. Thus, this actually created the rich density of ecological niches and flora/fauna species that we see today.

The changes in the environment that occurred at the end of the Pleistocene and at the beginning of the Holocene also impacted on the humans living in insular Southeast Asia (Bellwood, 2017). The large Sundaland landmass was broken up into smaller, separate landmasses and at the same time, forced the humans at that time to break up into smaller groups and move to different areas. Today, we find the Austronesian speakers are associated with sea-based and land-based lifestyles.

From the archaeological and ethnographical evidence found in Southeast Asia, four economic lifestyles can be recognised among the peoples in this area:

(1) nomadic hunting and gathering,
(2) semi-nomadic slash/burn horticulture,
(3) nomadic to semi-nomadic fishing, and
(4) sedentary rice agriculture.

In this chapter will see if the astronomical knowledge base found among 65–85 years-old informants from Kedah, Perlis and Seberang Perai (previously named as Province Wellesley by the British) in Penang correlate with these four different economic lifestyles. We used a cultural anthropological approach for this research and carried out field interviews between May 2015 and April 2018. All of the informants were still involved in the traditional economic activities.

17.3 Background

17.3.1 Physical and Geographical Setting of Kedah

Kedah's geography is unique, in that it was (and still is) greatly affected by the changes in the sea-level (Khairuddin, 1991, 2006, 2009). According to the *Hikayat Merong Mahawangsa* (the *Kedah Annals*), the Langkasuka Empire was founded by a King named Merong Mahawangsa in the middle of the sixth century (see Salleh, 1991; Wheatley, 2010). After a generation, the Langkasuka Empire was renamed the Kedah Empire, and it covered the area on the northern west coast of Peninsular Malaysia.

Two of its principal ports, Pengkalan Bujang (Malay *pengkalan* = port) and Sungai Mas (Mal. *sungai* = river) were once located near the coastline. However, the coastal landscape of Kedah changed markedly during the historic period, with a broad alluvial plain on the western coast gradually prograding through the deposition of silts and clays associated with erosion of the inland hills (Allen, 1991; Khairuddin, 2006, 2009).

In the interior of Kedah there are two mountain ranges, acting as the spines of Southern Thailand and Kedah, (1) Banjaran Kedah-Singgora on the north, and (2) Banjaran Bintang on the eastern interior (Mal. *banjaran* = range) (Shahriza, et al., 2013). Other than the high mountain altitudes, the tropical climate is uniformly warm, and the humid temperature ranges between 23° and 34°C. The seasons are marked by the cycle of monsoonal winds, where the northeast monsoon blows between November to March, and southwest monsoon from May to September, with transitional periods in between (Tukimat and Harun, 2011).

17.3.2 Brief History

The long history of Kedah involved occupation by people from Srivijaya, Chola and Acheh, and the Siamese, British and Japanese, until after the end of World War II. Kedah became part of the Federation of Malaya in 1948. Other than the Malays and the *orang asli*, the state was (and still is) also inhabited by Chinese, Tamils and Malaysian Siamese (also known as *Samsams*). Interactions with other kingdoms (other than the Siamese) such as Acheh, Bugis and Minangkabau had introduced the many groups within the Kedahans' Malay community (see Andaya and Andaya, 1984).

According to Andaya and Andaya (1984), under the sovereignty of King Rama V of Siam (reigned 1868–1910), Kedah, Perlis and Setul were controlled jointly under Sultan Abdul Hamid of Kedah (reigned 1881–1943). It was during this period that the Chief Minister of Kedah named Wan Mat Saman administered the construction of a 35-km long aqueduct connecting Alor Setar (Sungai Kedah) to Gurun at the foot of Gunung Jerai (Mal. *gunung* = mount) which helped to open new areas along the aqueduct for wide-paddy field plantations (see Omar, 1981; Ibrahim, 1991). Prior to this, most of the paddy plantation was focused on the area to the south of Gunung Jerai. According to the various informants, annual hill-rice varieties were first introduced instead of the present-day labour-intensive irrigated wet rice agriculture that enabled bi-annual harvesting.

However, monetary considerations later became a critical issue for Kedah. There were secret discussions between Siam and the British to appoint a resident to monitor the state's income and expenditure. Without any formal dialogue with the Malay rulers, all the northern Malay states (now part of Malaysia) were ceded to the British under the 1909 Treaty. Kedah therefore formally became an unfederated Malay state under British rule (refer Andaya and Andaya, 1984).

17.4 Asterisms and Ecological Systems

There were four different asterisms identified for this paper. They are (1) *Belantik*, (2) *Bintang Tujuh*, (3) *Pari*, and (4) *Biduk*. The first two are normally associated with land-based ecological niches, whereas the last two are usually linked with sea-based ecological adaptations. Further discussion of the various asterisms and their ecological associations are presented below.

17.4.1 Belantik

The first star asterism described by our Malay informants was *Belantik*, which forms only a small portion of the constellation of Orion, specifically from Orion's belt and below. The *Belantik* asterism symbolizes a spring-spear trap that can be used to kill land animals of any size, from as large as an elephant to as small as a porcupine.

According to J.A. Hale in Skeat and Blagden (1906), there were several different types of *belantik* present among the Malays including the *b'lantek parap* (slapping spring-spear), *b'lantek paut* (draw-back spring-spear) and *b'lantek tĕrbang* (flying spring-spear). The Reverend Charles Letessier in Skeat and Blagden's book, also mentions that the Selangor Sakai *orang asli* tribe who lived in the Kuala Lumpur district refer to *b'lantek paut* as *p'lantek*. The tribe of Kedah Semang according to Skeat and Blagden referred to *belantik* as *kembud*, but we were not able to record this name in any of the asterisms identified by the current *orang asli* in Kedah.

One particular *orang asli* group, the Semelai of Tasik Bera (Mal. *tasik* = lake) in the state of Pahang also identify an asterism that is similar to the imaginary trap of the Malays, however, they referred to it as the *Bintang Peyh* (Mal. *bintang* = star). The Semelais practise a form of Malay culture, but speak one of the Austro-Asiatic languages. Austronesian ethnic groups in the islands of the Philippines also recognizes an identical trap in their star asterism, but they pronounce it as *Balatik* (ethnic groups of Bukidnon, Bilaan, Bagobo, Antique, Tagalog and Maguindanao); *Bayatik* (Mandaya); *Belatik* (Manobo); *Gendaw Balatik* (Subanen); *Batik* (Sama Mapun and Sama Tawi-tawi); and *Binawagan Magsasawad* (Palawan) (Ambrosio, 2005, 2010).

For Meratus Dayaks (another Austronesian group) in Kalimantan, Indonesia, the story of *Belantik* which is known as *Baur Bilah*, is associated with the neighbouring constellation of Taurus, locally referred to as the *Ra'ang Bayi* (jaw of a wild boar) (Ammarell and Tsing, 2015). Knowledge of *Ra'ang Bayi* also is found among the Tiruray and the Maguindanao (known as *Baka*); on Palawan (identified as *Sangat* at Bjak); and Semelai (recognized as *Jekat*) (Ambrosio, 2005, 2010; Jaafar and Khairuddin, 2018).

17.4.2 Bintang Tujuh

The second asterism is *Bintang Tujuh* (Mal. *tujuh* = seven) which our informants pointed out to us as belonging to the Pleiades star cluster. Some Kedahans also refer to it as *Bintang Ketika* (Mal. *ketika* = moment), *Bintang Puyuh* (Mal. *puyuh* = quail) or *Bintang Suraya* (Mal. *suraya* = Ara. *thuraiya*) (Saad, 1986; Salleh, 1981).

Our informants described *Bintang Tujuh* as a group of four stars forming the head of a creature and another three stars making up its tail. One of the stars at the tail is noticed to be virtually dimmer compared to the other stars. We are unable to ascertain the actual identification of this so-called creature, however, both sea-farers and inland dwellers refer to this same thing. Based on our interpretations, we suspect that this creature was linked earlier to seafarers and might be a stingray; furthermore, there are celestial narratives of the Malays and the Mah Meri *orang asli* (refer Sub-subsection 17.4.3) that make us lean towards this interpretation.

Bintang Tujuh is normally well-known among the Malays as '*jula juli bintang tujuh*', a folktale about seven princesses who lived in fairyland and were contested by three different parties for their affections. This lore is somewhat associated with the folktale from Riau where one of the seven astral princesses was killed by a commoner as a result of an impermissible affair (Nugraha, 2017). Interestingly, there is a verse of *pantun* (a type of Malay poem) that can be associated with this Riau story that has been recorded among the Kedahan farmers by Saad (1986) where it is linked to the correct paddy planting period.

The linkages suggested above between the mentioned asterisms in terms of their shapes and lore seem to point towards an ancient relationship that once existed between the Austronesian speaking Kedah and Riau Malays and Austro-Asiatic speaking Mah Meri *orang asli* peoples. This, in turn, makes us wonder as to how and why subsequent changes in the lore and meanings took place. These particular questions, however, are outside the current scope of this chapter.

To make matters more complicated, there is one particular motif in the murals at the Borobudur temple in Indonesia that links *Bintang Tujuh* to the asterisms of the Big and Little Dipper star patterns because of some similarities between the patterns of these two constellations (Zaid, 2011). The association between *Bintang Tujuh* and the Big and Little Dipper(s) is an entirely different idea that has almost no relevance to this chapter other than that it represents a whole new line of research.

17.4.2.1 Piama

The Malays of Kedah have used the *Bintang Tujuh* asterism with what they call *piama*, a calendar that measures the changing seasons. Literally, *piama* means seasons (Hamid, 2015). Twelve monthly cycles of specific weather and bioclimatological signs were transformed into a body of empirical information referred to as the *Kalendar Piama* (Mal. *kalendar* = calendar) (Othman, 1968).

The origin of the term *piama* is still not well researched, but we suspect that the word might be a Malay contraction of the English word ‘farmer’, referring to the paddy planter (pers. comm. Abdul Halim Abdul Aziz, 8 November 2012). In Kedah’s culture, there are words relating to paddy planting that sound similar to those of the English language, for example *ban* (Mal. *ban* = bund), *belat* (Mal. *belat* = to block) and *pida* (Mal. *pida* = feeder) (pers. comm. Ahmad Shukri, 19–20 March 2016).

Haji Abdul Majid Abdul Wahid (2013) and The Honourable Tuan Guru Haji Ahmad Othman (1968) have incorporated each month of *piama* into the particular Arabic zodiacs. However, it is not within the context of this chapter to discuss further the assimilation of the Arabic zodiac (solar) calendar. Nevertheless, it is noteworthy because the normal Arabic calendar is based on the lunar cycle. There is a possibility that this twelve-month calendrical system originated during the era of Raja Merong Mahawangsa, who probably inherited this tradition from a so-called Hellenistic culture.

Unlike the solar calendar, the *piama* calendar apparently does not keep track of time over a solar year. Instead, it traces the changes of the wind direction, or monsoon. These wind changes affect the seasons in Peninsula Malaysia, impacting on both the flora and the fauna. Furthermore, it is interesting to note that the *piama* is being used by two different groups of people in Kedah. The first group are the fishermen who reside in the coastal areas, and the second group are the Malay paddy farmers who are primarily inland dwellers.

17.4.2.2 Heliacal Apparition

According to Schaefer (1987), the heliacal apparition (or the time of observability) of certain stars depends on their heliacal rising and setting. On the date of heliacal rising, the star is first glimpsed during the morning twilight (after it undergoes a period of invisibility when the Sun is nearby). Opposite to this, heliacal setting is the last day a star is glimpsed before it becomes invisible (the star is visible in the evening twilight after the Sun sets). Both of these events are associated to the *Bintang Tujuh* and the *piama.*

Because of the Earth's orbital motion about the Sun, the Kedahan farmers observe that *Bintang Tujuh* rises approximately two hours earlier each month. This is because each star rises and sets approximately four minutes earlier each night, and the star appears to have moved about one degree west if we observe the star at the same time every day. As a result, when *Bintang Tujuh* is in conjunction with the Sun, it becomes lost in the Sun's glare and is therefore not visible for approximately one month each year.

According to Salleh (1981) and Saad (1986), *Bintang Tujuh* could be seen for the whole year, except for the certain days of *menyelam* (Mal. *menyelam* = submerge), which occur during the *piama tujuh*. The first day of the year during *piama lapan* (Mal. *lapan* = eight) when *Bintang Tujuh* rises above the eastern horizon before the Sun (after the 15-day interval when it invisible) is referred to as heliacal rising. At that particular event, the Sun is still so far below the horizon such that it enables *Bintang Tujuh* to be visible to the naked eye in the morning twilight. Therefore, it can be deduced that the end of *piama enam* (Mal. *enam* = six) is the period when *Bintang Tujuh* undergoes heliacal setting.

Fishing Practices and Heliacal Apparitions

In reference to the Kedahan fishermen, one particular informant admits that his family once did have knowledge about the heliacal apparition of *Bintang Tujuh* but he no longer has that information today. We suspect that the introduction of the Gregorian calendar and modern fishing technology have contributed to the lack of use of *Bintang Tujuh* among the fishermen. These days the Kedahan fishermen are able to carry out deep-sea fishing within a shorter period of time, so they do not have to rely fully on the seasons.

If we track the monthly *piama* sequences and the annual movement of *Bintang Tujuh*, we can observe that *Bintang Tujuh* rises during the sunset of the *piama sa* (Mal. *sa* = one) calendar cycle. During this particular time period, the north-eastern wind starts to blow, signalling the beginning of the monsoon period. The Kedahans name this time *timur* (Mal. = east). This is referred to as the beginning of the *musim tengkujuh* (Mal. *musim* = season; *tengkujuh* = rainy monsoon) or the wet season by the Malays in the eastern coast of the Peninsula Malaysia, however *timur* signals the dry season on the northwestern-coast.

During *piama enam*, *Bintang Tujuh* sets in the west after sunset. The beginning of rain in the form of drizzle signals the arrival of the wet season in Kedah, which is named *barat* (Mal. = west). This is actually the commencement of another monsoon period that brings south-western wind to Peninsula Malaysia. The Kedahans also note that before the beginning of each monsoon season (during the inter-monsoon), the wind directions change erratically and make it very difficult for the fishermen to navigate their fishing vessels. They normally refer to this time period as *sembang timur*, *sembang barat* (Mal. *sembang* = to chat).

For the fishermen, the monsoon season is a time when the waves in the sea are extremely high and strong, and traditionally the fishermen hide their fishing vessels in the rivers away from the sea. During this time, the fishermen undertake other forms of economic activities in areas that are not affected by sea conditions.

Farming Practices and Heliacal Apparitions

In measuring the star's altitude, the farmers of Kedah introduce seven traditional angular measurement terms, each involving distinct events relating to the life of paddy planters. The terms are:

(1) *menatang benih* or *guling padi*;
(2) *terbit*;
(3) *melongsor gelang*;
(4) *mengangkat kening* or *rembang*;
(5) *condong*;
(6) *asar;* and
(7) *jatuh*.

Salleh (1981) noted that the heliacal rising of *Bintang Tujuh* at dawn was used by the farmers of Kedah to mark the time for paddy planting. During the *piama lapan*, when the height of the Pleiades cluster reaches 30^0 above the eastern horizon, the farmers identify this event as the *menatang benih* (Mal. *menatang* = to carry, *benih* = seeds), or *guling padi* (Mal. *guling* = to roll, *padi* = paddy) (Moain, 1990). *Menatang benih* or *guling padi* is a personification act to the paddy planters that pinpoints the time when they are supposed to carry the paddy seeds on the palms of their hands and perform the sowing of the seeds by scattering them. The farmers believed that the sowing of paddy seeds during this month would help to avoid plant diseases. From the perspective of the farmers, the rising of the Pleiades in the east is related to the growth of the paddy plants from seedlings. Therefore, *piama lapan* has also been called the *piama benih*.

Apart from *menatang benih* or *guling padi*, *terbit* (Mal. *terbit* = to rise) referring to *Bintang Tujuh* when it rises slightly above the horizon, *melongsor gelang* (Mal. *melongsor* = to slide off, *gelang* = bangle) is used for *Bintang Tujuh* when it achieves a height of approximately 60^0; *mengangkat kening* (Mal. *mengangkat* = to raise, *kening* = eyebrow) or *rembang* (Mal. *rembang* = zenith) when *Bintang Tujuh* achieves a 90^0 position or zenith; *condong* (Mal. *condong* = tilt) when the *Bintang Tujuh* moves downward approximately 30^0 from the zenith; *asar* (Mal. *asar* = late afternoon) when the *Bintang Tujuh* is approximately 30^0 from the western horizon; and finally *jatuh* (Mal. *jatuh* = to fall) when the *Bintang Tujuh* sets below the horizon.

When the angular height of the heliacal rising of *Bintang Tujuh* is between *menatang benih* to *mengangkat kening*, this marks the time for sowing the seeds. All of these events occur within a time period that starts with the beginning of *piama lapan* to the ending of *piama sepuluh* (Mal. *sepuluh* = ten). When *Bintang Tujuh* appears at the height of *menatang benih* in the eastern horizon after sunset, this in turn signals the beginning of the harvesting season in *piama dua* (Mal. *dua* = two).

Apart from this characteristic, the practitioners would also refer to the colours and brightness of *Bintang Tujuh* stars when choosing the best seeds for sowing (Saad, 1986). Seeds usually must be of the same colours as *Bintang Tujuh*, that is red, yellow or white. Reddish seeds are allocated for seasons when the stars of the head of *Bintang Tujuh* appears dimmer than those in its tail. Such sign indicates the possibility of a heavy rainy season, and therefore, the paddy planters should choose the seeds which require seven to eight months to reach its maturity. The red hued seeds are called *padi berat* (Mal. *berat* = weighty) and take longer to mature. On the other hand, the white or slightly yellowish seeds (*padi ringan*, Mal. *ringan* = light) will be assigned to a drier season as signalled by the stars of the head of *Bintang Tujuh* that appear brighter than those of its tail.

Another particular observation that we noticed was that both the fishermen and the paddy planters used shadows as a means of timekeeping. By using a human as the gnomon, they note there would be two days in a year when the gnomon does not cast any shadows, that is during the *rembang* (Sun positioned overhead). For these two days, according to Salleh (1981) they are marked respectively as the fifteenth day of the fifth and of the tenth *piama*. Based on Noor (2015), the spring equinox for the area of Bujang and Muda Valley in 2012 falls on 3 April, while the autumnal equinox falls on the 8 September.

From the above accounts, we would like to suggest that the *piama* was once a knowledge system about the seasons in Peninsula Malaysia that was influenced primarily by the changing prevailing wind directions. From the usage of the *piama,* we believe that coastal and inland peoples were once living together side by side in the Malayan Peninsula. Sometime in the past, the inland farmers adapted the *piama* to incorporate newer knowledge about planting paddy. They continued using the *piama*, which was tied to the changing winds, simply because the planting season was linked to the changing winds that coincide with the heliacal apparitions of the Pleiades.

17.4.3 Pari

The third local asterism identified in this chapter was found to be a part of the knowledge system of the fishermen; it is the *pari*, or stingray, which is mapped over the Southern Cross. Local people apparently used the *pari* as a marker for the southern direction at some time in the past. Our informants just recognize this asterism as pointing towards the south in a general manner, they do not fully utilise its tail as indicating a more precise direction to south.

So far, we have recorded three accounts about the stingray within the Kedahans. Two different songs were collected by Khairuddin and Ahmad (2006) from two separate traditional Hadrah performances, one in the Perlis-Kedah area, and the second in Perak's border with Kedah. The first song portrays various chants about the celestial *pari* floating in the air, whilst the second song is a rejection of the *pari* by the second group of people, who were more Islamic in their beliefs.

Another instance of the *pari* was gathered from the coastal *orang asli* community in Pulau Carey (Selangor) which is to the south of Kedah. The Mah Meri ethnic group possess an ancestral story about *Muyang Pari* (Mal. *moyang* = ancestor). The story goes that there was a boy who was born as a stingray to a normal poor couple. His unnatural birth was because he was originally a fairy prince. The story does not mention why he was born to that couple. The village people mocked him when they found out that he fell in love with a fairy princess. Eventually, he revealed that he was a fairy prince and afterwards he married the princess. Sometime later, they moved up to the skies as astral spirits.

Even though the Mah Meri currently have a sea-based lifestyle and knowledge of a systematic sea tidal calendar named *sépél*, linguistical glottochronological reconstructions seem to suggest that they are the ancestors to the present-day Semoq Beri, Semelai and Temoq (who are still associated with hunting-gathering, even though the Semelais have adapted to hill-rice swidden horticulture) (Benjamin, 2012). The various ancestral wood carvings of the *Muyang*s tend to depict inland rather than marine entities, which also suggests that the Mah Meri are relative novices to the maritime/coastal lifestyle.

Other than the Kedahans and the Mah Meri, various stories of stingrays also appear among the Sasak of Lombok; the Bugis of Sulawesi; the Titan speakers of Manus in the Admiralty Islands, Papua New Guinea; and the Yirrkala people of Arnhem Land in the Northern Territory of Australia (e.g., see Ammarell, 2016, 1999; Hakim and Pramudya, 2015). However, only the stingrays of the Sasak and Yirrkala are mapped out on the Southern Cross just like the Kedahans, whereas the Bugis and the Titan place the stingray in Scorpius.

17.4.4 Biduk

The last asterism documented in this chapter was found among coastal people, who also worked as fishermen, and is called *biduk*. This is a star alignment that is used to locate the northern direction. *Biduk* can be found within the constellations of the Big and Little Dipper, where the five stars that make up the long handles of both ladles are mapped out as *biduk*. *A biduk* is also a small paddle boat that can be used for catching fish, or ferrying goods along a river or in coastal areas. Its keel allows the *biduk* to cut across the waves, thus it is a sea-worthy vessel, unlike other riverine vessels.

Narratives on the *biduk* asterism can be found in discrete, incomplete pieces of information among the various ethnic groups in Southeast Asia. According to Ambrosio (2005), the Maguindanao of the Philippines also referred to the Big Dipper as *biduk*. In addition, in Palawan (also in the Philippines) it is called *Gubang ni Asak*, which translates as a rowboat that belongs to a man named Asak. The (Big/

Little) Dipper is also referred to by the Semelai and Batek *orang asli* when talking about an asterism that they call *jong* (Mal. *jong* = sailing vessel) (Jaafar and Khairuddin, 2018). The Bugis (Ammarell, 2016, 1999) portray the Big Dipper and the Little Dipper as *kappala'e* (Bug. *kappala'e* = baggo/lambo sailing ship).

17.5 Asterisms and Economic Lifestyles

We suspect that the four local asterisms listed in Section 17.4 above are a manifestation of the traditional cultural knowledge and practices of the Kedahans before the emergence of a Western free market economy in the area. Therefore, these asterisms should be associated with earlier economic lifestyles. As mentioned previously, we suggested that there were four broad groups of traditional economic lifestyles: (1) hunting-gathering, (2) shifting cultivation, (3) sedentary farming, and (4) coastal fishing. Therefore, in this Section we will try to link the asterisms to specific ecological adaptations and to specific economic lifestyles.

The *belantik* asterism was the best-known star pattern among our informants. Even though modern economic practices have seeped into local villages, hunting-gathering knowledge still survives, although it is not as extensive as previously. Knowledge of hunting is an inland-based skill that requires continuing mastery by the village men. It can be said that the attainment and maintenance of such hunting skills is one of the indicators that a male has reached the status of manhood.

In the interior of Kedah, there exists a Malay village called Kampung Belantek, that is located within the district of Sik, in slightly elevated foothills of the Bintang Mountain Range. In the district next to Sik, that is Baling, this district is home to the Kensiu *orang asli* (and previously the Kintak *orang asli* lived there too). Both of these *orang asli* groups are Austro-Asiatic speakers and have an inland-based ecological adaptation. Both of the Sik and Baling districts, and the Padang Terap district (which is adjacent to Sik), are part of the Greater Forest Reserve of Ulu Muda, which is extremely rich in biodiversity. Since all three districts and the Forest Reserve are in a slightly elevated forest environment, this area is more suitable for hunting animals using a *belantik*-type trap.

The Malays and *orang asli* hunter-gatherers admit that the *belantik* is the most dangerous of all of their indigenous traps, and it has been used by their ancestors for generations. However, we did not manage to gather further information about the seasons when the *belantik* were used, in contrast to what we were able to discover during fieldwork among the Semelais (Jaafar and Khairuddin, 2018).

For the gathering knowledge-base of the hunter-gatherers of Kedah, there is extremely little information that we were able to obtain directly, even though we do know that the *orang asli* still collect various forest products that they sell to traders (Andaya, 2002; Dunn, 1975; Rambo, 1985). Most of these trade goods are in the form of plant products. These products are difficult to acquire and require an intimate knowledge of the ecological niches within which these plants live. However, there are also animal products that are linked to indigenous hunting practices of the interior Malays and we suspect that they are probably using the *belantik* trap, based on the wide size-range of animals involved. The trading of some such animal products, including elephant ivory and parts of the tiger, currently are strictly banned by the Malaysian Government.

We believe that the *Bintang Tujuh* asterism was not only used by wet-land paddy planters, but also by shifting hill-paddy cultivators. The evidence for the following is not clear-cut, but is based on interpolation. Hill-paddy cultivation was probably the earliest form of paddy cultivation practised in present-day Kedah, as mentioned in the *Hikayat Merong Mahawangsa* (Salleh, 1991). The use of *piama* and *Bintang Tujuh* for paddy cultivation is obviously a newer adaptation from the original form, which was more suitable for a sea-based fishing lifestyle. This is because *piama* was originally linked to the changing wind patterns around the Malayan Peninsula, and seasonal variations in wind and rain along the coasts and out at sea was very important for the livelihood of the fishermen.

Both paddy varieties were planted during traditional times on low-land and higher ground, and relied entirely on rain water. The rainy and dry seasons thus had to be carefully monitored and geared towards a systematic planting and harvesting system that was tied to wind directions and the seasons (Othman, 1968; Saad, 1986; Salleh, 1981; Abdul Wahid, 2013). Therefore, *Bintang Tujuh* was used primarily as a time marker to indicate the arrival of the rainy season, which was the most suitable time for paddy sowing. The reliance on the rainy season for the traditional unirrigated paddy cultivation was probably the reason why the *piama* is unlike other agricultural calendars elsewhere, as these are normally tied to the solar or the lunar calendar.

It is also interesting to note that the traditional *piama* calendar does not portray the same characteristics as other paddy agriculturalist communities in that, their celebration of the harvests does not occur at the beginning of the farming season. As is the norm elsewhere, the beginning of *Pesta Kaamatan* of the Kadazan-Dusuns, *Hari Gawai* of the Dayaks, and *Menyulung Tahun* of the Semelais' commences with the celebration of the harvest festival (Ishak, 2010; Sapura, 2010), that is dedicated to the rice goddess, and to purge evil spirits from the cultivated land. Strangely, for the Kedahans, the harvesting period was performed between the third to fourth month of the *piama*.

Based on our observations of the Semelais, planting of unirrigated hill paddy not only required access to fertile soil, but in fact the swidden area had to be changed annually (to maintain soil fertility and since the best land was occupied by sedentary agriculturalists). The unmonitored and unplanned opening up of new elevated areas for hill-paddy may be one of the reasons why deposition is occurring at lower altitudes. According to Mahmud (1969), the Malays planted dryland rice and millet (*sekoi*/*ekor kucing*) in the Bintang Range piedmont zone (as described earlier). These cultivation activities destroyed the vegetation cover on the hillsides, causing erosion of the fragile topsoil and its ultimate deposition down the valley (see also Allen, 1991; Hill, 1977). Other than the Malays proper, some of the Kedah Semangs were recorded by Skeat and Blagden (1906) to have been involved in slash and burn horticulture, having obtained millet and paddy seeds from the Malays.

Archaeological evidence from China and mainland SE Asia (e.g. see Bellwood, 2005) and the formation of the present-day alluvial delta prior to the erosion suggests that the wet paddy agricultural lifestyle originally was imported from elsewhere. Massive numbers of Hindu-Buddhist shrines along the main river routes suggest that there was a link between the introduction of wet-rice planting and the emergence of these shrines (Mahmud, 1969). The migrations of Thai peoples (*Samsams*) and Indonesians later in the nineteenth century could also have contributed to the assimilation of knowledge and practices connected with wet rice agriculture. This hypothesis of an external origin for Malaysian wet-rice agriculture appears to be supported by the use of other names for *Bintang Tujuh*, such as *Bintang Ketika* (probably imported from Hindhu-Buddhists and Javanese who respectively referred to the Pleiades as *Krittika* and *Kartika*) and *Bintang Puyuh* (the Thai name for the Pleiades is Dao Luk Kai, Th. *dao* = star, *luk kai* = chick; Pengkaew, 2009). As it is right now, the actual origin of wet rice agricultural knowledge and its introduction into the Peninsula Malaysia is still debateable, even though the authors tend to believe that the body of knowledge has all the trademarks of the genius of the local Kedahans.

In western Kedah, the coastal topography covers several maritime ecological systems, including estuarine, mangrove swamp, littoral and maritime. The use of the *pari* asterism among the Kedahan Malays is a strong indicator that they could have lived in the above ecological systems. This is because, according to the informants, stingrays can easily be found on sandy and muddy shore environments, encompassing the above-mentioned ecological systems.

Apart from its function as a fishing boat, the *biduk* can also be used for transportation in shallower coastal waters. According to de Koninck (1988), Kedah had already involved itself in extra-regional trade exchanges between India, the Middle-East and China from the early centuries A.D. Of course, the Kedahans controlled the best ports, where the smaller boats of the locals were probably an important mode of transport for carrying inland products to the ports and also for transferring the various items between the docks and the anchored trading ships. In addition, their extensive knowledge of local winds, waves and currents suggests that the ancestors of Kedahans may also have been renowned seafarers, akin to the Mandar (Rasyid et al., 2021) and the Bugis (Ammarell, 2016, 1999) of neighbouring Indonesia.

17.6 Concluding Remarks

Because celestial objects in the sky have existed since time immemorial, the sky must have influenced much of the human activities here on the Earth. From the various data and premises presented earlier in this chapter, it can be concluded that the traditional Kedahans did employ some astronomical knowledge to assist economic activities within their own particular local ecological systems. We have shown that it is probable that their local ecological adaptations played a role in the division and naming of their asterisms.

In order to reconstruct a more coherent picture of the movement of the peoples in Southeast Asia, more detailed and comparative studies need to be carried out in most of the islands in the Malay Archipelago, as well as among the different Austronesian and Austro-Asiatic language speakers. The linkages between the asterisms listed on the previous sections provide preliminary support for the Austric hypothesis, and demonstrate how two different language families could have originated from one ancestral language.

It would also be interesting in tracing the movement of kindred astronomical knowledge that is shared across different regions to supplement the archaeological record and identify the inter-regional influences. As an example, how *bintang ketika* (originally from India), traversed island SE Asia and reached as far as the Hawaiian Islands and Rapa Nui (Easter Island) in Polynesia.

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Chapter 18
Star Patterns in Mandar Navigation

Adli A. Rasyid, Taufiq Hidayat, and Wayne Orchiston

18.1 Introduction

18.1.1 Trade and a Seafaring Tradition

Indonesia is a country that consists of thousands islands. In ancient times, the main link between islands was waterborne transport. In addition, Indonesia's coastline is very long, at around 81,000 km. Therefore, maritime activities were quite important in Indonesian society (e.g. see Lapain, 1996; Lampe, 2016).

In the course of Indonesian history, maritime civilizations influenced governments, defense and security, sea transportation and trading, the management of ports, and the law of the sea. These characterized the main maritime kingdoms of the archipelago, such as Srivijaya, Tarumanegara, Majapahit, Banten, Samudera Pasai Aceh, Gowa, Makassar, and the two sultanates of Buton and Ternate. This maritime tradition was mostly carried out by ethnic groups such as the Bugis Makassar, Mandar, Bajo, Buton and Madura, and some Javanese communities. As a matter of fact, this seafaring tradition was associated with Indonesia's important location in Southeast Asia, as it lay on three important international trade routes: the 'silk route' that connected China and Constantinople; the 'ceramic route' to China; and the 'spice route' that connected Indonesia to Europe and the Mediterranean Sea (Tan, 2010).

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18.1.2 The Ethnic Groups of Sulawesi

Ethnic groups are related social groups based on ancestry and place of origin. Ethnic identity was ascribed at birth, and members of an ethnic group customarily acquired their characteristics during childhood. Later on, these characteristics became the main supports during life, because they reflected identity and honor. As mentioned previously, some ethnic groups in Sulawesi that were (and still are) famous for their distinctive cultural characteristics are the Bugis Makassar, the Mandar and the Bajo. They are famous as traders and as seafarers (Lampe, 2016). Their places of origin are shown in Figure 18.1.

18.1.3 Navigation Using Star Patterns

The sailing tradition that has developed since ancient times makes the sea the lifeblood of those ethnic groups, especially those inhabiting the coast. They continuously migrate to or trade with other islands, and capture and utilize marine resources, not just for their own consumption but also to be traded. Navigating the seas of the archipelago often required fishermen or traders to spend weeks, or even months, away from home. In order not to get lost during these long voyagers, the sailors had to know how to navigate.

For these voyages around the Archipelago, and even as far afield as the northern coasts of Australia, the seafarers used wooden ships equipped with sails (e.g. see Fig. 18.2). Until recently, they did not have access to modern navigation equipment such as magnetic compasses, binoculars, or sextants, and of course the GPS. Instead, out in the open ocean with no land in sight, the sailors had to use celestial bodies for navigation. During the day, undoubtedly they used the Sun as a benchmark, and also the Moon if it happened to be visible during the day. But at night they recognized certain stars and groups of stars (asterisms) that allowed them to pinpoint the cardinal directions. And so they developed a body of knowledge involving key stars and star patterns, that traditional navigators passed down from generation to generation.

18.2 The Mandar Ethnic Group

18.2.1 Short History of the Mandar Ethnic Group

The Mandar ethnic group is centred on the West Sulawesi area (see Fig. 18.1). Presently, West Sulawesi has the status of a new province in Indonesia, created in 2006, after being split from the province of South Sulawesi. The location of the Mandar region stretches from South to North, namely from Binanga Karaeng in the South to Suromana in the North, with the following limits:

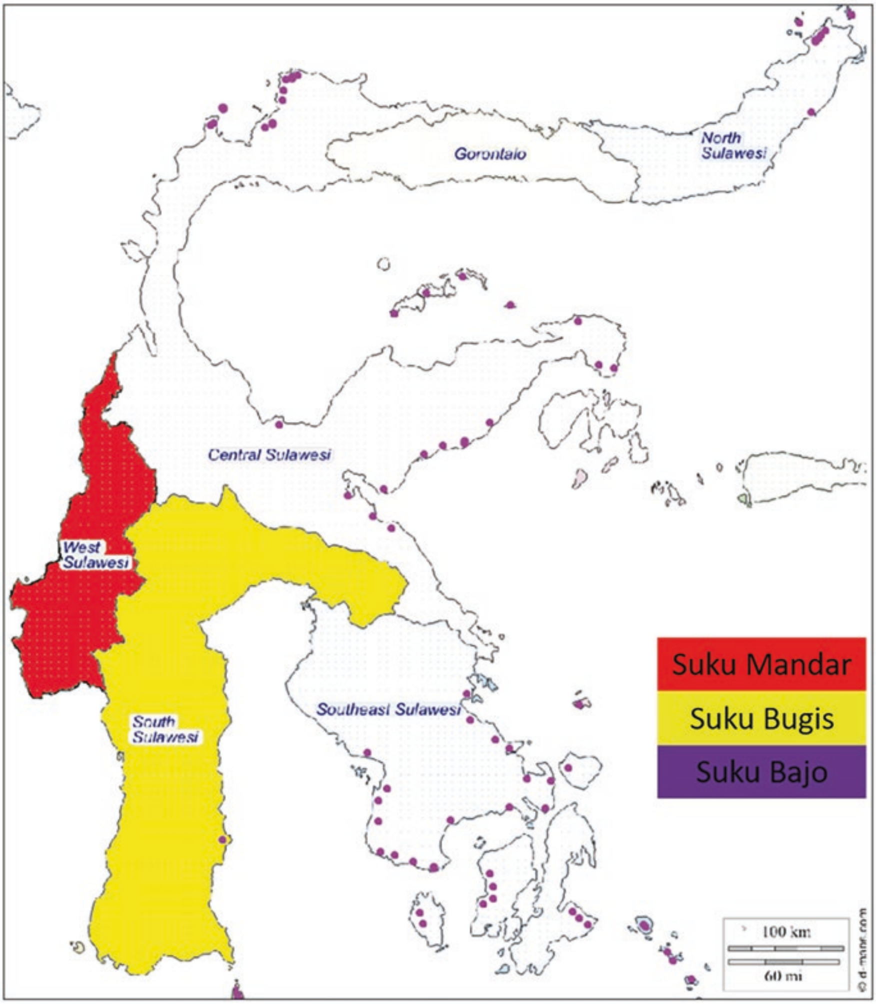

Fig. 18.1 Places of origin of Bugis, Mandar, and Bajo ethnic groups in Sulawesi (map: A. Rasyid).

- In the south it is bordered by Pinrang Regency and Tanah Toraja Regency
- In the north it is bordered by Tanah Toraja and Luwu Regencies
- In the north bordering Central Sulawesi Province
- In the west it is bordered by the Makassar Strait.

The history of the Mandar ethnic group was first recorded in the the sixteenth century (Mandra, 1986). The Mandar area used to consist of several different kingdoms. Originally there were seven kingdoms, and they united into one constitutional organization to form a federation called *'Pitu Babana Binanga'*. The seven original kingdoms were:

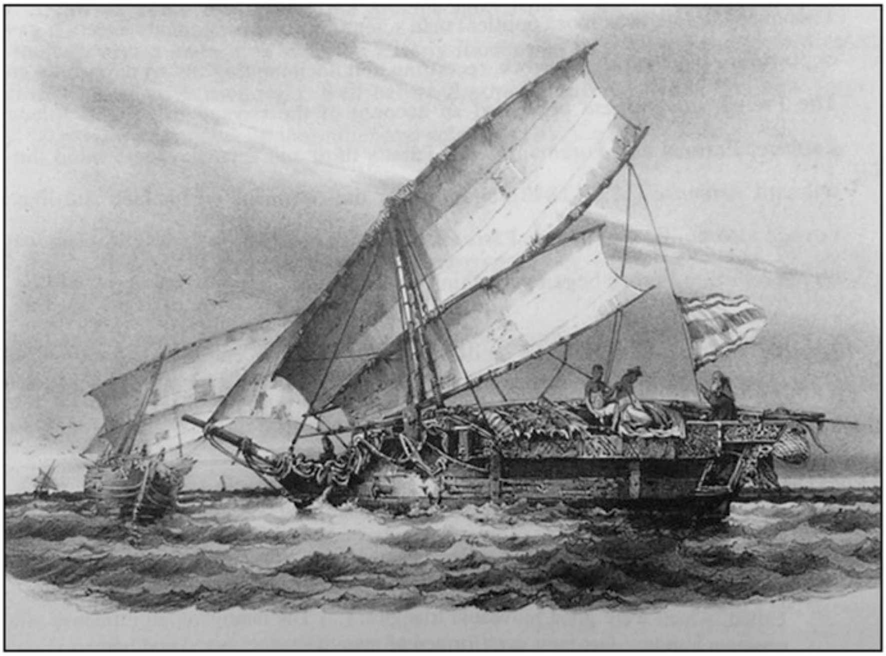

Fig. 18.2 For hundreds of years fleets of *prahu* like these, drawn in 1839, made the long and navigationally-challenging trip from Sulawesi to the northern coast of Australia in order to collect the sea cucumber, a Chinese delicacy (https://www.abc.net.au/news/2018-01-16/aboriginal-people-asians-trade-before-european-settlement-darwin/9320452).

- The Kingdom of Balanipa
- The Tjenrana Kingdom
- The Kingdom of Banggae
- The Kingdom of Pambaoeang
- The Tappalang Kingdom
- The Mamuju Kingdom, and
- The Kingdom of Binuang.

The literal meaning of *'Pitu Babana Binanga'* is the 'Seven Estuaries of the River'. This naming is based on the geographical location of the kingdoms and their proximity to the coast.

In addition, for the sake of strategy, both for war and trade, *'Pitu Babana Binanga'* re-established alliances with seven other kingdoms located inland, in the mountains:

- The Kingdom of Rattebulahan
- The Kingdom of Aralle
- The Mambi Kingdom
- The Bambang's Kingdom
- The Kingdom of Messawa

- The Tabulahan Kingdom, and
- The Matangnga Kingdom.

The name of these seven kingdoms federation is '*Pitu Ulunna Salo'*, which means 'Seven Upper Section of the River'. The name is in accordance with the location of the seven kingdoms, which are located in an inland mountainous area where there is a tributary of the river.

18.2.2 The Character of the Mandar Ethnic Group

Given the geographical location of the Mandar ethnic group, it is no surprise that in the past many Mandar people were fishermen or merchants. While fishing was mainly carried out in the oceans around Sulawesi, as we have seen from Fig. 18.2 Mandar fisherman-merchants sometimes ventured as far afield as the northern coasts of Australia for sea cucumbers (*trepang*).

Like their Bugis neighbours (see Ammarell, 1999), the Mandar acquired an international reputation as merchants, throughout Indonesia. Apart from selling their marine catches they traded spices and merchandise. In the West Sulawesi region, and especially the Majene District, the Mandar produced woven fabrics, silk sarongs, copra, rattan, wood, coconut oil and gold powder. These were processed into materials used by the Mandar community, especially during the west monsoon season when fishermen could not go to sea due to unfavorable weather. Meanwhile, the weaving was performed by women, especially the wives of sailors who were away on lengthy voyages, and they used their spare time while awaiting the return of their husbands.

18.2.3 Trade and Agriculture

Traditional Mandar voyages are widely known, and went in all four cardinal directions:

- Eastern voyages went to Maluku, Ternate, Kei Island, Aru, Tanimbar, Papua and North Australia. The main aim of these voyages was to buy spices and copra, and catch sea cucumbers.
- Western voyages went to Sumatra, Kalimantan (Borneo), Java, Singapore, Malacca, Cambodia and Siam (Thailand). The main purpose of these voyages was to sell proceeds from the east and bring goods obtained during the voyage back to Sulawesi to be resold.
- Northern voyages went to ports in North Sulawesi and the Philippines.
- Southern voyages went to Java, and even further afield to the islands of West Nusa Tenggara and East Nusa Tenggara, including East Timor.

To facilitate these voyages, the Mandar took advantage of the monsoons: during June–September they went in a westerly direction with the southeast monsoon, and returned to Sulawesi between December and March with the northwest monsoon.

With all of this voyaging, some Mandar people chose to settle in areas that they visited. In his dissertation, Lopa (1982) mentions that apart from the western coast of Sulawesi, Mandar people are also found in

- Almost all of the islands in the Makassar Strait and the Flores Sea;
- Almost all of islands to the south, such as Pulau Marabatua, Pulau Denawang, Pulau Payongpayongan, and those in the Pulau Sembilan District;
- Balikpapan, Samarinda; and
- Java, Nusa Tenggara, Sumatra and in Sandakan, East Malaysia.

18.3 Mandar Navigation

18.3.1 Research Methodology

The research methodology used in this study was through interviews with retired fishermen, and the first two authors followed up with field observations for verification. All of the fishermen were more than 70 years old, and were known to have knowledge about Mandar star patterns. Unfortunately, we did not have an opportunity to go sailing with them. We noted, however, that the younger fishermen did not use star patterns for their navigation.

Next, we conducted an astronomical analysis by identifying the stars that formed the asterisms in question and determining when they would appear. We used *Stellarium* astronomical software to simulate the star maps and to identify the star patterns. The date of the simulation was set at around the beginning of the twentieth century (January 1900) and the location of the observer was set at the city of Majene in West Sulawesi.

18.3.2 Mandar Star Patterns

Star constellations are formed from several stars. Mandar ethnic groups used these star constellations to navigate during night-time sailing. We note, however, that not all direction-indicators were stars or star patterns because celestial objects also included Venus and a star cluster.

Star patterns or asterisms that we identified during this study were *Bittoéng Sapo Kepang, Bittoéng Tuwallu, Bittoéng Mangiwang, Bittoéng Lambaru, Bittoéng Panjala, Bittoéng Malunus, Bittoéng Tallu-tallu, Bittoéng Pambawa Allo, Bittoéng Bawi,* and *Bittoéng Naga.* In astronomical terms, they comprise seven star patterns, the Milky Way, the Pleiades star cluster, and the planet Venus, all of which were used for navigation. This shows that the practice of astronomical navigation has long been used by Mandar seafarers.

Bittoéng, above, means ‘star’, or *Bintang* in the Indonesian language and *Bintoéng* in the Bugis language. The following is an explanation for each star or star pattern.

(1) *Bittoéng Sapo Kepang:* This means a slanted house. This star pattern is used as an indicator for the south (see Fig. 18.3). Usually one can begin to observe this star pattern in the evening sky in May. We can see five stars that form a house with uneven ‘foundations’. The part that forms *Bittoéng Sapo Kepang* is the roof and two supporting pillars, as shown in Fig. 18.3. Comparison with star maps shows that the roof consists of stars δ Cen, γ Cru and δ Cru, where δ Cen is the roof top. The two pillars are formed by β Cru and γ Cru (the short pillar), and α Cru and δ Cru (the long pillar). The stars that form this asterism are listed in Table 18.1.

(2) *Bittoéng Tuwallu:* This means the widow star. This ‘star’ is actually a pair of stars just below the *Bittoéng Sapo Kepang,* so it is also a sign for the south direction. Usually one can begin to observe these stars in the evening of May. We see two stars that are bright and close together and have colors that look a little different: one red, the other green. We know that the ‘red widow’ is α Centauri and the ‘green widow’ is β Centauri. These two stars are also listed in Table 18.1 and shown in Fig. 18.3.

(3) *Bittoéng Mangiwang*: This means the shark stars. This asterism marks the entry of the northwest monsoon season. It usually rises in the morning at the end of December. You will see a triangular shark fin shape in the middle and a tail at the back. The parts that make up the shape of this shark are the fins, head, stomach and tail, as shown in Fig. 18.4. Our identification shows that the fin is formed by

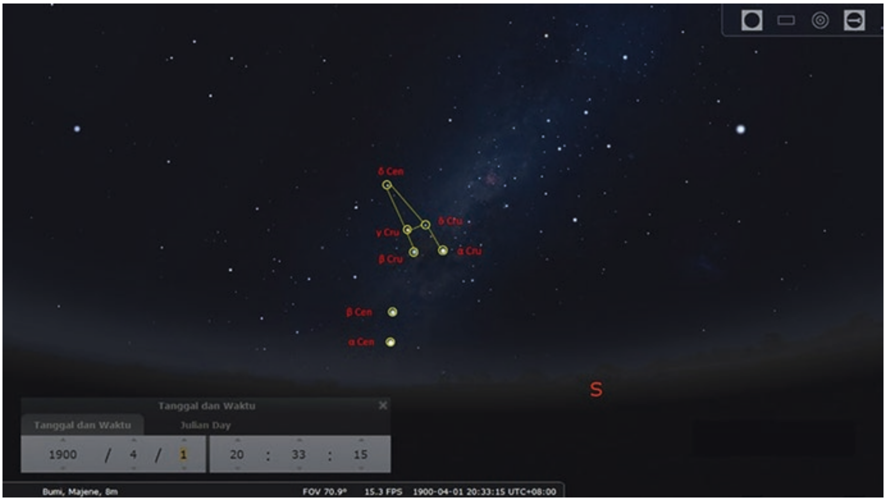

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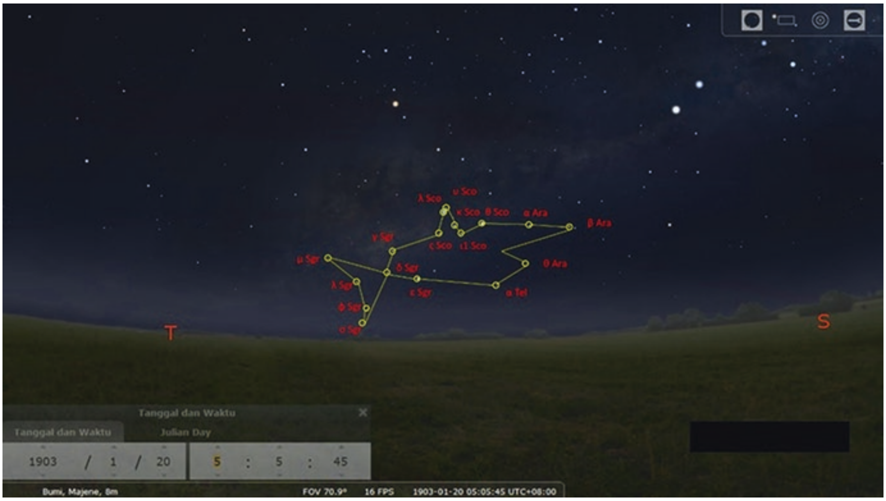
Fig. 18.3 The shape of *Bittoéng Sapo Kepang* and its constituent stars seen from the location of the city of Majene (simulated using Stellarium). *Bittoéng Tuwallu*, identified as α Cen and β Cen, is also shown.

Table 18.1 List of the stars forming *Bittoeng Sapo Kepang* and *Bittoeng Tuwallu.*

Star Pattern	Star	RA	DEC
Bittoéng Sapo Kepang	α Cru	$12^h\ 26^m\ 36.28^s$	–63° 06′ 00.4″
	β Cru	$12^h\ 47^m\ 43.99^s$	–59° 41′ 20.1″
	γ Cru	$12^h\ 31^m\ 11.59^s$	–57° 06′ 21.3″
	δ Cru	$12^h\ 15^m\ 09.26^s$	–58° 44′ 56.9″
	δ Cen	$12^h\ 08^m\ 21.88^s$	–50° 43′ 19.5″
Bittoéng tuwallu	α Cen	$14^h\ 40^m\ 09.60^s$	–60° 55′ 19.1″
	β Cen	$14^h\ 03^m\ 49.99^s$	–60° 22′ 24.5″



Tanggal dan Waktu

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Fig. 18.4 The shape of *Bittoéng Mangiwang* and its constituent stars seen from the location of the city of Majene (simulated using Stellarium).

stars ς Sco, λ Sco, υ Sco, κ Sco and ι1 Sco, where υ Sco is the upper end of the fin. The head part consists of α Ara, β Ara and θ Ara, where β Ara is the tip of the head. The abdomen consists of α Tel and ε Sgr. The tail part of the shark is formed from stars δ Sgr, μ Sgr, λ Sgr, φ Sgr and σ Sgr, where δ Sgr connects the tail and the body of the shark. The stars that form this asterism are listed in Table 18.2.

(4) *Bittoéng Lambaru:* This means stingray stars. This asterism is an early clue to the arrival of the northwest season and usually rises in the morning at the end of November. There are two eyes in the shape of a stingray's head that are above *Bittoéng Mangiwang*. The parts that make up the stingray's shape are the head and tail, as shown in Fig. 18.5. The head of the stingray is formed by the stars β1 Sco, δ Sco, η Sco, ρ Sco and σ Sco, where δ Sco and η Sco are the stingray's eyes and σ Sco is a connector between the tail and the head. In addition, the stingray's tail consists of the stars α Sco, τ Sco, ε Sco, μ1 Sco and ζ2 Sco. The stars that form this asterism are also listed in Table 18.3.

Table 18.2 List of stars forming *Bittoéng Mangiwang.*

Star Pattern	Star	RA	DEC
Bittoéng Mangiwang	α Ara	$17^h 31^m 50.89^s$	–49° 52′ 27.6″
	β Ara	$17^h 25^m 18.31^s$	–55° 31′ 45.2″
	θ Ara	$18^h 06^m 37.94^s$	–50° 05′ 28″
	α Tel	$18^h 19^m 46.38^s$	–45° 58′ 00.3″
	γ Sgr	$18^h 05^m 49.23^s$	–30° 25′ 06.0″
	δ Sgr	$18^h 20^m 59.44^s$	–29° 49′ 38.2″
	ε Sgr	$18^h 24^m 11.07^s$	–34° 22′ 55.2″
	λ Sgr	$18^h 27^m 58.74^s$	–25° 24′ 58.1″
	μ Sgr	$18^h 13^m 58.81^s$	–21° 03′ 31.7″
	σ Sgr	$18^h 55^m 15.84^s$	–26° 17′ 42.4″
	φ Sgr	$18^h 45^m 39.02^s$	–26° 59′ 26.9″
	θ Sco	$17^h 37^m 19.08^s$	–42° 59′ 52.0″
	ι1 Sco	$17^h 40^m 35.09^s$	–40° 07′ 36.5″
	κ Sco	$17^h 42^m 29.34^s$	–39° 01′ 45.1″
	λ Sco	$17^h 33^m 36.49^s$	–37° 06′ 10.7″
	ς Sco	$17^h 49^m 51.11^s$	–37° 02′ 39.0″
	υ Sco	$17^h 30^m 45.00^s$	–37° 17′ 42.1″

(6) *Bittoéng Malunus.* This term has no special meaning, but marks the Pleiades star cluster. This asterism (Fig. 18.6) is used as a clue to the increasing number of flying fish (or fish *tipping-tuing*) in the Makassar Strait during the southeast monsoon. It usually rises in the east at 5 o'clock in the morning at the end of June.

(7) *Bittoéng Bawi*. This means a pig star. This star is usually used by mountain people as a cautious sign because pigs will come out looking for food. This is actually the planet Venus.

(8) *Bittoéng Pambosei*. This means the star of fishermen. This star is a marker towards the north. This star usually appears in February, part way through the northwest monsoon.

(9) *Bittoéng Naga.* This means the 'dragon star'. This 'star' is used by fishermen for a good fishing location. It usually rises in the southeast. When this 'star' disappears, fishermen will be afraid because strong wind will show up. This is actually not a 'star' at all, but is the Milk Way.

(10) *Bittoéng Panjala*. This means the fishing net stars. This asterism is used as an indicator of the entry of the cool season (between the two monsoons) and the emergence of the bambang fish. This asterism usually rises around midnight in April. The parts that make up *Bittoéng Panjala* are the fishermen and the boat, as shown in Fig. 18.7. The identification shows that the boat is formed from the stars α UMa, β UMa, λ Dra, κ Dra, α Dra and θ Boo. In addition, fishermen are formed by stars γ UMa, δ UMa, ε UMa, ζ UMa and η UMa, where δ UMa, ε UMa and ζ UMa are the fishermen and γ UMa and η UMa are fishing equipment. The stars that form this asterism are also listed in Table 18.4.

1902 / 12 / 25 5 : 2 : 49

Bumi, Majene, 8m FOV 70.9° 15.3 FPS 1902-12-25 05:02:49 UTC+08:00

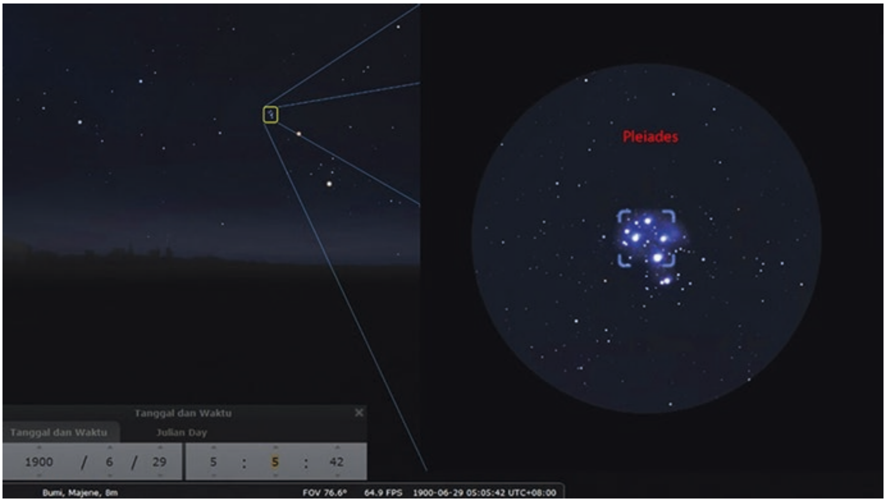
Fig. 18.5 The shape of *Bittoéng Lambaru* and its constituent stars seen from the location of the city of Majene (simulated using Stellarium).

Table 18.3 List of stars forming *Bittoéng Lambaru.*

Bittoéng Lambaru	α Sco	16^h 29^m 24.53^s	-26° 25′ 52.7″
	β1 Sco	16^h 00^m 26.27^s	-19° 48′ 16.8″
	δ Sco	16^h 00^m 20.06^s	-22° 37′ 13.8″
	ε Sco	16^h 50^m 14.27^s	-34° 16′ 54.5″
	η Sco	15^h 58^m 51.9^s	-26° 06′ 47.8″
	μ1 Sco	16^h 51^m 52.28^s	-38° 02′ 48.0″
	ζ2 Sco	16^h 54^m 35.43^s	-42° 21′ 16.0″
	ρ Sco	15^h 56^m 53.18^s	-29° 12′ 48.0″
	σ Sco	16^h 21^m 11.38^s	-25° 35′ 32.1″
	τ Sco	16^h 35^m 53.00^s	-28° 12′ 55.4″

(11) *Bittoéng Tallu-tallu.* This means a group of three stars. These stars are a sign towards the east after *Bittoéng Malunus*. One may observe three stars in a line which are quite bright at dawn. The parts that make up *Bittoéng Tallu-tallu* are two groups of stars that each have three stars in line, as shown in Fig. 18.8. Obviously these are in the modern constellation of Orion. The first part consists of stars δ Ori, ε Ori and ζ Ori. The other part consists of π3 Ori, π4 Ori, and π5 Ori. The stars that form this asterism are listed in Table 18.5.

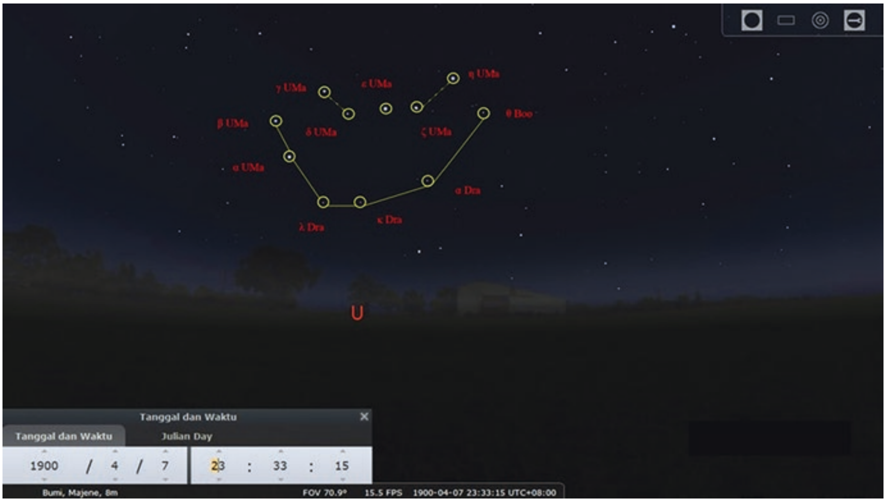
(12) *Bittoéng Pambawa Allo.* This means a star carrying the Sun. This star is a sign that the Sun will rise about an hour later. It is usually seen around 4 o'clock in the east. Actually this is the planet Venus.



1900 / 6 / 29 5 : 5 : 42

Bumi, Majene, 8m FOV 76.6° 64.9 FPS 1900-06-29 05:05:42 UTC+08:00

Fig. 18.6 The form of *Bittoéng Malunus* seen from the location of the city of Majene (simulated using Stellarium).



1900 / 4 / 7 23 : 33 : 15

Bumi, Majene, 8m FOV 70.9° 15.5 FPS 1900-04-07 23:33:15 UTC+08:00

Fig. 18.7 The shape of *Bittoéng Panjala* and its constituent stars seen from the location of the city of Majene (simulated using Stellarium).

18.4 Concluding Remarks

We have identified eleven celestial patterns in Mandar navigation, but only six of them related to star patterns useful for navigation. The Mandar view of star patterns is obviously related to the livelihoods of the fishermen, such as the patterns of fish, a boat and a fishing net. Other celestial patterns are used as a sign of the presence of fish in significant numbers or particular environmental features. Presently, many young Mandar sailors and fishermen have little knowledge of stars and other environmental features and rely exclusively on the magnetic compass and charts to guide their ships. So it is very important to retain the old navigational methods that use celestial bodies, as this is part of the rich traditional culture of the Mandar people.

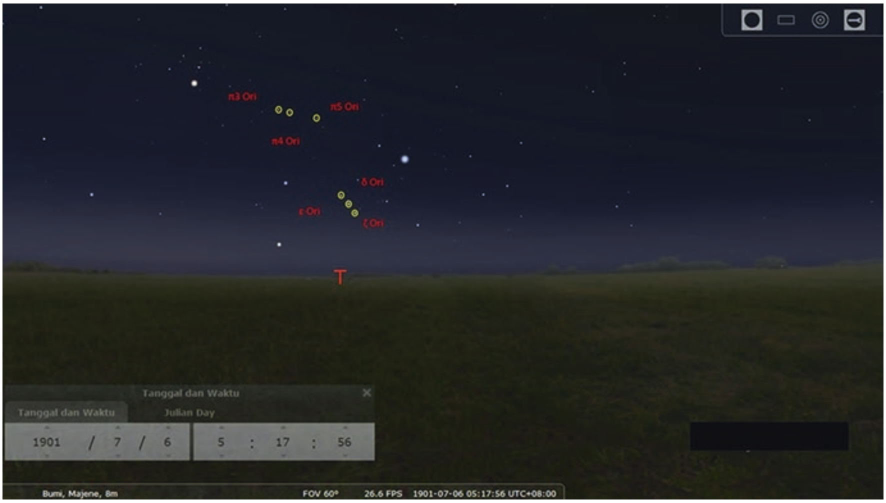
In Table 18.6, we compare the star names of the Mandar and Bugis, two ethnic groups that have a strong seafaring tradition. We see that the asterisms are similar, both in name and in form, which shows the close cultural links between these two neighbouring ethnic groups.

We should not be surprised by these similarities, for the Bugis and the Mandar both owe their oceanic maritime prowess and their astronomical systems to the Austronesians, who migrated from Taiwan to the Philippines about 4000 years ago. One branch of the population then moved eastwards, and eventually out into the Pacific (Carson et al., 2013), while the other branch moved southwards into Sulawesi, bringing with them (amongst other things) rice cultivation, domesticated pigs and a distinctive red-slipped pottery (Bellwood, 2017). Evidence of these early Austronesian settlers has been excavated at a number of archaeological sites in the Karama Valley, where radio carbon dates indicates their arrival around 3,500 years ago (e.g. see Anggraeni et al., 2014). There also is strong genetic evidence that supports this Austronesian settlement of Sulawesi (see Lipson et al., 2014). Non-coastal groups and some coastal people were committed to agriculture, but other coastal groups decided to focus instead on fishing and maritime commerce, honing the highly advanced navigational skills and oceanic technology introduced by their Austronesian forefathers.

Elsewhere in this book, Khairuddin and Jaafar (2021) have proposed that among Austronesian speakers in Southeast Asia there is a correlation between asterisms that an ethnic group recognizes in the sky and their ecological links to the local

Table 18.4 List of star-forming stars in *Bittoéng Panjala.*

Star Pattern	Star	RA	DEC
Bittoéng Panjala	α UMa	$11^h\ 03^m\ 44.98^s$	61° 44′ 50.4″
	β UMa	$11^h\ 01^m\ 49.31^s$	56° 22′ 56.2″
	λ Dra	$11^h\ 31^m 24.80^s$	69° 19′ 47.9″
	κ Dra	$12^h\ 33^m\ 29.57^s$	69° 47′ 23.4″
	α Dra	$14^h\ 04^m\ 24.20^s$	64° 22′ 36.8″
	θ Boo	$14^h\ 25^m\ 13.79^s$	51° 51′ 45.7″
	γ UMa	$11^h\ 53^m\ 48.69^s$	53° 41′ 39.8″
	δ UMa	$12^h\ 15^m\ 24.26^s$	57° 01′ 51.9″
	ε UMa	$12^h\ 54^m\ 0.38^s$	56° 30′ 08.6″
	ζ UMa	$13^h\ 23^m\ 54.05^s$	54° 55′ 30.4″
	η UMa	$13^h\ 47^m\ 33.65^s$	49° 18′ 51.6″



Tanggal dan Waktu
1901 / 7 / 6 5 : 17 : 56

Bumi, Majene, 8m FOV 60° 26.6 FPS 1901-07-06 05:17:56 UTC+08:00

Fig. 18.8 The shape of *Bittoéng Tallu-tallu* and its constituent stars seen from the location of the city of Majene (simulated using Stellarium).

Table 18.5 List of stars forming *Bittoéng Tallu-tallu.*

Star Pattern	Star	RA	DEC
Bittoéng Tallu-tallu	δ Ori	5ʰ 31ᵐ 0.39ˢ	–1° 17′ 56.7″
	ε Ori	5ʰ 36ᵐ 12.81ˢ	–1° 12′ 06.8″
	ζ Ori	5ʰ 40ᵐ 45.51ˢ	–1° 56′ 33.5″
	π3 Ori	4ʰ 49ᵐ 47.66ˢ	6° 57′ 39.6″
	π4 Ori	4ʰ 51ᵐ 12.38ˢ	5° 36′ 18.3″
	π5 Ori	4ʰ 54ᵐ 15.10ˢ	2° 26′ 26.4″

environment. We have noted that more than half of the Mandar asterisms mentioned in this chapter relate in some way to fishing or maritime activities. It will now be interesting to survey the astronomical knowledge-base of inland Mandar groups engaged in rice cultivation and see if they also recognize the marine asterisms of their ancestors, or whether they have already developed their own suite of agriculturally-inspired asterisms. Or will we find an interesting mix of both traditions?

Table 18.6 A comparison of Bugis (Ammarell, 1999) and Mandar star names.

Bugis Name	Star	Mandar Name	Star
Bintoèng Balè Mangiwèng		*Bittoéng Mangiwang*	α Ara
			β Ara
			θ Ara
			α Tel
			γ Sgr
			δ Sgr
			ε Sgr
			λ Sgr
			μ Sgr
			σ Sgr
			φ Sgr
	π Scorpio		θ Sco
	θ Scorpio		ι1 Sco
	ι Scorpio		κ Sco
	κ Scorpio		λ Sco
	λ Scorpio		ς Sco
	υ Scorpio		υ Sco
Bintoèng Lambaruè	α Scorpio	*Bittoéng Lambaru*	α Sco
	δ Scorpio		β1 Sco
	τ Scorpio		δ Sco
	β Scorpio		ε Sco
	ε Scorpio		η Sco
	μ Scorpio		μ1 Sco
	ζ Scorpio		ζ2 Sco
	η Scorpio		ρ Sco
			σ Sco
			τ Sco
Bintoèng Bola Kèppang	α Crux	*Bittoéng Sapo Kepang*	α Cru
	β Crux		β Cru
	δ Crux		γ Cru
	γ Crux		δ Cru
	μ Cen		δ Cen
Bintoèng Baluè	α Centauri	*Bittoéng tuwallu*	α Cen
	β Centauri		β Cen
Bèmbè'è	Coal Sack Nebula		
Worong porongngè	Pleiades	*Bittoéng Malunus*	Pleiades
Bintoèng Pitu			

(continued)

Table 18.6 (continued)

Bugis Name	Star	Mandar Name	Star
Bintoèng balu Mandara'	α Ursa Mayor	*Bittoéng Panjala*	α UMa
	β Ursa Mayor		β UMa
Bintoèng Kappala'è			λ Dra
			κ Dra
			α Dra
			θ Boo
	δ Ursa Mayor		γ UMa
	ε Ursa Mayor		δ UMa
	η Ursa Mayor		ε UMa
	γ Ursa Mayor		ζ UMa
	ζ Ursa Mayor		η UMa
Tanra Tèlluè	δ Orion	*Bittoéng Tallu-tallu*	δ Ori
	ε Orion		ε Ori
	ζ Orion		ζ Ori
			π3 Ori
			π4 Ori
			π5 Ori
Wari wariè	Venus	*Bittoéng Pambawa Allo*	Venus
Bintoèng Bawi		*Bittoéng Bawi*	
Bintoèng Nagaè	Milky Way	*Bittoéng Naga*	Milky Way
Tanra Bajoè	Awan Magellan		
Bintoèng Timoro'	Altair		
Pajjèkoè	β Orion		

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Chapter 19
Ethnoastronomy in Madura, Indonesia: Observations of the Night Sky and Eclipses

Siti Fatima, Wayne Orchiston, and Taufiq Hidayat

19.1 Introduction

Many ethnic groups on the Earth have their own distractive ways of perceiving and observing the night sky. Their perceptions are usually influenced by their culture and their environment. They also use the predictable appearance and disappearance of stars and asterisms in their everyday activities, as seasonal markers, as natural clocks or as navigational aids. The way in which people respond to eclipses is also influenced by their culture and based on their interpretation and understanding of these events. Eclipses are quite rare in any particular place so they are always noted, especially by those living in traditional villages in remote areas. People know of two kinds of eclipses that can occur during their lifetime, lunar eclipses and solar eclipses.

In this chapter we will explore the ways in which many elderly people from the Indonesian island of Madura used the stars while farming, fishing and voyaging. They had their own unique interpretations of the night sky and recognized its relevance in everyday life. The Madurese also observed the Sun, the Moon and eclipses and had their own understanding of what these celestial objects and events meant.

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Fig. 19.1 A map of the main islands of Indonesia (in green). Madura is the island inside the white ellipse, off the north-eastern coast of Java (map modification: Wayne Orchiston).

The island of Madura is located close to the north-eastern coast of Java, near Indonesia's second-largest city, Surabaya (see Fig. 19.1), and currently extends from latitude 6° 45′ S to 7° 15′ S and from longitude 112° 15′ E to 114° 05′ E. This is the first detailed study that has been made of Madurese ethnoastronomy, and was only possible because the first author of this chapter hails from the island.[1]

19.2 Madura and the Madurese

Currently Madura has a total land area of 5475.14 km^2 but, unlike neighbouring Java, is infertile, with poor soil and little water (Melalatoa, 1995). The average precipitation is about 2500 mm per year, and the average temperature on the island is 27.5° C. This limits the types of crops that can successfully be grown to mainly vegetables, and especially corn. Dry rice cultivation is challenging. The Madurese are also pastoralists, raising herds of cattle and horses. Bull-racing (see Fig. 19.2) is a sport for which Madura is internationally known (Pudyanto, 2014).

After farming, a second major occupation for those living round the coast of Madura is fishing. Since time immemorial the Madurese have also been known as great merchant-sailors, trading their wares not only within the Indonesian Archipelago, but as far afield as Singapore. So the sea has had a big influence in

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[1] The first author of this chapter was born into a Madurese family: her mother was from Sampang regency and her father from Bangkalan regency. She grew up in a village not far from Sampang city. Her family still pass down to the young generations some traditional beliefs and myths that probably were influenced by animism (and sometimes also were mixed with elements of Islam). The family still practices some of these traditions, such as holding a *slametan* when there are special events or phenomena, such as lunar eclipses (and she has experienced many of them).

This research is going-on, as she explores the ethnoastronomy of the ancient Madurese and seeks to document the history and heritage of this important aspect of Madurese culture.

Fig. 19.2 The Madurese love challenges, and especially their traditional bull-racing called *Keraban Sapeh* (https://modernfarmer.com/2014/01/karapan-sapi/).

their lives. Madura is also known as Pulau Garam or 'Salt Island'. Salt is produced by evaporation near the beaches by Madurese salt farmers, and is exported to Java. This is just one of the ways in which the Madurese try to compensate for the poor agricultural potential of their island.

Because of these debilitating geographical conditions life is very difficult for many Madurese, which is why there has been a great deal of out-migration especially over the past 50 years, and now there are many more Madurese living elsewhere in Indonesia—and especially in eastern Java—than on the island of Madura. Nonetheless, most of these relocated people continue to preserve their Madurese culture and speak their traditional Austronesian language (Davies, 2010).

For those who remain on Madura, adaptation to harsh conditions has led to an ethnic group with a similar culture and religion (Islam) to their Javanese neighbours but otherwise with very different characteristics (Rifai, 1993, 2007). It is well known that Madurese men are brave, are fierce fighters, and are hard workers, but they also are strong willed, aggressive, and can display violent behaviour that may result in fatalities (Dharmawan et al., 2018: 1).

19.2.1 Changing Sea-levels, Changing Populations and Changing Religion

Environmental changes triggered mainly by variations in sea level have had a profound influence on the biogeography and human history of the Madura region. The earliest human inhabitants of the Indonesian region were *Homo erectus* populations, which arrived in what is now Central Java about 1.5 million years ago (Zaim et al., 2011) and although it is possible that they ventured as far east as the Madura region, it is more likely that the first inhabitants of what is now the island of Madura arrived around 50,000 when the earliest *Homo sapiens* from Africa followed the coastline from ancestral India and moved down into what us now island Southeast Asia and on into Australia, New Guinea and some of the Melanesian islands off the coast of New Guinea (Kealy et al., 2016; O'Connell et al., 2018). We refer to these people as Australo-Melanesians, and they survive today in Australia as the Aboriginal Australians, in New Guinea as the indigenous inhabitants (O'Connor et al., 2017), and in south Thailand, Peninsular Malaysia and various islands in the Philippines as the distinctive negrito populations (Carey, 1976; Orchiston, et al., 2021).

The Australo-Melanesians were hunter-gatherers, and over the millennia their lives we influenced by the changing nature of their habitats as sea-levels slowly rose and fell (see Kealy et al., 2017), starting from a level around 30 metres below present sea level at the time of their original arrival. Fig. 19.3 shows the best current

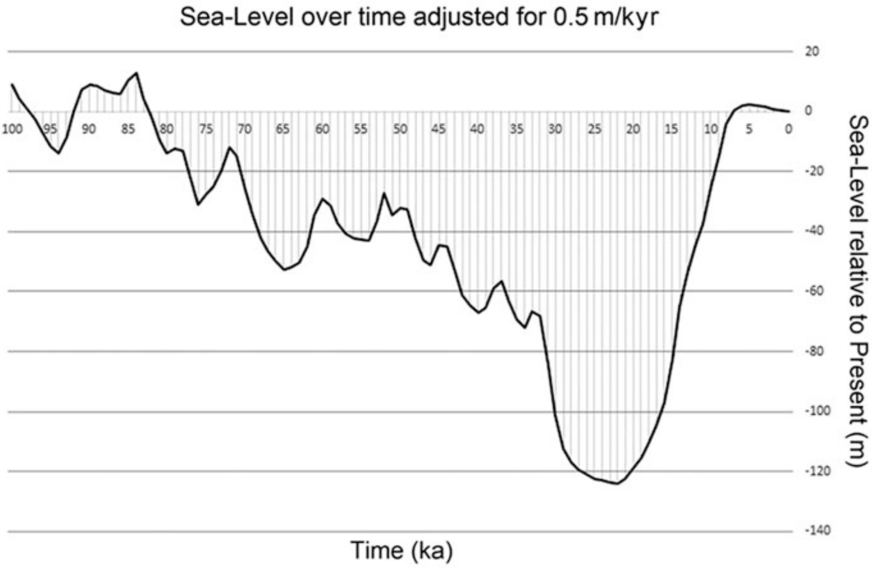

Fig. 19.3 A plot showing the changing sea levels in the Southeast Asian region over the past 100,000 years (after Lambeck and Chappell, 2001, but incorporating an isostatic uplift of 0.5 meters per thousand years, as calculated by Kealy et al. 2017).

estimate of the way in which seal-levels varied in the island Southeast Asian region over the past 100,000 years. As we can see, despite the small-scale oscillations, there was a general lowering of sea level from 50,000 years ago until 31,000 years ago. Then the seas dropped rapidly, reaching the Last Interglacial Sea Level Low at 22,000, when they were about 125 metres lower than the present level. Seas then began rising rapidly, reaching their current levels about 6000 years ago.

From the time the first *Homo sapiens* entered the Madura region, it was an inland location, on a larger landmass that is known as Sundaland, much of which is now offshore, hidden under the ocean (Oppenheimer, 1998). Initially, the Madura region was some distance from the coast and from the major riverine system shown in Fig. 19.4 that flowed from the northwest to the southeast and entered the sea east of Madura. The distance of the Madura region from this river and from the coast continued to vary as sea levels fluctuated, and it as only from 22,000 years ago that a consistent pattern began to emerge, as the shoreline slowly retreated to the northwest. By 12,000 years ago the Madura area lay south of a major bay, but it was only about 9000 years ago that the Borneo region separated from Java/Sumatra, Sundaland was finally drowned (Sathiamurthy and Voris, 2006), and that the ocean flowed from what is the South China Sea into the Java Sea (see the excellent animation in the paper by Gomes et al., 2015). It was probably at about this time that people began to live in the Madura region in any numbers, because O'Connor et al.

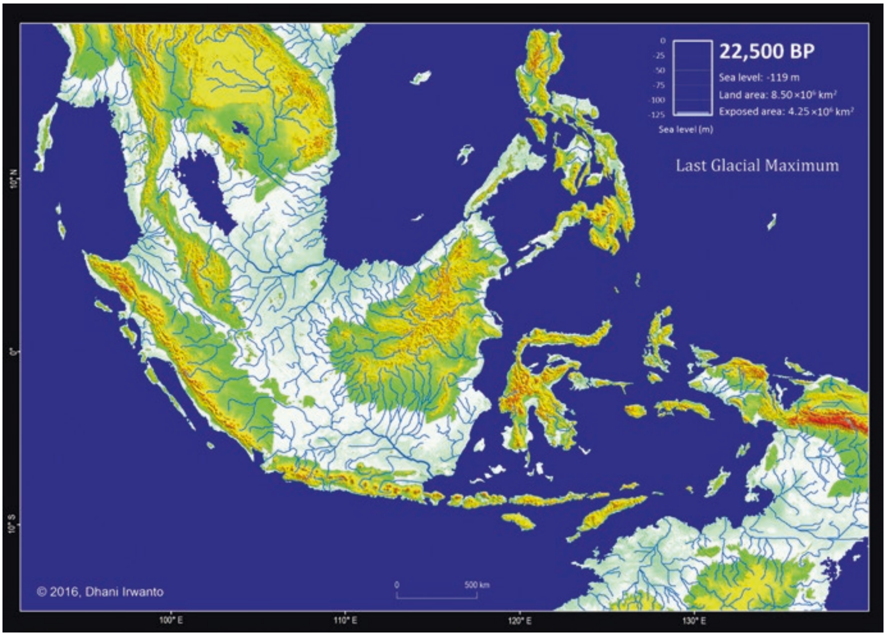

Fig. 19.4 Sundaland at the time of the last inter-glacial low sea level, showing the major riverine systems, and Madura's inland location quite near one of these major rivers (https://atlantisjavasea.files.Wordpress.com/2015/05/last-glacial-period-of-sundaland.gif).

(2011) and Samper Carro et al. (2016) amongst others, have presented a strong case that the Australo-Melanesian hunter-gatherers were a predominantly coastal people who ecologically were primarily dependent on marine, littoral and estuarine resources (fish, marine mammals, crustaceans, birds, shellfish). These sources of protein would have been supplemented by edible plants and berries from near-coastal biomes and the coastal-rainforest ecotone (but see Storm et al., 2005), while rivers and streams provided fresh water and routes to the interior used when gathering specific seasonal resources or accessing stone that could be used to manufacture implements.

As the seas continued to rise providing fresh aquatic and coastal resources so too did the population of the Madura region until about 6,000 years ago when water first flowed through what is now Madura Strait and Madura became an island. With finite coastal resources, and an uninviting economically impoverished hinterland, we can postulate that there was soon population pressure on land as all of the desirable coastal habitats were utilised. Each section of coast had to be evaluated on its merits in terms of available resources. Rocky shores offered crustaceans and different types of shellfish to sandy or muddy shores, and protected bays offered greater access to off-shore fishing than did open bays exposed to the elements. A river or stream was necessary for fresh water, and if this also was associated with an estuarine environment then further aquatic resources, not to mention avifauna (birds), were an added bonus. According to the hypothesis of Khairuddin and Jaafar (2021) this is when the local inhabitants would have developed an astronomical knowledge base that focussed on marine hunting and gathering.

All this was to change dramatically about 3500 years ago when Austronesians who had migrated from China and down through Taiwan, the Philippines and Sulawesi arrived in the Java-Madura area. The Austronesians had an advanced maritime technology, made pottery, and—most important of all—were agriculturalists. They not only grew rice, but also brought a range of other edible plants such as bananas, coconuts, jackfruit, pineapples, taro and yams, not to mention domesticated chickens, dogs and pigs (see Bellwood 2005, 2017). Evidence of the arrival of this new population in Madura is reflected in the language and culture of the current inhabitants of the island, and is documented in Indonesia by archaeological and genetic evidence (e.g., see Hill et al., 2007; Lipson, et al., 2014; Noerwidi, 2011/12). The original Australo-Melanesian inhabitants of Madura now realised that total reliance on coastal resources was no longer essential if they chose to imitate the Austronesian newcomers and try their hand at farming. This was when the agricultural backbone of the island's economy was established, but the poor soils, and lack of major river systems for irrigation prevented a repetition of the successful schemes that were introduced elsewhere in island Southeast Asia by the Austronesians.

Fig. 19.5 purportedly shows the main routes of the Austronesians once they entered island Southeast Asia. One branch of the population quickly moved eastwards from the Philippines and islands of Indonesia to the islands off New Guinea and eventually out into the Pacific (Tumonggor et al., 2013), while a second branch went southwards from the Philippines (Tabbada et al., 2010). Present evidence suggested that this latter group moved down through Sulawesi as far as the chain of Lesser Sunda Islands, where they split and migrated to the east and to the west

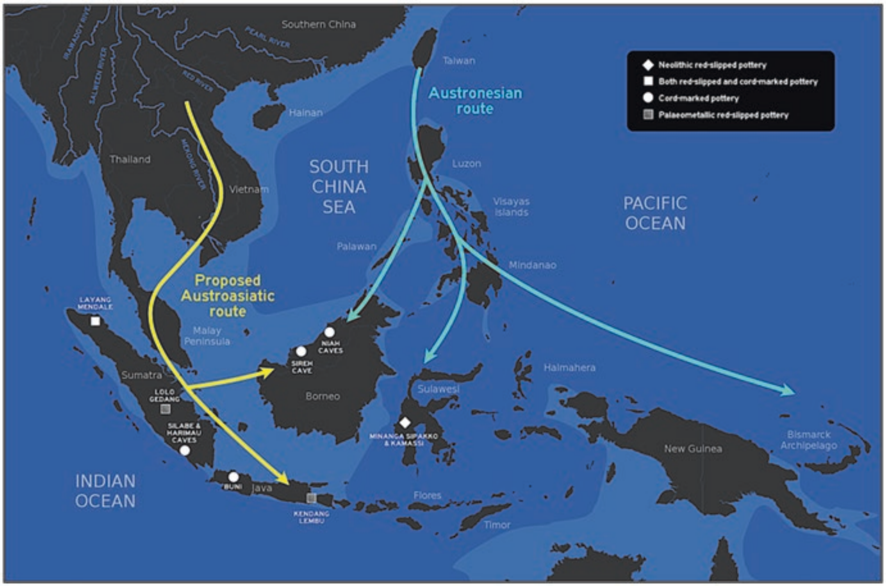

Fig. 19.5 A map showing the proposed routes of the Austronesian (blue) and Austro-Asiatic (yellow) migrations into the Java-Madura region about 3500 and 3000 years ago, respectively. We believe these migration routes need to be revised, as discussed in the text of this chapter (based on Simanjuntak, 2017).

(Karafet et al., 2010; Lipson, et al., 2014; Mona et al., 2009). It was this western group that settled in Madura and Java, and we believe that this group of Austronesians also migrated to Sumatra and northwards from Java and/or Sumatra into the island of Borneo. We do not believe that Borneo was settled directly from the Philippines.

Fig. 19.5 also shows the next phase in the occupation of Madura, this time by Austro-Asiatic speaking people who migrated from Southwest China, via Vietnam, Thailand and the Malayan Peninsula into Sumatra, Borneo, Java and Madura (Matsumura et al., 2011). Their arrival in Java and Madura can be dated to about 3000 years ago and is strongly supported by genetic evidence (e.g. see Karafet et al., 2010; Lipson, et al., 2014). Once again, we believe that the map needs to be revised. Instead of showing the Austro-Asiatic group migrating down through Vietnam and Cambodia, then sailing across the Gulf of Thailand to the Malayan Peninsula, we believe that they used a land route throughout, as evidenced by the latest archaeological and genetic evidence.

The Austro-Asiatic settlers also grew rice and manufactured pottery, and they quickly merged with the Austronesian inhabitants of Java and Madura, forming the ancestors of the present-day populations of these two islands. However, in most areas of Southeast Asia where they settled (except in some parts of Peninsular Malaya) the Austro-Asiatic groups decided to abandon their original mainland Southeast Asian language and adopt the Austronesian languages that already were widely spoken and accepted throughout Island Southeast Asia. Given the South

Chinese origins of the Austronesian *and* Austro-Asiatic populations and their association with agriculture we must query whether there is any way that we can distinguish the various astronomical elements of their ancestral astronomical systems when we review that astronomical beliefs and practices of the present-day Madurese. More on this later in the chapter.

But we digress, because there were later elements of Madurese (and Javan) history with strong astronomical implications that we also must discuss. First was the arrival of Hinduism, which was particularly popular in central Java between the ninth and fourteenth centuries, leaving many temples, and their ruins, all of which incorporated aspects of Hindu cosmology. Professor Taufiq Hidayat from ITB and a succession of his students have been researching these (e.g. see Khairunnisa et al., 2021; Rodhiyak and Hidayat, 2019). Although Trowulan is a major Majapihat Hindu temple complex in eastern Java near Surabaya, and there are Hindu temple ruins scattered throughout the mountains inland from Surabaya, Madura is not known for its Hindu temples, and it would appear that Hindu astronomy and cosmology never took root there.

The same certainly cannot be said for the next major religion to embrace Indonesia. Islam spread through the Indonesian region during the fifteenth and sixteenth centuries (see Fig. 19.6) and was quickly adopted by the population of Madura. Although the religion came with basic astronomical precepts, not all of which related to prayers and identifying the direction of Mecca, as we shall see in the following study, some Madurese were quick to incorporate animistic and other early astronomical practices within their Islamic beliefs.

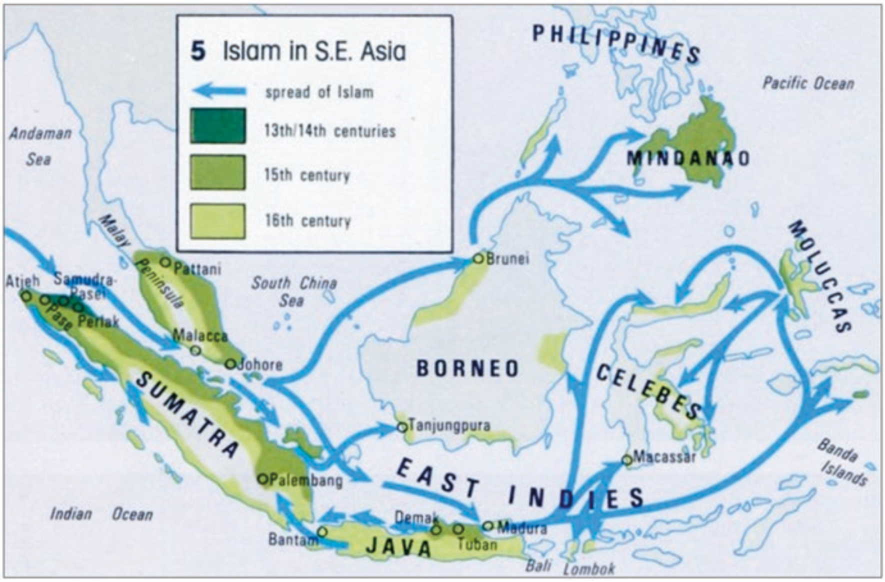

Fig. 19.6 Map showing the introduction of Islam into island Southeast Asia. It reached northern Java and Madura in the fifteenth century (xenohistorian.wordpress.com).

19.3 Ethnoastronomy Research: Documenting Madurese Astronomy

19.3.1 Introduction

This is the first ethnoastronomy survey of Madura. As a relatively small island without any large cities, light pollution has, for the most part, not been an issue, so those Madurese who have a knowledge of and interest in celestial objects and events are afforded excellent views of the night sky. They try to relate their knowledge of astronomy, and especially lunar eclipses to their culture. Thus, Madurese farmers use celestial objects as a calendar that forewarns them of the beginning of the wet season when they must plant the rice, while the fishermen and marine-voyagers use celestial objects for navigation.

Thanks largely to 'modern education', many younger Madurese are not interested in ancient astronomical lore, so as knowledgeable elderly people die this aspect of their culture dies with them. Therefore, it is important to document traditional Madurese astronomical knowledge while it is still possible to do so. This is an urgent task that must be addressed now, otherwise the history and heritage of Madurese astronomy will be lost forever.

Perhaps the easiest task is to record current knowledge of and behaviour relating to eclipses, as these are still observed in a traditional manner in parts of Madura. Also, the Sun and the Moon were the most favoured celestial objects in the pre-telescopic era.

In order to carry out this study we gathered data from the following sources:

(1) A survey of the relevant archaeological, astronomical, ethnographic, genetic and geological literature; and
(2) A ethnoastronomical field survey.

Details of (2) are provided below.

19.3.2 The Madurese Ethnoastronomical Survey

The first author of this chapter carried out a survey of about 100 families resident throughout the island in the course of two different field trips. The first occurred from 21 December 2015 to 3 January 2016 and second on 16 and 17 July 2016. Where possible, in-depth interviews were conducted with elderly Madurese known to have a knowledge of astronomy, and in some communities it also was possible to carry out direct observations. Fig. 19.7 is a map of Madura, and the 28 different villages visited are shown in red. Note that these were located on the coast and in inland areas, and that collectively they represented about 56% of all of the villages shown on the map. Fig. 19.8 shows three photographs of the first author of this chapter while she was engaged in the ethnoastronomical survey. The fact that she was a Madurese and knew some of the interviewees personally proved an advantage.

Fig. 19.7 Madura Island map showing well-known localities. Ethnoastronomical data were gathered at all of those marked in red (map: Siti Fatima).

19.3.3 Observations of the Night Sky

One of the things the first author of this chapter tried to learn was names for different stars and asterisms used by Madurese people, and these are listed below in Table 19.1.

As mentioned previously, that Madurese have a great maritime tradition. Like the Bugis (Ammarell, 1999) and the Mandar (Rasyid et al., 2021), this probably originated with the Austronesians, who brought an advanced maritime technology with them when they came to Java and Madura. We see this represented today in Madurese vessels used for commerce and inter-island voyaging. At present there are many fishing villages along the coast of Madura, and some of the fishermen still use the stars and asterisms for navigation as well as using modern technology, but in other villages the fishermen still have the knowledge but do not use it any more. Some of the younger fishermen do not have any of this traditional knowledge. Those who knew and used astronomy during fishing or voyaging added the prefix *bintang* (star) to almost all stellar objects. They used the term *bintang tera'* (bright stars) when navigating to the north, for example, and *Bintang tera' bhiruh* (blue bright star), which we recognized as Vega. They also used the asterism *Bintang Sekoh* (elbow stars) or what we know of as the 'Summer triangle' (Vega–Altair–Deneb), while to the south they used *Tara laok*, known to us it as Alpha and Beta Centauri. But, their most popular asterism was *Bintang Pe'-Kope'an*, a kind of Madurese fish that is also known by some other names. To us, it is the constellation Crux. They also used Crux as a clock for sailing time in particular months. Sometimes, they also used asterisms or specific stars as seasonal indicators of the presence of particular fish.

For Madurese farmers, the most popular asterism was *Bintang Nangghala* (the plough) which was the central part of the constellation that we know of as Orion. They used this asterism as a seasonal indicator when they saw it rise just after sunset. They also used the Milky Way as a clock, and referred to it as *Bintang Ngaisongaian* (The River). The Madurese also liked to play games using the stars. For example, they would have a competition to see who could count the most stars in the

Fig. 19.8 Three photographs of Siti Fatima taken while she was conducting interviews for the ethnoastronomical survey (photographs: Siti Fatima).

Fig. 19.8 (continued)

Pleiades. They called the Pleiades *Bintang Portekah* or *Bintang Mortekah* or *Bintang Kartekah.*

19.3.4 Observations of Eclipses

The Madurese were familiar with both solar and lunar eclipses, and recognised the fact that the former were rare events. They had no special methods of calculating up-coming eclipses in advance, merely recognising each eclipse as it occurred. It seems that they were only interested in them as individual events, and it did not occur to them that they may exhibit some long-term regularity. Although there are some ancient Madurese manuscripts, these only describe individual solar or lunar eclipses—there is no mention of any pattern.

19.3.4.1 Lunar Eclipses

Compared to solar eclipses, lunar eclipses are comparatively common, and they occur at night. The Madurese notice that as the eclipse progresses the light of the Full Moon becomes fainter than usual and the air is cooler. Then, when the eclipsed Moon changes to a distinct red or orange colour (e.g. see Fig. 19.9), the Madurese have their own standardised cultural responses. They are sensitive to these colours,

Table 19.1 A list of stars and asterisms known to the Madurese.

Celestial Object		Meaning	Use
Western Name	Madurese Name*		
Pleiades	*Portekah*		A seasonal/time sign Games
	Mortekah		
	Kartikah	Seven stars	
Milky Way	*Ngai-songaian*	River	Clock
	Lei-bheleian	Part of a traditional Madurese ship	
Venus	*Terang sobbhu*	Star of *Subuh* (time before sunrise)	Sign of time
Vega	*Tera' bhiruh*	Blue and bright	North direction
Arcturus	*Tera' koning*	Yellow and bright	East or west direction
Sirius	*Tera'*	Bright	East or west direction
α and β Centauri	*Jejer duwe'*	Two stars	South direction
	Tara laok	Two stars in the south	
Canopus and Capella	*Ba-lomba*	The dolphin stars	East or west direction
Crux (Southern Cross)	*Pe'-kope'an*	A distinctive Madurese fish	South sign
	Bhuk-soblughan	Traditional rice cooker	Clock
	Ghendet/ Jeng-lajengan	Kite	
Orion	*Nangghala*	Plough	Time for farming
Corona Australis	*Lengker*	Circular	
The 'Summer Triangle' (Vega-Deneb-Altair)	*Sekoh*	A right-angle triangle shape	North direction
Large Magellanic Cloud	*Kaddhu'*	A sack	South direction

*The word *bintang* (star) should be added to all of these names.

which indicate a 'hot' condition, and the more intense the colour appears the more grounds there are for concern. So the appearance of the eclipsed Moon scares the Madurese and tells them that there is something wrong with it. Obviously it is 'sick'. So they refer to it as *Bulen Gherring* (*Bulen* = Moon and *Gherring* = sick), and they want to help it recover. They do this by sending the Moon a loud and clear 'get well' message using a percussion musical instrument known as a *kentongan*, in the hope that whatever is causing the Moon to be sick will be frightened away. A *kentongan* (see Fig. 19.10) is usually made from bamboo cylinders, and is played with two small beaters. This practice of serenading the sick Moon using a *kentongan* is also found with Java, and presumably the idea originated in Java and was adopted by the Madurese (as with other aspects of Madurese culture). Incidentally, *Tong-tong* music played on the *kentongan* at times when there is no eclipse is popular with the Madurese (Bouvier, 2002).

Fig. 19.9 Example of a ‘very sick Moon’ during the lunar eclipse of 28 August 2007 (photograph courtesy: John Drummond, Patutahi, New Zealand).

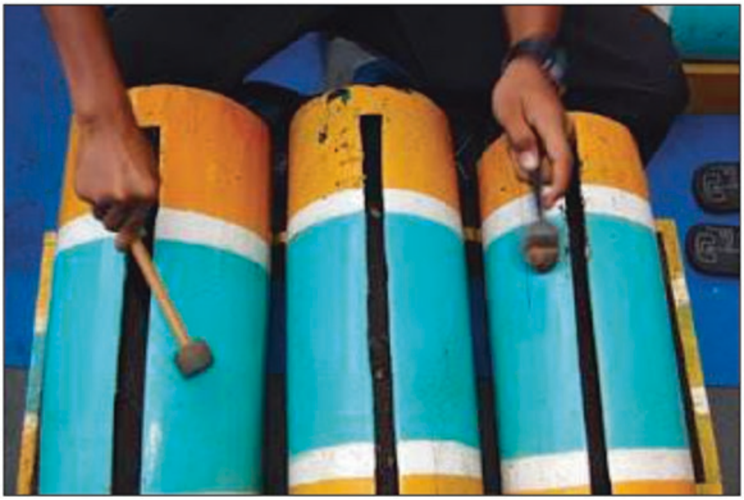

Fig. 19.10 Example of a colourful *kentongan* (slit-drums) (https://www.eastjavatraveler.com).

Besides worrying about the ‘sick Moon’ during a lunar eclipse, the Madurese are also afraid the Moon’s sickness will spread to their own precious possessions, and they also carry out ceremonies to prevent this from happening. So they tap their precious things, such as their houses, livestock and plants if farmers and ships and associated tools if fishermen or sailors to slowly wake them up, using this unique mantra: “Heey … jeghe-jeghe sapeh, ajem, kabbi, bheres-bheres, jek norok gherringah Bulen …” This means: “Heey…. wake up, cow, chicken, and all of you, get well, don’t be sick like the Moon …” By using this mantra they hope that their precious possessions will be stronger because they are awake and alert instead of sleeping. They also are afraid that the Moon’s sickness will spread to their children, so they hold the child’s head for a moment in two hands. Sometimes they also lift the head up a little. Then they slowly lift the child in the air to prevent them getting sick like the Moon.

Another Madurese tradition connected with a lunar eclipse is to hold a *slametan*, or thanksgiving ceremony. *Slametans* provide safety during dangerous conditions, and are used throughout Indonesia, but in different ways. During a lunar eclipse the Madurese will hold a *slametan* and put *bhu’-sobhu’* (special offerings such as a small mirror, a needle, yarn, flowers, a comb, a popular paste made from spices, and other items) in a large bowl, and then place this in the middle of their front yard during the eclipse. They hope that the Lord will receive their *bhu’-sobhu’* and they will be safe and protected from any dangerous incidents caused by the sick Moon during the eclipse.

19.3.4.2 Solar Eclipses

While the Madurese were aware of total and annular solar eclipses, generally they would not notice partial solar eclipses. This is mainly because it is only during an annular or a total solar eclipse that day will appear to briefly turn into night, that the air will cool, and that chickens will go to roost. The Madurese also were aware that total or annular solar eclipses occurred at New Moon when the combined tidal effect of the Sun and Moon was strongest and in some locations king tides and coastal flooding could occur. In Madura, for example, this occurred in Sampang city and at several villages along the south coast near Pamekasan during an eclipse remembered by some of our informants. So, they remembered that the eclipse occurred at the same time as the disastrous floods. They also typically associated solar eclipses with a disaster or something bad that would happen, and they therefore had a traditional way of responding to such an event. As with lunar eclipses, this also involved myths and legends, and the performance of appropriate cultural activities.

Because there was no fore-warning, the Madurese would only become aware of a solar eclipse when it actually was happening. The eclipse therefore surprised them and it created fear. Their reaction was to immediately go inside their houses and close all doors and windows. Some people would also use a *samper* (a traditional Madurese cloth) to cover any holes in their houses. They also would make sure they did not look outside and see the eclipse, because this action could blind them. A solar eclipse therefore was a very dangerous event, and it fore-shadowed a big disaster: an earthquake, a famine, a flood or even the collapse of an Empire. This idea was reinforced by a tale in the *Lontar Madura* (traditional literature from Madura) about the origin of the Kingdom of Madura, which occurred during a total solar eclipse, when darkness enveloped the Earth.

Another Madurese belief is that during a solar eclipse a pregnant woman must pick up a *Beddhung* with her teeth and place it in the bottom of their bed. A *Beddhung* is a tool that farmers use to cut wood into pieces. This is simply a custom: there is no logical reason why this must happen. Some Madurese also hold a *slametan* at this time to get protection from the Lord.

If we carefully examine Espenak and Meeus' (2006) on-line volume *Five Millenium Canon of Solar Eclipses: –1999 to +3000* and check for solar eclipses where the path of totality crossed the island of Madura during the period from 1999 BCE to CE 2015 we find about 40 examples, and these are listed in Table 19.2. Note that we say "about 40 examples" because Madura is a small island on the scale of the world maps plotted by Espanek and Meeus for each solar eclipse, and depending on the width of the path of totality and the position of Madura *vis-a-vis* that path, even after enlarging the image very substantially it still was not always possible to be *absolutely certain* whether Madura did see or just missed seeing a solar eclipse. These events are listed as "Probable Eclipses" in Table 19.2. This table contains 40 entries, 31 eclipses where we are reasonably confident that Madura lay on the path of totality, and 9 'probables'. The 9 probables comprised 6 annular eclipses, 2 total eclipses and 1 hybrid eclipse. The corresponding figures for the definite eclipses are 15 annular, 11 total and 5 hybrid eclipses. Note that in spite of the small numbers, there is no statistically-significant difference between these two samples. One notable feature of the Table 19.2 listing is the relative paucity of eclipses that occurred within a time-span of 30 years of each other, the sort of time interval where it is was possible for the same person—assuming they saw the eclipse when relatively young and then lived to old age—could have viewed both eclipses in the pair during their lifetime. In the list of definite eclipses, such pairs only occurred in 592-567 and 567-552 BCE and CE 117-139, although the pairs increase significantly if the 'probable' eclipses of BCE 1807, 1461, 1416, 1388, and 183 and CE 139 and 414 indeed lay on the path of totality. In this instance the consecutive pairing of the BCE 1416-1409, 1409-1388 and 1388-1362 eclipses is important, providing four different viewable eclipses during a 53-year interval, assuming that weather conditions made such observations possible.

This climatic rider is critical given that Madura is in the tropics and is subject to monsoons. So, the chances that the Madurese saw even half of the eclipses listed in Table 19.2 is remote. But even allowing for this statistic, it is clear that there would have been enough successful observations of total and annular solar eclipses from Madura during the 4014 year period surveyed for the Madurese to have built up a local body of knowledge about solar eclipses based on actual observations, with the accounts passed down from generation to generation and the overall view modified where necessary by new eclipse occurrences. Moreover, this time-frame of more

Table 19.2 Solar eclipses visible or probably visible from the island of Madura between 1999 BCE and CE 2015 (after Espenak and Meeus, 2006).

Date			
Year	Month	Day	Type of Eclipse*
Definite Eclipses			
1933 BCE	June	02	A
1833 BCE	December	31	A
1612 BCE	August	20	A
1503 BCE	April	20	H
1470 BCE	July	12	T
1409 BCE	April	01	T
1362 BCE	September	15	T
903 BCE	January	18	A
867 BCE	August	04	T
801 BCE	January	30	H
707 BCE	January	11	A
667 BCE	May	16	A
592 BCE	October	21	A
567 BCE	June	19	T
552 BCE	August	31	A
440 BCE	February	28	A
292 BCE	September	05	H
165 BCE	November	10	T
CE 38	June	21	H
CE 117	March	21	A
CE 139	January	18	T
CE 305	August	07	A
CE 435	August	10	T
CE 714	February	19	T
CE 790	January	20	A
CE 1025	November	23	A
CE 1502	April	07	T
CE 1571	July	22	A
CE 1683	July	24	T
CE 1807	June	06	H
CE 1810	April	04	A
Probable Eclipses			
1807 BCE	August	16	A
1461 BCE	December	28	A
1416 BCE	February	19	H
1388 BCE	August	04	T
1001 BCE	October	14	A
953 BCE	March	31	A
183 BCE	May	06	A

(continued)

Table 19.2 (continued)

Date			
Year	Month	Day	Type of Eclipse*
CE 414	April	06	T
CE 1752	November	06	A

*A = Annular Eclipse; H = Hybrid Eclipse; T = Total Eclipse

than 4000 years, allows for observations from Madura by the Austronesians and the later Austro-Asiatic inhabitants. There is ample ethnographic evidence, from Australia for example (see Hamacher and Norris, 2009; Nunn and Reid, 2016), that accurate oral history accounts of significant witnessed scientific events—such as the rise in sea level during the last interglacial or the impact of a meteorite—were preserved in traditional astronomical and geological lore and faithfully transferred from generation to generation over many thousands of years. There is no reason why an accumulating lore relating to solar eclipses should not have survived in a similar fashion on Madura. If this is so, then it has implications for some of the Madurese names listed for different astronomical objects in Table 19.1. We return to this theme in Sub-section 19.4.1 below.

19.4 Discussion

19.4.1 Origins, Continuity and Change

The present-day astronomical system of the Madurese is based on an amalgam of Austronesian, Austro-Asiatic, Islamic and Javanese influences, and one of the challenges we face as ethnoastronomers is to try and identify the various contributing elements in this ‘astronomical jigsaw puzzle’. In this context, we must remember that indigenous astronomical systems merely form part of the culture of the host group, and that culture generally is not static but changes with time. Normally cultures—or elements of them—evolve, but sometimes circumstances can lead to cultural devolution. In many cultures chronological changes through time can lead to the existence of regionally distinctive astronomical systems, as was found for example in Maori astronomy when New Zealand was first settled by Europeans (see Orchiston, 2016). However, the limited land area of Madura and the regular interaction of the population throughout the island possibly prevented this from happening.

Khairuddin and Jaafar (2021) have documented how indigenous Malaysian astronomical systems are correlated with the ecological circumstances of their host groups, and amongst others they distinguish fishing from farming astronomical systems. Fishing and farming are the two principal ecological orientations of the present-day Madurese, and were inherited from the Austronesians 3500 years ago and reinforced 500 years later by the Austro-Asiatic immigrants. This raises four questions relating to the listings in Table 19.1 where 'fishing' and 'farming' stars and asterisms are obvious:

(1) Were the fishing-related names listed in the table only provided by informants located in coastal fishing settlements shown in the Fig. 19.7 map, or were they sometimes also mentioned by informants from inland farming communities?
(2) Conversely, were the farming-related names listed in the table only provided by informants located in inland farming settlements shown in the Fig. 19.7 map, or were they sometimes also mentioned by informants from coastal fishing communities?
(3) How are the different names used for the Pleiades best explained? Are *Portekah*, *Mortekah* and *Kartikah* merely regional variants of the same original Austronesian term (notwithstanding our suggestion that we may not expect to find evidence of regionalism in Madurese astronomy)?
(4) In the case of Crux three very different names are listed: *Pe'-kope'an*, *Bhuksoblughan* and *Ghendet/Jeng-lajengan.* The first of these relates to fishing, the second to farming and the third to neither practice. We are not linguists, but the three terms look and sound very different. Could they perhaps reflect the different cultural backgrounds of the Austronesians and the Austro-Asiatics, or is there also an Islamic element? A similar question relates to the two very different names assigned to Alpha and Beta Centauri.

It would be interesting to conduct further fieldwork aimed at distinguishing more clearly the geographical distributions of the fishing and farming celestial terms by preparing three different versions of Table 19.1, one for inland and coastal communities reliant solely on farming; a second one for coastal communities dependent primarily on fishing; and a third table for communities that combined fishing and farming.

Returning to the theme of cultural change, we see this reflected in contemporary Madurese astronomy. One of the amazing results of our ethnoastronomical survey of Madura was the nearly-identical response to eclipses throughout the island, even though in some places—especially in the towns—the knowledge still existed but the expected patterns of traditional behaviour had been abandoned. There were two quite different elements at work here. Firstly, some of the younger generation no longer knew about eclipses because their parents or grandparents had not passed on the astronomical lore to them. Secondly, Islam is also responsible for a change in attitude, as some people now prefer to respond to eclipses in a traditional Islamic way through *shalat* (prayers), even if they are aware of the traditional Madurese responses expected during eclipses.

19.4.2 Madura and Java: Similarities and Differences

The way in which the Madurese observed the night sky was influenced by their culture, which leans heavily on Javanese culture, especially as it relates to farming. Thus, both cultures use the Pleiades and Orion as signs of farming time, and the names of the associated stars and asterisms are quite similar: such as *Bintang Nangghala* for 'the plough'.

But, the names that the Madurese fisherman and sailors use are quite different: in Madura Crux is known as *pe'-kope'an*, or a Madurese fish, but in Java is a kite. The image of the fish, of course, derives from the maritime environment of the Madurese fishermen. Meanwhile, although we have good knowledge of Bugis and Mandar navigation, the role of stars and asterisms in Madurese navigation and oceanic voyaging still needs to be studied.

Although Madurese people think that the Moon and the Sun are sick when eclipses happen, their responses are different for each of these events. They have an offensive response to a lunar eclipse by doing something positive outdoors and trying to send a message to the Moon (and use of the *kentongan* even encouraged the performance of *Tong-tong* music as an accepted form of traditional music in Madura). But with a solar eclipse the Madurese response is defensive, as they lock themselves away in the safety in their houses. This is because solar eclipses were seen to be much more dangerous than lunar eclipses.

19.5 Concluding Remarks

The Madurese have their own ideas and perceptions of the night sky that tend to have been influenced by fishing or farming activities, and also by Javanese culture. During solar and lunar eclipses, the Madurese express their response based on their perception of changes to the environment that they notice during the eclipse. In the case of a lunar eclipse they believe that the Moon is sick so they play a traditional musical instrument, the *kentongan*, sending 'get well' messages to the Moon, because in ancient times when this practice was introduced nobody had any idea about what was really happening during an eclipse. These cultural practices have persisted through to the present day among the Madurese, but the current generation of children and young adults now learn about the scientific reality of eclipses through school programs, television and publications and pay little attention to traditional beliefs. This, therefore, is our last chance to capture traditional Madurese astronomical beliefs and practices and record Indonesian astronomical heritage while the elderly people with such knowledge are still with us. Soon it will be too late.

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Chapter 20
The *Pengalantaka Eka Sungsang Ka Paing* System and a Diagram for Determining *Purnama* and *Tilem* in the Balinese Calendar

Ni Putu Audita Placida Emas, Alif Husnul Fikri, and Rendy Darma

20.1 Introduction

Hindus in Bali have many ceremonies and holy days. There are two holy days based on the Moon's phases, *purnama* (Full Moon) and *tilem* (New Moon). When these phases occurs, Hindus in Bali will perform a ceremony at a *Pura* (temple). At this time, Hindus in Bali are expected to do self-purification because it is believed that *Sang Hyang Candra* (*Sang Hyang* in Bali means God, *Candra* means Moon) or *Sang Hyang Surya* (*Surya* means Sun) are doing tapas for the safety of the Universe.

To determine the phases of the Moon more easily and conveniently than making observations, a system referred to as *pengalantaka* has been developed. This system is based on a script written on palm leaves called *lontar* and titled "*Pengalihan Purnama-Tilem*", which means the shifting of Full Moon and New Moon. *The pengalantaka* system is part of the astronomical heritage of Balinese Hindus, who use it to determine Full Moon and New Moon for ceremonies. I Gede Marayana is an expert on the Balinese Calendar, and in 1979 he created a circular diagram named *Pengalantaka Eka Sungsang* to make the *pengalantaka* system easier to use and to understand. This diagram can be found on Balinese calendars that are commonly used by Hindus in Bali.

The purpose of this chapter is to explain the *pengalantaka* system as an example of Balinese astronomical heritage that is still used today, and to show how the *Pengalantaka Eka Sungsang Ka Paing* diagram is used to determine New Moon and Full Moon.

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20.2 The *Pengalantaka* System

20.2.1 Introduction

Tilem is a term for New Moon and *purnama* for Full Moon in Bali. The days from *tilem* to *purnama* are called *penanggal* or *suklapaksa*, and one *penanggal* usually has 15 *tithis* (days). The days from *purnama* to *tilem* are called *panglong or kresnapaksa*, and they usually also have 15 *tithis*. However, we say 'usually' because not all months have 15 days of *panglong* and *penanggal.* In some months, there will only be 14 days of *panglong* or *penanggal* because in order to keep the differences between the estimated time and the actual time small a one-day reduction is required.

The term *pengalantaka* derives from the word *kala* which means time. *Pengalantaka* is a collection of formulae used to determine the days of *purnama* and *tilem* that have occurred (Marayana, 2015). *The pengalantaka* system is a combination of the *wuku* calendar system (*pawukon*),[1] and *wewaran*,[2] and especially *pancawara* (a 5-day-a-week system) and *saptawara* (a 7-day-a-week system).

20.2.2 Pengunalatri

The *pengalantaka* system has a one-day reduction system for particular *wuku* every 63 days, which is named *pengunalatri*. The *pengunalatri* system is written on *sloka pengunalatri*, where a *sloka* is a collection of verses that are written on *lontar* (palm-leaf manuscripts) or in a book. There are 15 rules about the one-day reduction, and those are:

1. *Pancadasi* = *penanggal/panglong* 14 changed into 15 (14/15)
2. *Caturti* = *penanggal/panglong* 3 changed into 4 (3/4)
3. *Asthami* = *penanggal/panglong* 7 changed into 8 (7/8)
4. *Dwidasi* = *penanggal/panglong* 11 changed into 12 (11/12)
5. *Praptipada* = *penanggal/panglong* 15 changed into 1 (15/1)
6. *Pancami* = *penanggal/panglong* 4 changed into 5 (4/5)
7. *Nawami* = *penanggal/panglong* 8 changed into 9 (8/9)
8. *Triyodasi* = *penanggal/panglong* 12 changed into 13 (12/13)
9. *Dwitya* = *penanggal/panglong* 1 changed into 2 (1/2)
10. *Sadsti* = *penanggal/panglong* 5 changed into 6 (5/6)
11. *Dasaiwah* = *penanggal/panglong* 9 changed into 10 (9/10)
12. Caturdasi = *penanggal/panglong* 13 changed into 14 (13/14)

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[1] This is a calendar system that contains 30 *wuku* (weeks), and every *wuku* consists of seven days (see Chatterjee, 1997).

[2] This is the system of a week in the Balinese calendar. There are several types of *wewaran* in the Balinese calendar, where every *wewaran* has different days from the others.

13. *Triyanca* = *penanggal/panglong* 2 changed into 3 (2/3)
14. *Saptaika* = *penanggal/panglong* 6 changed into 7 (6/7)
15. *Ekadasanca* = *penanggal/panglong* 10 changed into 11(10/11)

It means, two *penanggal* or *panglong* are counted for only one *penanggal* or *panglong*. For example, *Pancadasi* falls at *penanggal* or *panglong* 14, but at the same time it will be counted as *penanggal* or *panglong* 15.

These *sloka pengunalatri* will be combined with 10 *wuku pengunalatri,* which means two days in that week will be combined into one day. The length between two consecutive *wuku pengunalatri* is nine *wuku* (equals 63 days). These *wuku* are:

1. *Eka Sungsang*
2. *Dwi Tambir*
3. *Tri Klau*
4. *Catur Wariga*
5. *Panca Pahang*
6. *Sad Bala*
7. *Sapta Kulantir*
8. *Asta Langkir*
9. *Nawa Uye*
10. *Dasa Sinta*

The first word is an ordinal number. The second word is *wuku*. For example, *eka sungsang* means first is *sungsang*. There will be 30 combinations by pairing the *wuku* with *sloka pengunalatri* in sequence (*eka sungsang* will be paired with *pancadasi*, *dwi tambir* will be paired with *caturti*, and so on). These combinations will be used to determine *purnama* and *tilem*. Futhermore, these 30 combinations will be combined with the currently-used system for certain period of years.

20.3 *Pengalantaka Eka Sungsang Ka Paing*

20.3.1 Introduction

There are several formulations to determine *purnama* and *tilem* based on *wuku*, examples are *eka sungsang*, *eka wariga*, *eka juluwangi*. *Eka* means one; on the other hand, *sungsang*, *wariga*, and *juluwangi* are names of *wuku*. If *eka* and name of the *wuku* are combined, that *wuku* will become an epoch of *pengalantaka* (for example, *wuku sungsang* is an epoch of the *Pengalantaka Eka Sungsang* system) (see Ardhana, 2005, 2007; Bidja, 2011). Based on the results of a study by Hindu religious leaders in Bali and knowledge of the Balinese calendar Marayana (2015) said the most accurate formulation is *eka sungsang*. *Pengalantaka Eka Sungsang* has five types of divisions corresponding with its *pengunalatri*. Determining *pengunalatri* is based on *pancawara* and *saptawara* contained on *wuku sungsang*. These five division are:

1. *Pengalantaka Eka Sungsang Ka Umanis*, the first *pengunalatri* will fall at *Coma-Umanis Sungsang* (means that, it will fall at *Coma* or Monday with *pancawara Umanis*).
2. *Pengalantaka Eka Sungsang Ka Paing*, first *pengunalatri* will fall at *Anggara-Paing Sungsang* (means that, it will fall at *Anggara* or Tuesday with *pancawara Paing*).
3. *Pengalantaka Eka Sungsang Ka Pon*, first *pengunalatri* will fall at *Buda-Pon Sungsang* (it will fall at Wednesday or *Buda* with *pancawara Pon*).
4. *Pengalantaka Eka Sungsang Ka Wage*, first *pengunalatri* will fall at *Wrespati-Wage Sungsang* (It will fall at Thursday or *Wrespati* with *pancawara Wage*).
5. *Pengalantaka Eka Sungsang Ka Kliwon*, first *pengunalatri* will fall at *Sukra-Kliwon Sungsang* (it will fall at Friday or *Sukra* with *pancawara Kliwon*).

These five divisions of *Pengalantaka Eka Sungsang* start from *Pengalantaka Eka Sungsang Ka Kliwon* until *Pengalantaka Eka Sungsang Ka Umanis*, consecutively. The relevance of these divisions is based on the result of *paruman sulinggih* (meetings of Hindus religious leaders in Bali) conducted by the *Persatuan Hindu Dharma Indonesia* or PHDI (Indonesia Hindu Dharma Association).

At the *paruman sulinggih* on 25 July 1998 it was decided that from 1 January 2000 the *Pengalantaka Eka Sungsang Ka Paing* system should be enacted. Prior to this, the *Pengalantaka Eka Sungsang Ka Pon* system had been used. The transition from *pon* to *paing* caused a leap of two tithis from panglong eight to panglong ten. This was required to adjust *tilem* and *purnama* in CE 2000 so they were realistic. Actually, the *Pengalantaka Eka Sungsang Ka Paing* system had been valid from 1900 Saka to 1979 CE. In CE 1979, there was a big ceremony named *Eka Dasa Ludra* at Pura Besakih. This ceremony recurs every 100 years, and the next one will be in CE 2079. When this happens, the *Pengalantaka Eka Sungsang Ka Paing* system will come to an end and the *Pengalantaka Eka Sungsang Ka Umanis* system will start.

20.3.2 Formulations of the **Pengalantaka Eka Sungsang Ka Paing** *System*

Pengalantaka Eka Sungsang Ka Paing formulations are based on a combination of 15 *sloka pengunalatri* with 10 *wuku pengunalatri*. This system's epoch falls at Tuesday (*Anggara*) *paing*, *penanggal* 14/15. *Paing* is a *pancawara* system and *penanggal* 14 will be merged into one day with *penanggal* 15. On that day, there will be a Full Moon. The formulations are written in Table 20.1.

From Table 20.1, the *Pengalantaka Eka Sungsang Ka Paing* system was started with the Full Moon at *anggara paing sungsang penanggal* 14/15 (Tuesday *paing*, at *wuku sungsang*, 14 days after New Moon). These formulations will start from the first row of A column and end at the last row of C column. For example, this system's *pengunalatri* starts from *anggara paing penanggal* 14/15. Then the next

Table 20.1 *Pengalantaka Eka Sungsang* formulations, obtained from combinations of *wuku* and *sloka pengunalatri* and *wewaran* at wuku pengunalatri.

	A	B	C
I. *Eka Sungsang*	*Anggara Paing Penanggal* 14/15 *PURNAMA*	*Anggara Paing Panglong* 9/10	*Anggara Paing Penanggal* 4/5
II. *Dwi Tambir*	*Anggara Kliwon Panglong* 3/4	*Anggara Kliwon Panglong* 13/14 *Buda Umanis TILEM*	*Anggara Kliwon Penanggal* 8/9
III. *Tri Klau*	*Anggara Pon Panglong* 7/8	*Anggara Pon Penanggal* 2/3 Redite Umanis TILEM	*Anggara Pon Penanggal* 12/13 *Wrespati Kliwon PURNAMA*
IV. *Catur Wariga*	*Anggara Umanis Panglong* 11/12	*Anggara Umanis Penanggal* 6/7	*Anggara Umanis Panglong* 1/2 *Coma Kliwon PURNAMA*
V. *Panca Pahang*	*Anggara Wage Panglong* 15/ *Tanggal 1 TILEM*	*Anggara Wage Penanggal* 10/11	Anggara Wage Panglong 5/6
VI. *Sad Bala*	*Anggara Paing Penanggal* 4/5	*Anggara Paing Penanggal* 14/15 *PURNAMA*	*Anggara Paing Panglong* 9/10
VII. *Sapta Kulantir*	*Anggara Kliwon Penanggal* 8/9	*Anggara Kliwon Panglong* 3/4	*Anggara Kliwon Panglong* 13/14 *Buda Umanis TILEM*
VIII. *Asta Langkir*	*Anggara Pon Penanggal* 12/13 *Wrespati Kliwon PURNAMA*	*Anggara Pon Panglong* 7/8	Anggara Pon Penanggal 2/3 Redite Umanis TILEM
IX. *Nawa Uye*	*Anggara Umanis Panglong* 1/2 *Coma kliwon TILEM*	*Anggara Umanis Panglong* 11/12 *Sukra Wage TILEM*	*Anggara Umanis Penanggal* 6/7
X. *Dasa Sinta*	*Anggara Wage Panglong* 5/6	*Anggara Wage Panglong* 15/*tanggal 1 TILEM*	*Anggara Wage Penanggal* 10/11

pengunalatri will happen at *anggara kliwon panglong* 3/4 (tuesday *kliwon*, at *wuku tambir*, 4 days after New Moon) and move until the end of the column. Then start again at the first row of B column and move until the last row on C column. When these formulation ends, it will start from *anggara paing sungsang* again at *penanggal* 14/15, making it form a cycle. One turn of the cycle is called *nemugelang* (*nemu* means find, *gelang* means bracelet). This cycle will stop after the *pengalantaka* system is changed. One *nemugelang* equals 270 *wuku* or 1890 days. Every rotation, there will be 64 Full Moons and 64 New Moons. There will be 34 months that have 30 days, and 30 months that have 29 days.

20.3.3 *The* Pengalantaka Eka Sungsang Ka Paing *Diagram*

The *pengalantaka* diagram is a circular diagram that has symbols and lines on it. This lines are made to divide the diagram into several parts. In Fig. 20.1 we can see many symbols and codes.

From Fig. 20.2 we can have a closer look at the diagram. The red circles represent *purnama* and black squares represents *tilem*. We can see at Fig. 20.2b that there are seven two-letter codes that are arranged radially and represent *saptawara*, and

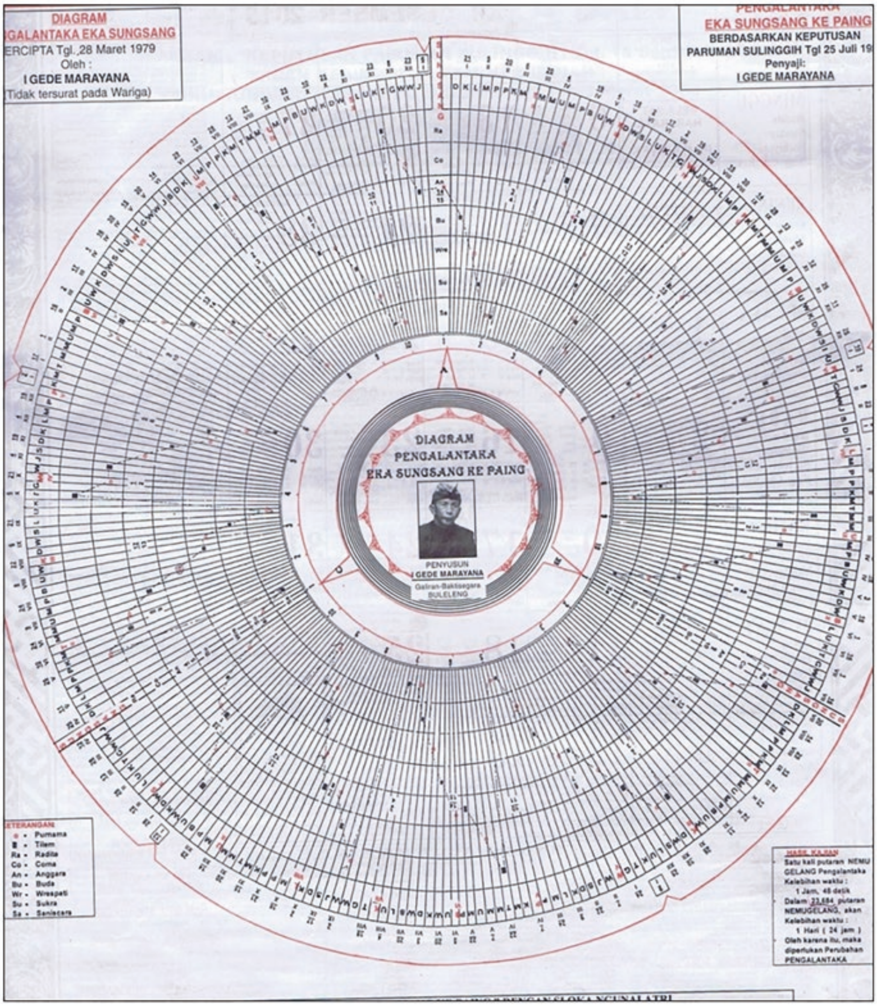

Fig. 20.1 The *Pengalantaka* Diagram. Circle diagram with several lines, codes, and symbols. At the center there is the face of the creator of this diagram, I Gede Marayana. The letters that surround the diagram and are located before the outermost black ring are wuku.

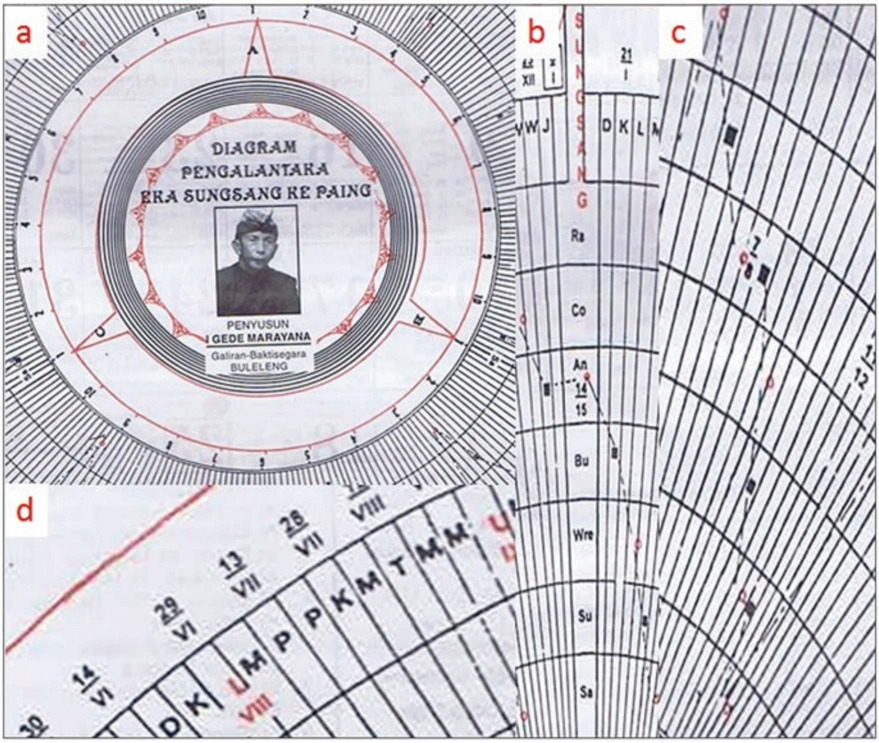

Fig. 20.2 (a) A closer look of the center of the diagram. There are A, B, and C letters corresponding to *pengunalatri* of the *Pengalantaka Eka Sungsang Ka Paing* as explained in Sub-section 20.3.2. Numbers 1 to 10 are indicators for every 10 *wuku*. (b) A closer look of the diagram. There are two letter codes that are arranged radially. (c) A closer look of the middle part between the innermost and the outermost black rings in the diagram. There are black squares and red circles that represent *tilem* and *purnama*, respectively. There are two numbers in the middle, and these are *pengunalatri* for this system. (d) A closer look near the outermost black ring of diagram. The letters are *wuku*. Below the red-colored letters there are Roman number that are used to indicate *pengunalatri*. Outside the black ring there are Arabic numbers and Roman numbers.

from Fig. 20.2d there are one-letter codes that surround the diagram and represent *wuku*. From this, there will be combinations of *wuku* and days for determining Full Moon and New Moon. Some of one-letter codes (*wuku*) are colored red. Below it, there are red-colored Roman numbers that indicate *pengunalatri* explained in Sub-section 20.3.2. From Fig. 20.2a, the numbers from one to ten (that circulating near the center of diagram) are the same as the Roman numbers under the *wuku* code, and are used to make the diagram easier to read. There are also A, B, and C that correspond to *pengunalatri* (see Sub-section 20.3.2, Table 20.1). There are also Roman numbers and Latin numbers around the outside of diagram. These numbers were originally used to mark the beginning of *wuku* in the year this diagram was made, so those numbers can no longer be used. *Purnama* or *tilem* are determined by combinations of *wuku*, *wewaran*, and *sloka pangunalatri* as we can see at Fig. 20.2c.

When reading this diagram, we compared the data it provided with calculations of the Balinese calendar provided by Sudharta et al. (2013).

20.4 Discussion

20.4.1 Analysis of the Period of the Pengalantaka *System*

One period of *nemugelang pengalantaka* equals 1890 days. The synodic period of the Moon equals 29 days 12 hours 44 minutes 3 second or 29.53059 days. There will be 64.00143038 months in one period of *nemugelang pengalantaka*. This is based on the data for one period of *nemugelang pengalantaka* and one period of Moon synodis. This means that there will be 64 *purnama* and 64 *tilem* in one *nemugelang*. As you can see, there is an excess of 0.00143038 months per *nemugelang*, which equals 1 hour 49 seconds. Because of this excess, at 23.68055292 *nemugelang pengalantaka* or about 122.5 years, there will be an excess of about one day. This one-day excess causes determination of *purnama* and *tilem*, using the cycle of the *Pengalantaka Eka Sungsang Ka Paing*, one-day faster than 'true' *purnama* and *tilem*. Because of this, we need the new cycle after the end of *Pengalantaka Eka Sungsang Ka Paing*, *Pengalantaka Eka Sungsang Ka Umanis*.

In reality, the period of a *pengalantaka* will be valid for 100 years. This is because the *Eka Dasa Ludra* ceremony is only performed in the Besakih Temple every 100 years, when the *paruman agung* (religious leader meeting) will discuss changing the *pengalantaka* system.

20.4.2 Analysis of the Pengunalatri *on System*

Day reductions (*pengunalatri*) are required in this system. If there are no day reductions, the durations of both *penanggal* and *panglong* will equal 15 days, and one month will be equal to 30 days. Thus, for one *nemugelang* (64 months) cycle there will be 1920 days. If we use one month that equals the synodic period of the Moon (29.53059 days), then one *nemugelang* cycle will equal 1889.95776 days or about 1890 days. There will be a difference between a 30-day month and a synodic month, about 30 days for *nemugelang pengalantaka* cycle. This means that there is an excess of about one day in every 63 days (or 9 *wuku*). That is why in every 63 days there must be a reduction of one day, so that the duration of *penanggal* and *panglong* will not always have 15 days, but sometimes 14 days, depending on when *pengunalatri* will happen (one month will be equal to 29 days because of *pengunalatri*).

20.4.3 Comparison of the **Pengalantaka Eka Sungsang Ka Paing** *System and Astronomical Calculations*

The comparison of the *Pengalantaka Eka Sungsang Ka Paing* system and astronomical calculations is required to know whether the system can still be used or not. Therefore, in this section we will compare the *Pengalantaka Eka Sungsang Ka Paing* system with astronomical calculations derived from the following website about the phases of the Moon: http://aa.usno.navy.mil/data/docs/MoonPhase.php.

In the Balinese Calendar the day starts at 06.00 AM Indonesia Central Standard Time (ICST/ UTC+8). If in the astronomical calculation *purnama* and *tilem* occur after *pengalantaka* before 06.00 AM ICST, then *purnama* and *tilem* based on *pengalantaka* are the same as the astronomical calculations. As an example, suppose New Moon occurred on 12 November 2015 at 1.47 AM ICST based on astronomical calculations. *Pengalantaka* says New Moon occurred at 11 November 2015. But p*engalantaka* is not wrong because 11 November 2015 in the Balinese Calendar ends at 5.59 A.M. ICST and New Moon occurred at 1.47 A.M ICST. We compared the astronomical data of *tilem* and *purnama* from 2015 until 2080. We choose 2015 because we started the research on the Balinese calendar in 2015, and 2080 because this year is one year after the prediction of *the Pengalantaka Eka Sungsang Ka Paing* system is valid (since it will end in 2079). We wanted to see the difference in *purnama* and *tilem* predictions based on the *pengalantaka eka sungsang ka paing* system and astronomical calculations.

In the comparison, from August 2015 until December 2080, there are 133 *tilem* and 131 *purnama* that do not happen in the same day as the astronomical calculations from a total of 809 *tilem* and *purnama*. There is a one day difference between the *Pengalantaka Eka Sungsang Ka Paing* calculation and the astronomical calculation. But, there are *tilem* data that show two 2-days difference, i.e. in March 2018 and March 2026. The reason for these different results relate to differences in the assumptions used. The *Pengalantaka Eka Sungsang Ka Paing* system assumes that the synodic period of the Moon is 29.53 days while in the astronomical calculations the synodic period of the Moon ranged from 29.26 days to 29.80 days because of perturbation of the Moon's orbit by the Sun.

Further analysis for the period 2015–2080 shows that the *Pengalantaka Eka Sungsang Ka Paing* system is the best to use from 2040 to 2080, with a difference of 45 *tilem* and 42 *purnama* from a dataset of 516 *tilem* and *purnama*. From this analysis, we need to check the enforceability of *Pengalantaka Eka Sungsang Ka Paing* after 2079. But, in this era the *Pengalantaka Eka Sungsang Ka Paing* is the best system even though there is a one day difference compared to the astronomical calculations. However, this difference causes no problems because the determination of *purnama* and *tilem* contains religious meaning.

20.5 Concluding Remarks

Pengalantaka is a system used to determine Full Moon and New Moon in the Balinese calendar. Today Hindus in Bali use *Pengalantaka Eka Sungsang Ka Paing*. It can be used for about 100 years based on a decision of a ceremony held in Pura Besakih. After this system ends, it will be turned into *Pengalantaka Eka Sungsang Ka Umanis*. There are day-reductions (*pengunalatri*) in this system due to synchronization with Moon's synodic period. From astronomical calculations we found that there were 133 New Moons and 131 Full Moons in this system that occur on different days between August 2015 and December 2080. This is not a significant problem because Hindus in Bali tend to use the Balinese calendar to determine the phases of the Moon to pinpoint ceremonies, rather than using astronomical calculations or naked eye observations. Nevertheless, further research is needed to learn more about the *pengalantaka* system in general.

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Part IV
Southeast Asia in Regional Context

Chapter 21
Possible Influences of India on Southeast Asian Astronomy: A Brief Review of the Archaeoastronomical Record

Mayank N. Vahia and Srikumar M. Menon

21.1 Introduction

Migrations date back to very early periods in the history of humankind. The history of migrations embodies narratives of early experiences and the devising of new ways of adapting to the new environments encountered. Migrations also lead to exchanges between cultures, which allow people to adopt good ideas and progress. Communication of good ideas, adoption of relevant ideas and the creating of new ones are the hallmark of human cultures (see e.g. Bromham et al., 1999; Kielan-Jaworowska et al., 2004; Vahia et al., 2016).

Such connectivity seems to be particularly strong between the Indian Subcontinent and Southeast Asia. It has involved not only taking some of the Indian traditions to Southeast Asia but also rulers from Southeast Asia, such as the Ahoms, ruling parts of the present-day India. The two groups have connected genetically as well as culturally, and have enriched each other.

Cultural contacts between India and Southeast Asia in historical times, and reflection of these in temple-building traditions, is well studied, especially in historic periods. The nature of these contacts involved "… an intense exchange of ideas, knowledge systems, objects and people traversing vast expanses over land and seas …" (Dhar, 2018: 325). The influence of India on monument-building traditions in Southeast Asia is most evidently seen in the surviving temples built of stone, as well as brick, which date to the seventh-eighth centuries CE and later periods

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(Dhar, 2018). Dhar (ibid.) also outlines a need to investigate the transmission of architectural ideas and forms between the two regions from periods earlier than this.

India is rich in megalithic monuments, prehistoric monuments generally associated with the Indian Iron Age, especially in the peninsular portion, though prominent pockets of megalithism are also encountered in other parts of the country (Brubaker, 2001). These monuments, usually (but not necessarily) built of large blocks of stone, generally predate temples, and at least in some cases are thought to be architectural precursors to certain monument types, like stupas (Menon, 2016, 2018) and memorial temples (Menon, 2014, 2017, 2018). Indian megaliths come in a vast variety of forms (Menon, 2012a; Moorti, 1994, 2008) and at least some of them display definite astronomical intent in their design and layout (Menon et al., 2012, 2014). The knowledge systems embedded in these prehistoric monuments are also echoed in many later monuments, like Sun-facing temples (Menon, 2019a). Megaliths are also known to occur in Southeast Asia (Akbar, 2017; Munandar, n.d.), and Von-Furer Haimendorf (1964) has suggested that there is a single megalithic complex extending from the Naga and Khasi Hills, in Northeast India through Sumatra to Flores in Southeast Asia.

We have simulated, with the help of a mathematical model, the possible migration of humankind from India to Southeast Asia, in prehistoric periods. We present below the results of the modeling, and also examine the possibility of cultural exchange in various periods ranging from the megalith-building periods to the periods of temple-building, from examination of the archaeological record.

Studies of cross-cultural influences between India and Southeast Asia will benefit substantially if researchers in these regions share details of different monument types from various phases in history and prehistory, on a common platform. This chapter is intended to provide an impetus for such collaboration.

21.2 Simulation of Human Migration From India to Southeast Asia

Human migration and settlement patterns can be thought of as driven by human desire to live on flat land close to food and water, which permits simulation of the movement of humans (Vahia et al., 2016) in actual landscapes. Dividing the Indian subcontinent and neighbouring regions into small regions whose geographical conditions (flatness, altitude and proximity to water body) are known, one can insert a human population anywhere on the continent and simulate its migration to regions based on their absolute habitability, environment and the population density present in the region, and map the patterns of such migration (ibid.).

Fig. 21.1 below presents the results of one such simulation. Starting with Central Asia, one can understand the movement of humans over time. In the map, the landmass is divided into squares of 8 km by 8 km and movement is considered based on human wanderlust and habitability of the landscapes involved. Each step in time

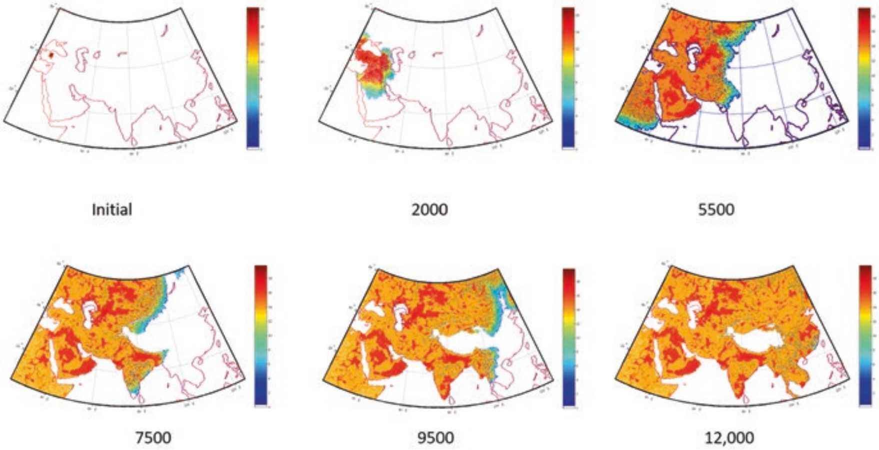

Fig. 21.1 A computer simulation of the migration pattern of *Homo sapiens sapiens* in the Eurasia area (after Vahia et al., 2016).

corresponds to about 8 years and the number at the bottom of each figure detail the steps of the simulation starting from Central Asia.

The simulation makes it clear that the existing populations in Southeast Asia would have encountered migrant groups from South Asia long before they encountered groups from China, and indeed there should be significant genetic similarity between early residents of present day South China and the people of South East Asia. It also highlights patterns of large settlements in various regions that agrees well with the population distribution today suggesting that the simulation provides an accurate picture of human migrations (Vahia et al., 2017).

Clearly this suggests significant cultural connectivity between the people of South East Asia and the Indian subcontinent (ibid.). As these groups settled in their environment and became aware of the long term changes in seasons and association with the location of sunrise, it is quite probable that they began building markers to keep track of the Sun and astronomy took root (Vahia, 2016).

21.3 Megalithic Traditions in India and Southeast Asia

21.3.1 The Megalith-building Tradition in India

Megaliths are mostly sepulchral or memorial monuments that were erected over a large geographical region within the boundaries of the present-day state of India during prehistoric periods. A large fraction of the megaliths in India is concentrated in Southern India, although prominent pockets of megalithism are also encountered in the Vidarbha region of Maharshtra, Kashmir, Kumaon, Jharkhand etc. (Brubaker, 2001). A vibrant megalithic tradition is also seen in the states comprising Northeastern India, with a living tradition of erecting megaliths persisting in some of these areas. The megaliths of peninsular India are widely believed to have been erected during the South Indian Iron Age, or approximately between 1500 and 500 BCE (Bauer et al., 2007), although the origins of megalithism could date even earlier (Menon, 2018). Production and use of megaliths could also have persisted into later periods, like the Early Historic period, and it is increasingly felt that looking at megaliths as monuments strictly of the Iron Age is inaccurate (Morrison, 2009).

Indian megaliths display a wide variety in forms, ranging from a single erect stone called a menhir (Fig. 21.2), or rings of boulders encircling burials, called

Fig. 21.2 A menhir at the megalithic site at Nilaskal, Karnataka. This is part of a larger layout of many menhirs, known as a stone alignment.

Fig. 21.3 A large stone circle at a megalithic site in the Cauvery Wildlife Sanctuary, Karnataka. The loose stones within the circle once formed a mound, called a cairn, before it was disturbed.

Fig. 21.4 An elaborate portholed dolmen, with two slab circles surrounding it, at Mallasandram, in Tamil Nadu.

Fig 21.5 A *kudakkal*, made of the soft and porous laterite stone which is endemic to Kerala.

stone circles (Fig. 21.2), to complex arrangements of stone slabs to form dolmens, sometimes with encircling rings of stone slabs (Fig. 21.4). Detailed discussions of the entire repertoire of megalithic forms can be found in Moorti (1994) and Menon (2012a). Though most of these megalithic forms can be encountered throughout their range of occurrence, certain forms are more commonly encountered in certain regions (Brubaker, 2001), while a few forms are endemic to some regions (Menon, 2012a). For instance, the mushroom-shaped *kudakkal* (Fig. 21.5) is endemic to the laterite-rich regions of Kerala. Note that unless stated, all of the photographs in this chapter were taken by the second author.

Though megaliths are believed to be the sepulchral or memorial monuments erected by some prehistoric cultures, the purpose of some megalithic structures is still debated. Stone alignments are large numbers of menhirs erected in a geometrical pattern, usually a square or rectangular grid, or a staggered grid (Fig. 21.6). Menhirs have been encountered in sepulchral as well as non-sepulchral contexts (Menon, 2018), but stone alignments are usually non-sepulchral monuments whose purpose is unresolved.

Fig. 21.6 One of the largest stone alignments in India, at Hanamsagar, in Karnataka. The portion near the center of frame is disturbed by agricultural activity.

21.3.1.1 The Megaliths of Northeast India

As mentioned earlier, megaliths are also found in widely separated geographical contexts, like the Kashmir Valley and Northeast India. Megaliths of various forms are found from the Jaintia and Khasi Hills of Meghalaya, and the Karbi Anglong in Assam, to the Naga Hills (Sarma and Hazarika, 2014). It is generally understood that the megalith-building tradition in Northeast India, like the megalithic tradition of Kashmir Valley, is culturally distinct from the megalithism of peninsular India, though more focused studies have to be conducted to rule out cultural contact. Though some of the megaliths of the Jaintia Hills, for instance, at the well-known megalithic site of Nartiang (Fig. 21.7), look older because of their rough and unfinished appearance, in several places like the Khasi Hills, megalithism is a living practice (Hutton, 1926). From such living megalithic practices, we are able to understand that erect stones commemorate male ancestors (Fig. 21.8), while horizontal slabs propped up on stone supports (Fig. 21.9) commemorate female ancestors. Clan ossuaries, containing relics of deceased members of each clan, are common. Generally, in the matrilineal Khasi tradition, it is common to find one horizontal slab, propped up on smaller boulders (sometimes classified as a ‘dolmen’) commemorating the clan mother, and three, five or more erect stones behind, commemorating her brothers (Fig. 21.10). However, there are other sites, like the

Fig. 21.7 A portion of the large megalithic site at Nartiang, in the Jaintia Hills of Meghalaya.

ancient iron-smelting site of Rangjyrteh, near Sohra, or Cherrapunji, which has layouts of a large number of megaliths (Fig. 21.11), some of which are in unique arrangements. Generally, the Khasi monuments appear well-worked, with rounded tops, compared to the Jaintia monuments.

In Nagaland, menhirs are erected not only to commemorate the dead, but also as memorials to social accomplishments, such as "Feasts of Merit" (Von-Furer Haimendorf, 1964). Von-Furer Haimendorf (1964: 222) states that "… the same ideas seem to lie at the root of the megalithic cultures of Indonesia and thus suggest a unity of the megalithic complex extending from Naga and Khasi Hills over Nias and Sumatra to Flores, Ambon and Ceram."

21.3.1.2 Astronomical Intent in the Layout of Some Indian megaliths

Astronomical intent, or sometimes evidence of astronomical knowledge, as embedded in the design and layout of structures, has been detected in megalithic monuments at several places in the world (Hadingham, 1983; Ruggles, 1999). In Indian monuments, astronomical intent has been reported in some stone alignments, like Nilaskla and Byse in South Karnataka (Menon et al., 2012, 2014), Hanamsagar (Rao, 2005) and Vibhutihalli in South Karnataka (Rao and Thakur, 2010), and several sites in Jharkhand (Das, 2018).

Fig. 21.8 An erect menhir which commemorates a male ancestor, at Nartiang.

The most common type of intentional astronomical orientation in Indian megaliths appears to be alignments to points of astronomical significance on the local horizon, like sunrise and sunset points on the shortest and longest days of the year (Menon et al., 2012, 2014). For instance, pairs of menhirs appear to frame the rising and setting sun during the solstices at Nilaskal (Fig. 21.12) and at Byse. The men-

Fig. 21.9 A horizontal stone slab supported on smaller rocks, which commemorates a female ancestor, at Nartiang.

hirs forming the foresight and backsight are well separated along the line of sight. In addition, it was noticed that the same stones pair up with different menhirs for framing the rising/setting sun on the two solstices (Menon et al., 2014). It has been demonstrated that such alignments could not have arisen by chance (Menon, 2012b). The meaning this alignment held for its builders is lost to us; it could either have been a calendar device to reckon time, or an alignment of 'magical' importance to ancestor worship. However, the knowledge of astronomy extant in the culture which built these monuments remain embedded in their design and layout, giving us important clues to the knowledge systems possessed by the megalith builders.

21.3.1.3 Continuity of Architectural Traditions from Prehistoric to Later Times

The monuments which succeeded the megaliths in their range of distribution in peninsular India are stupas, which became popular as commemorative worship places for the relics of the Buddha, and temples, the earliest surviving specimens of which date no further back than the fourth century CE. Many Buddhist stupas which survive date back to the period of Mauryan rule in India, though most of them had been enlarged and embellished by subsequent ruling dynasties. Several researchers have pointed out the possible links between megaliths and both stupas and temples (Kramrisch, 1976; Menon, 2018; Schopen, 2010; Venkataramanayya, 1992).

Fig. 21.10 A recently built set of megaliths, with the 'dolmen' commemorating a clan ancestress, and the three menhirs commemorating her brothers, near Nartiang.

Several of these studies point out that in a large number of cases (too large to be mere coincidences) later monuments like stupas and temples were erected in already existing megalithic sites, without destroying the megaliths, thus suggesting that the megaliths were of cultural significance to the stupa-and temple-builders. In some cases, it appears that the later monuments are carrying forward the tradition of commemoration (Menon, 2014, 2017, 2018).

It has been demonstrated how the stupa could have evolved from the simple burial mound or megalithic cairn, the principles of evolution being the necessity of structural innovation to build larger and more prominent mounded structures (Menon, 2016). An example of an intermediate stage in this evolution is a ruined megalith at Mallasandram, near Krishnagiri in Tamil Nadu, South India (Fig. 21.13).

In the case of temples too, several studies have shown links between prehistoric megaliths and later temples (Menon, 2014, 2017, 2018; Venkataramanayya 1992). Kramrisch (1976) has suggested that the dolmen was the inspiration for the flat-roofed temple. The Pattadakal group of temples in the Malaprabha Valley of North Karnataka, a World Heritage Site, has, in addition to its celebrated large temples, numerous small shrines, some of them resembling dolmens in construction (Fig. 21.14). It is possible that this is a complex of commemorative temples, known examples of which (Fig. 21.15) exist in the Malaprabha Valley (Menon, 2014, 2018). Even in the case of megaliths of Northeast India, we find places of worship

Fig. 21.11 The megaliths of Rangjyrteh, near Cherrapunji in Meghalaya.

Fig. 21.12 Two widely separated menhirs framing the setting sun during winter solstice at Nilaskal, Karnataka.

Fig. 21.13 A megalithic dolmen at Mallasandram, surrounded by a ring of closely set stone slabs and rubble mound within (mostly disturbed by vandals), which resembles a stupa in construction.

Fig. 21.14 A small shrine at the Pattadakal group of temples in Karnataka, a World Heritage Site, which is constructed in a similar manner as a dolmen. The bigger temples of the site can be seen in the background.

Fig. 21.15 A memorial temple at Huligyemmanna Kolla, near Pattadakal. An inscription near the entrance portal identifies it as a memorial, possibly even sepulchral temple.

coming up in close proximity to earlier megalithic sites (Fig. 21.16), something that needs to be studied further.

Thus, it is quite possible that megaliths inspired at least certain types of temples in later times, though other influences determined the various categories of forms that regional variants of temples assumed.

21.3.2 Megalith-building Traditions in Southeast Asia

Reports on megaliths in Southeast Asia (Akbar, 2017; Munandar, n.d.) suggest similarities with the megalithic traditions of Northeast India. Munandar (ibid.) reports a living tradition of construction of menhirs and dolmens in the manner of Northeast India. From his quote of the description by Soekmono in 1973, it appears that the "… stone table with menhirs as legs …" is similar to the structure commemorating female ancestors in Northeast India, and "… pillars of stone …" are erected to commemorate male ancestors. He classifies the traditional form of granaries and megaliths as sacred structures, and traces cultures with and without contact with Indian mythology. He also reports slab dolmens containing human skeletal remains, which seem to be similar to the ossuaries of Meghalaya.

Fig. 21.16 The Durga Temple at Nartiang, with megaliths in the foreground.

Both Munandar (ibid.) and Akbar (2017) report menhirs with details of human figures sculpted on them. Munandar reports the erection of menhirs "… with a simple form, static figure, without legs …", and he mentions only facial features carved in shallow relief upon the stone, in Indonesia. Akbar (2017) reports a three-sided menhir with sculptured reliefs on all three sides, from Mount Tilu in Kuningan, West Java. These recall the anthropomorphic figures (Fig. 21.17) associated with the megalithic tradition in South India, and subsequent hero stones, erected in medieval times, to commemorate valorous deaths (Fig. 21.18). Dolmens with the inside surface of the rear stone engraved with figures of the dead person being commemorated are also common in South India (Fig. 21.19). It is believed that the early commemorative stones were bare memorial stones, without sculptural relief, while in later periods, crude shaping to resemble a gendered human figure and figures in shallow relief were commonly employed.

Steimer-Hermet (2018: 1) gives a comprehensive picture of the various types of megalithic constructions in Indonesia, and assigns their creation to two periods.

> The first began in the 7th and 8th centuries in East Java and spread to the rest of the island, South and Central Sumatra and Lore Lindu in Central Sulawesi. It persisted in these regions until the 13-15th centuries. The second period stretches from the 16th century to the present, and in some ways is a continuation of the first but encompassing other islands and regions: Sumba, Flores, Nias, North Sumatra by the Batak and Central Sulawesi with the Toraja.

Fig. 21.17 A crude anthropomorphic figure at the Archaeological Museum at Aihole, Karnataka. It was found at the megalithic site at Meguti Hill in Aihole.

From the descriptions and photographs, several megalithic forms appear to resemble their counterparts in peninsular India as well as Northeast India, although some forms seem endemic to the region.

In his discussion of the “Megalithic culture of Indonesia” Perry (1918) describes the term “… to include not merely the East Indian Archipelago, to which it is usually applied, but also Assam, Burma, the Malay Peninsula, the Philippine Islands,

Fig. 21.18 A hero stone commemorating a deceased couple at Avathi, near Bangalore, Karnataka.

and Formosa, which are inseparably linked with it by racial and cultural bonds." However, he speaks of evidence suggesting connections between India and Java as early as 700 BCE, and regular commerce between these regions.

It is clear that the links between the megalithic complexes in peninsular India, Northeast India and Indonesia merit further study.

Fig. 21.19 A dolmen with a sculptured rear slab at Avathi, Karnataka, commemorating a warrior who died in battle.

21.3.3 Possibilities of Cultural Contact and Transmission of Megalithic Traditions

Megalithism, or the cultural trait of erecting large structures in stone, ostensibly to mark interments of human remains or as memorials, appears to be a worldwide phenomenon. The similarities in form between megaliths in vastly separated regions of the world had led antiquarians and other early researchers on megaliths to hypothesize a 'megalithic culture' which originated in one place and diffused to other regions over time (Moorti, 1994). Modern archaeology discredits such 'diffusion theories' and believes that most megalithic traits are indigenous, with several independent centers of origin, although 'modified diffusionism' involving diffusion of ideas finds more favour with the archaeological community (ibid.). However, considering the mass of data available today, and considering similarities in even detailing of components such as portals of dolmens etc. it might be time to revisit the thorny problem of origins and possible spread of megalithism (Menon, 2019b).

In this perspective, it would be beneficial to cast a detailed look at the megalithic complexes in peninsular India, Northeast India and Indonesia, and also situate these within the framework of megalithic structures worldwide. A lot of information is embedded in the monuments themselves, in the crafting and detailing of the various components such as orthostats, portholes, portals etc. (Menon, 2018) and detailed comparisons can suggest possibilities of influence, which can be followed up through other methods of investigation.

From the knowledge of astronomy evident from the design of at least some of the Indian megaliths, it is clear that those who designed them had an intimate understanding of at least the solar cycle, i.e., the extreme points of sunrise and sunset on the local horizon, and that these were somehow of sufficient importance in their cultures to warrant incorporation of alignments to these points.

It is important to examine more monuments and monument types in South India for such embedded astronomical knowledge, as well as to look for the existence of such knowledge in the megaliths of Northeast India and Indonesia. Knowledge systems are often shared between regions that have cultural contacts with each other, and examination of this aspect can complement other studies of contact between India and Southeast Asia.

21.4 The Temple-building Traditions in India and Southeast Asia

21.4.1 A Brief Overview at the Temple-building traditions in India

The oldest places of worship in India date back to at least the late Paleolithic, as suggested by a stone used for worship, on a rubble platform excavated at Baghor I, Madhya Pradesh (Paddayya and Deo, 2017). However the earliest places of worship associated with historic religions may have originated in the first few centuries BCE. Many of the early temples were rock-cut sanctuaries, hewn out of living rock, like the Barabar and Nagarjuni Caves in present-day Bihar, excavated during the rule of the Mauryan Emperor Asoka. The earliest structural temples visible in the archaeological record in India date to the early centuries CE (Deva, 1969; Srinivasan, 1972), although the earliest fragmentary record of a brick and timber temple is from third century BCE, at Bairat, Rajasthan (Deva, 1969). The earliest temples were made of perishable materials such as timber and thatch, and later temples replicated these forms in stone.

Though stone was increasingly preferred as a medium to construct temples from the fifth century CE onward (Dhar, 2018), it was by the sixth and seventh centuries CE that Indian temples in stone had more or less developed distinct idioms of construction, with certain forms being more prevalent in certain regions. For instance, the *Nagara* tradition (Fig. 21.20) was more prevalent in northern India, while the *Dravida* tradition (Fig. 21.21) was commonly encountered in the south (Hardy, 2012), a division that was more or less crystallized by the sixth and seventh centuries. Hardy (2012) points out, though, that neither tradition was strictly confined to any specific geographical region. These are only two of many other traditions that showed regional characteristics, such as, for instance, the *Kalinga* tradition of temple building in the Orissa region.

Fig. 21.20 A temple at Pattadakal, built in the eighth century CE, in the northern *Nagara* idiom of temple architecture.

Fig. 21.21 Another temple at Pattadakal built in the southern *Dravida* idiom, also in the eighth century. Pattadakal is one of the rare sites where there are temples in the two different idioms adjacent to each other.

All these traditions evolved over time and developed complex forms within the bounds of a given tradition. An example is the transformation of the forms of the components of the *Dravida* tradition to give rise to the *Vesara* temple-type in the *Karnata Dravida* idiom (Figs. 21.22 and 21.23) of temple construction (Hardy, 2012).

Thus we see that the temple building tradition in India, which originated in structures built of perishable materials before the advent of the Common Era, gets codified into distinct regional types with their typical components and logic of construction, by the sixth century and evolves over later periods.

21.4.1.1 Astronomy in Indian Temples

Astronomical themes are represented in Indian temples at several levels—ranging from depictions of themes and myths of an astronomical nature on structural components (Fig. 21.24), astronomical deities like the Sun (Fig. 21.24) and planets, guardians of the directions, and orienting temples to permit direct sunlight into the sanctum on specific days (Menon 2019a). The cult of Sun Temples became quite dominant in the tenth-eleventh centuries, though the practice of building Sun Temples had begun much earlier. Sun-facing structures, ranging from a small rock-cut sanctuary (Fig. 21.26) to elaborate structural temples (Fig. 21.27), are known.

Fig. 21.22 The Mukteshwara Temple at Chaudadanapura, Karnataka, built in the evolved *Vesara* idiom, in the eleventh century.

There exist several known cases of interaction of structural temples with the solar cycle, with sunlight penetrating the sanctum on certain dates of the year (Rao and Thakur, 2011; Vyasanakere et al., 2008), or interacting otherwise with the temple structure (Shylaja, 2007). The festival known as *Kiranotsava* (literally, festival of the Sun-ray) at the Mahalakshmi Temple at Kolhapur, is an example of the former. The rays of the setting Sun penetrate to various extents inside the sanctum of the west-facing temple twice in a year, between 31 January and 2 February and between 9 November and 11 November (Fig. 21.27).

Zodiacal stones (Fig. 21.28), which formed part of the ancillary structures of some temples, are also well-known, and were worshipped.

21.4.2 A Brief Overview of Temple-building Traditions in SE Asia

In Southeast Asia, well-preserved temple structures exist from about the seventh century onwards, though fragmentary remains of earlier structures are present in the archaeological record, and in references in the literature (Dhar, 2018). The influences of India on city design (see Saelee et al., 2021) and temple architecture in Southeast Asia is well documented (Freeman and Jacques, 1999; Keay, 2000; Khairunnisa et al., 2021):

Fig. 21.23 The Lakshminarasimha Temple at Hosaholalu, Karnataka, built in a further evolved *Vesara* idiom, in the twelfth century.

Fig. 21.24 A motif symbolizing a lunar eclipse, shown as a snake nibbling at a disc, on the external wall of a temple at Kavaledurga, Karnataka.

Fig. 21.25 An icon of Surya, the Sun God, depicted on the ceiling of a temple at Pattadakal.

> Several thousands of temples, built within a time span of about a thousand years, before the fourteenth century, stand witness to the creative geniuses of different communities of Southeast Asia. They also testify to the … cultural dialogue between India and Southeast Asia centered on the architectural and planning experiences as coded in the *silpasastra* texts of India. (Sahai, 2012: v–vi).

Fig. 21.26 A Sun-facing small rock-cut cave at Badami, Karnataka. The rising Sun illuminates the rear wall of the cave throughout the year after it rises above a sandstone mountain ridge opposite.

However, Dhar (2018) cautions that to see the process of temple-building in Southeast Asia as ‘Indianization’ would be erroneous, and more emphasis should be given to the ‘localization’ process. With the example of the Candi Arjuna in Central Java, Dhar (2018) points out the similarities with Indian temples such as the manner in which the distinctive storeys of the superstructure of the Candi Arjuna resemble those of the seventh century temple called Upper Sivalaya at Badami, in Karnataka (Fig. 21.29), while also showing how many of the building components have a distinctive Javanese character: “The formality and logic of Candi Arjuna certainly reveals Indian influence, but it also indicated processes of localization that had begun to mature into a distinctive architectural language by this time.” (Dhar, 2018: 332–333).

Dhar (2018: 330) also feels that “… the beginnings of the transmission of architectural ideas and forms between India and Southeast Asia need to be investigated from a period earlier than that of the earliest, well-preserved seventh-eighth century temples from Southeast Asia.” Dhar (2016) outlines the possible evolution of temples of Campa from modest beginnings with no more than a tree-shaded platform to structures with light roofs of wood and tiles to more elaborate structures.

In India, as well as Southeast Asia, the challenge to understanding the origins of the trajectories that temple architecture took, lies in the difficulty of finding examples which survive from the early formative periods, when temples were built out of perishable materials. Some clues persist in representations of these early shrines of wood and thatch as embellishments of early stone monuments, such as the second

Fig. 21.27 Sunlight penetrating the sanctum of the Mahalakshmi Temple at Kolhapur, Maharashtra, during the *Kiranotsava*.

century CE Buddhist stupa at Kanaganahalli, in north Karnataka (Fig. 21.30). According to Dhar (2018), such representation of earlier building traditions in wood and brick, as ornament or embellishment, also exist in Southeast Asian temples,

Fig. 21.28 A zodiacal stone which used to be worshipped, at the Amruteshwara Temple at Amritapura, Karnataka.

exemplified by the ‘flying palaces’ carved on the exterior walls of the brick temples at Sambor-Prei-Kuk.

Dhar (2018) also examines the concept of the mythical mountain Meru, which dominates forms of Indian and Southeast Asian temples. Meru as the mountain of the gods and the center of the Universe permeates Hindu, Buddhist as well as Jain cosmology, and is the underlying imagery for conceiving the form of temple superstructures (Fig. 21.31). Vatsyayan (2015), Dhar (2015) and Menon (2019c) discuss in detail how temple towers, or *shikharas*, in India, irrespective of region, are conceived as a model of Meru. Dhar (2018: 338) discusses the image of Meru as an idea that spread from India to Cambodia, not an architectural model:

> Despite a known shared basis for temple forms in ancient India and Cambodia, the transmission of influence in this case cannot be classified as a formal correspondence. Rather, it reveals transference of an idea or text – a “mental” image, which journeys across. When translated to materiality, it results in the … composition and formalization of a new type of monumental architecture …

These refer to the celebrated ‘temple mountains’ of Cambodia, such as the Ta Prohm Temple (Director General, ASI, 2006), the most evolved form of which is represented by the twelfth century temple at Angkor Wat.

This claim of “… visualizations of the Meru of Indian textual discourse … [assuming] forms that have no close parallels on Indian soil …” (Dhar, 2018: 338)

Fig. 21.29 The Upper Sivalaya at Badami, the superstructure of which is organized into storeys in the same manner as the Candi Arjuna,

may not be accurate. The unfinished rock-cut temple at Masrur (Fig. 21.32), attributed to the eighth century, is hewn out of a sandstone ridge in the Kangra Valley in Himachal Pradesh, India. Meister (2006) has studied the monument in its present unfinished condition and hypothesized that it is a unique *sarvatobhadra* (lit. "auspicious from all sides", and in the literature on temple architecture, signifying a temple where access to the sanctum is from all four sides). Meister (ibid.) likens the conception of this temple to that of the temple mountains of Cambodia, and compares it to the oldest example of such temples, the eighth century brick temple of Prasat Ak Yum in Siem Reap. With the lake in front of the temple, and the lesser spires surrounding the main tower of the temple, this temple complex does seem to be a conception of Meru in the same manner as the Cambodian temple-mountains. Meister (2000) gives a summary of the cosmological symbolism in the design of Angkor Vat, and other temple-mountains of Cambodia.

Thus it can be seen how the interflow of ideas and architectural forms between India and Southeast Asia need more careful and focused analysis.

Fig. 21.30 A slab from the ruined second century Buddhist stupa at Kanaganahalli, depicting in shallow relief an earlier shrine made of perishable materials. Such depictions help us understand the form of these early monuments, traces of which do not exist today.

21.5 Discussion and Concluding Remarks

The Indian subcontinent has been in close contact with Southeast Asia from a very early period. While travel to West Asia required passage through mountain ranges and deserts, passage to the Southeast was much easier. There was, therefore, a significant connection between the two regions, and they influenced each other throughout history.

Fig. 21.31 A relief on the wall of a temple at Belur, showing the myth of the demon Ravana shaking Mount Kailasa. The mountain is shown as a temple tower, complete with finial in this depiction.

Fig. 21.32 The eighth century rock-cut temple at Masrur, in Himachal Pradesh. This temple is close enough in form to Cambodian temples to be considered a precursor.

In the archaeological record too there are tentative and definite traces of links between the two regions. The megalithic traditions of Southeast Asia, which bear, on a first look, resemblances with those of Northeast India, need to be investigated further from the specific point of view of possible cultural contacts. The study of megaliths all over the world has been impacted by the absence of a uniform classification of megalithic forms worldwide (Menon 2018). This can be addressed by adopting a uniform terminology for different types of megaliths based purely on their form and structure; and also by having a visual database of megalithic sites from the whole world. With such an approach, similarities and differences can be discerned easily, which will greatly aid studies of cultural contacts between different regions during periods of megalith-building.

There have not been concerted efforts to examine astronomical knowledge evident from the design and layout of megalithic structures in different parts of India. Even lesser studies on this aspect have been conducted in Southeast Asia. It would be of immense interest to see if structures akin to the stone alignments of South India, which appear to show definite astronomical basis for their layout, are present in Northeast India as well as Southeast Asia. Examination of all megalithic structures for preferential orientations to astronomically significant directions is a long overdue study.

The later temple traditions show definite exchange of ideas between India and Southeast Asia, although, as pointed out by Dhar (2018), the exchange of ideas before the seventh century needs to be examined, even if the archaeological evidence is meager. The extent of assimilation of ideas from India and the aspects of the process of localization of specific temple forms also need further study. Since Indian temples have a lot of astronomical symbolism, in imagery on structural components, as well as design and layout of the structure itself, it would be beneficial to look for similar treatment in Southeast Asian temples, to understand what astronomical knowledge was transferred.

The way forward in understanding the origin of the temple-building traditions in the two regions, as well as tracing the intense exchange of ideas, knowledge systems, objects and people between India and Southeast Asia will lie in a thorough investigation of early monuments—both megaliths and temples in the respective regions, for all the above-mentioned aspects.

In conclusion, we invite like-minded researchers in India and Southeast Asia to participate in collaborative ventures that address these issues.

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Chapter 22
The Influence of India on Southeast Asian Astronomy: Of Calendars and Calculations

Lars Gislén and J. C. Eade

22.1 Introduction

The Hindu and Southeast Asian calendars are all lunisolar calendars like many of the present and earlier calendar schemes east of the Mediterranean (Gislén and Eade, 2019a). A lunar year with twelve synodic lunar months has about 354 days, 11 days shorter than a solar year of 365 days. These 11 days have to be taken care of by the intercalation of extra lunar months, and also of intercalation days for the lunar year to keep in pace with the solar year and for the lunar calendar to keep in step with the Moon (see Gislén, 2018).

22.2 The Hindu Calendar

The origins of Indian astronomy have very ancient roots. Some conceptions certainly were introduced already in Vedic times and there are indications of ideas coming from Hellenistic and Persian astronomy from around the times of the beginning of the Christian Era (CE), especially in astrology. The Indian zodiacal names are direct translations of the Greek ones. Other influences may have come from Babylonia and China and certainly there are many later independent Indian ideas. There is still an ongoing debate on the details of these roots.

The Hindu calendar is based on the *mahâyuga*, a period of 4 320 000 years. This period is taken to consist of an integer number of days. We will here refer to three different Hindu canons: the *Âryabhaṭa* and the original *Sûryasiddhânta* (old)

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canons, both conceived around 500 CE, and the modern *Sûryasiddhânta*, from about 1200 CE. The latter is described in great detail by Burgess (1860). The number of days in a *mahâyuga* for the different canons (Billard, 1971) is:

1 577 917 800 *Sûryasiddhânta* (old)
1 577 917 500 *Âryabhaṭa*
1 577 917 828 *Sûryasiddhânta*

In what follows we will mainly deal with the *Sûryasiddhânta* (old). The length of the solar year in this canon is 1577917800/4320000 = 365.25875 days. A mean solar month = 365.25875/12 = 30.438229 … days. The mean solar daily movement is 360°/365.25875 = 0.985603 … °

This is a sidereal year, i.e. a year determined by the Sun's return to a specific point relative to the stars. The Gregorian year, used since 1584 CE, is a tropical year of 365.2425 days and is determined by the Sun's return to the vernal point, the crossing between the ecliptic and the celestial equator. The true tropical year is 365.2422 days.

The starting point, or epoch, of the Indian calendar is 18 February 3102 BCE, the *kaliyuga* era, when the Sun, the Moon and the planets all are taken to have had zero mean longitudes. For the *Âryabhaṭa* canon the precise epoch moment is dawn, *audayika*, for the other canons it is midnight, *ârdharâtrika*. Ujjain, located in northern India, defines the prime meridian of Indian astronomy, equivalent to the Greenwich meridian in modern astronomy. We can now easily compute the mean solar longitude for any given day by multiplying the number of days since the epoch, the *ahargaṇa*, by the mean Sun's daily movement, skipping multiples of 360°.

For the Moon it is assumed that it makes 57753336 revolutions in a *mahâyuga*. Relative to the Sun it then makes 57753336 – 4320000 = 53433336 revolutions. Thus the lunar synodic month is 1577917800 / 53433336 = 29.530587… days. This is very close to the modern value 29.530589 … days. An important time measure in Indian and Southeast Asian astronomy is the *tithi* that is 1/30 of a lunar month or 0.984353 … days. The *tithi* was used already in Babylonian astronomy.

For simplicity we will, in what follows, assume that the calendar uses mean reckoning for the solar and lunar longitudes. This will avoid the mathematical complications that arise using true longitudes.

The backbone of the Hindu calendar is the solar year with its twelve solar months. The solar months start when the Sun's sidereal longitude is 0°, 30°, 90° … 330° respectively. Their zodiacal names are

Meṣa, Vṛṣabha, Mithuna, Karka. Siṃha, Kanyâ,
Tulâ, Vṛṣcika, Dhanus, Makara, Kumbha, Mîna

As a solar month does not contain an integer number of days, it can start at any time of the day. The lunar months start when the Sun and the Moon have the same longitude, i.e. at New Moon, the *amânta* system. (The northern regions of India instead use the Full Moon, the *purimânta* system.) This can also happen at any time of the day and at any day in a solar month. The name of the lunar month is determined

Table 22.1 Hindu solar and lunar months.

Meṣa मेष	(Aries)	*Vaiśâkha* वैशाख
Vṛṣabha वृषभ	(Taurus)	*Jyeṣṭa* ज्येष्ठ
Mithuna मिथुन	(Gemini)	*Âṣâdha* आषाढ
Karka कर्क	(Cancer)	*Śravaṇa* श्रावण
Siṃha सिह	(Leo)	*Bhâdrapada* भाद्रपद
Kanyâ कन्या	(Virgo)	*Aśvina* आश्विन
Tulâ तुला	(Libra)	*Kârttika* कार्तिक
Vṛṣcika वृश्चिक	(Scorpio)	*Mârgaśîrṣa* मार्गशीर्ष
Dhanus धनुस्	(Sagittarius)	*Pauṣa* पौष
Makara मकर	(Capricornus)	*Mâgha* माघ
Kumbha कुम्भ	(Aquarius)	*Phâlguna* फाल्गुन
Mîna मीन	(Pisces)	*Caitra* चैत्र

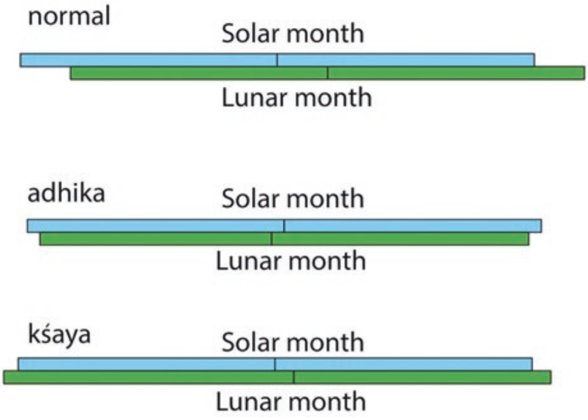

Fig. 22.1 Intercalation scheme (cf. Gislén, 2018).

by the solar month in which it starts. The correlations between the names of the solar and lunar months are shown in Table 22.1:

As the mean lunar month is shorter than the mean solar month, several cases can appear, as shown in Fig. 22.1:

In the first case there is only one lunar month starting in a given solar month and will be given its corresponding name. In the second case there are two lunar months starting in the same solar month. The first lunar month will be an intercalary month and given the corresponding name, but prefixed with the word *adhika*. If the canon reckons with true solar and lunar longitudes, both the solar and lunar months vary in length and it can sometimes, although very seldom, happen that no lunar month starts in a solar month. The corresponding lunar month will then be suppressed or *kśaya*. With this system of intercalation, the lunar calendar will automatically be aligned with the solar one.

When it comes to the numbering of the days in a month a similar system is in operation. The lunar days, the *tithis*, are numbered 1 to 30. The civil day is related to the number of the *tithi* that is current at the beginning of the day, being at 6 o'clock, or sometimes at sunrise or in some regions at midnight. As the lunar day, the *tithi*, is shorter than a solar day, it sometimes happens that a *tithi* is not current for any day in the month. That *tithi* number will then be suppressed and the corresponding lunar month will only have 29 days, 1 to 15 waxing and 1 to 14 waning, instead of 1 to15 waning.

This calendrical scheme will automatically synchronise the lunar calendar with the solar one and the lunar calendar with the Moon.

22.3 The Introduction of the Hindu Calendar in Southeast Asia

The appearance and development of the Hindu calendar in Southeast Asia was associated with the spread of the Hindu religion, not just into mainland and island Southeast Asia but also into China, Korea and Japan (see Fig. 22.2).

The Burmese calendar with roots in *Sûryasiddhânta* (old) is said to have been introduced in 640 CE in Pagan by King Popa Sawrahan. However, the month intercalation system became based on the Metonic 19-year cycle. During the Pagan Empire era, the calendar spread to adjacent states: Arakan, Northern Thailand and Laos. It was introduced in Thailand (Siam) during the Ayutthaya Kingdom but with a radical change of the intercalation system, possibly to mark independence from the rival Burmese state. From Siam this changed calendar spread further to Cambodia although much later, about 1500 CE (Gislén and Eade, 2019b). It is interesting to note that the calculation scheme for solar and lunar longitudes as given in Faraut (1910) has an extra correction of 3 arc minutes for the mean longitude of the Sun and 40 arc minutes for the mean longitude of the Moon, a quite accurate correction for the longitude time difference from the Indian meridian of Ujjain and central Burma. This is a quite strong indication that the calculation scheme arrived in the Mainland Southeast Asia via Burma. Many of the astronomical technical terms in Southeast Asia have a Sanskrit or Pali origin.

The Mainland lunisolar calendars fell out of official status in several mainland Southeast Asian states with the arrival of European colonialism. The Gregorian calendar was adopted in Cambodia in 1863, Burma in 1885, and Laos in 1889. In 1888 the Gregorian calendar also became the official civil calendar in the independent kingdom of Siam.

Vietnam mainly used a calendar that was essentially a Chinese lunisolar calendar, and in 1954 the Gregorian calendar became the official civil calendar (see Lê Thành Lân, 2019; Lê Thành Lân and Nguyễn Thị Trường, 2017a, 2017b). Apart from some indigenous groups, Indonesia and Malaysia adopted a calendar that was close to the original Hindu calendar (Eade, 2000), and use of this has continued on

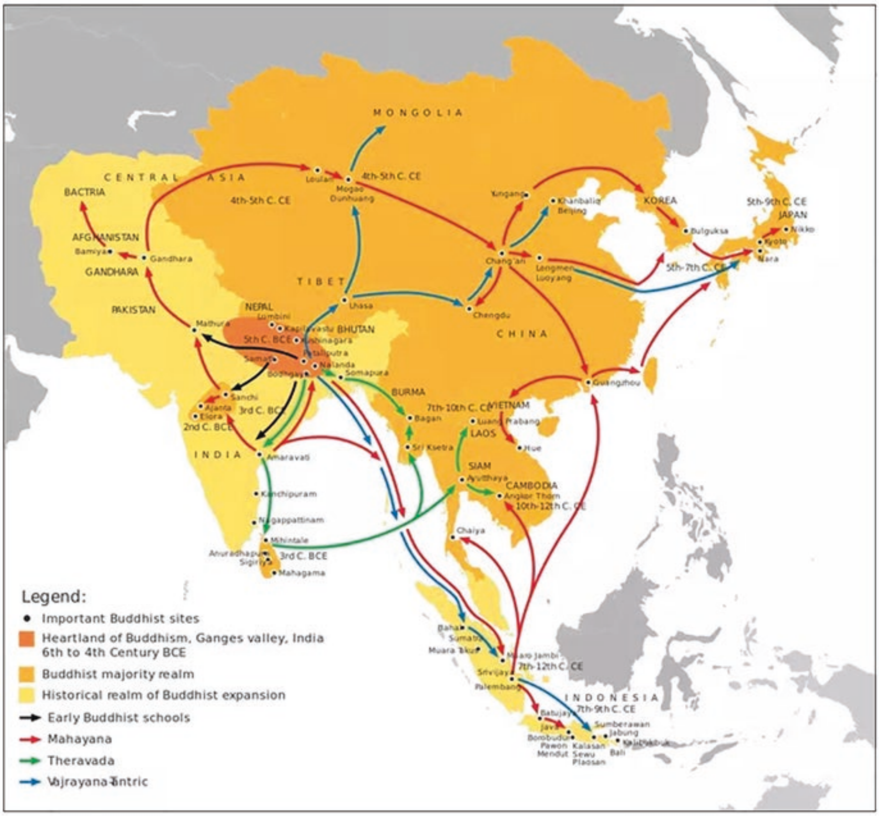

Fig. 22.2 The spread of Hinduism from the Indian subcontinent into East and Southeast Asia (https://i.redd.it/73ab2nn488k31.png).

the Indonesian island of Bali through to the present day (see Chatterjee, 1997; Emas et al., 2021; Proudfoot, 2007; van den Bosch, 1980). However, the current official calendars of Malaysia and Indonesia are for the most part based on the Gregorian and Muslim calendars (see Ammarell, 1988; Gislén and Eade, 2019c; Proudfoot, 2006, 2007). A special feature of the Indonesian calendar is the use of a five-day week.

In the following Sections we will cover the two calendrical systems on the Mainland Southeast Asia, the Burmese and the Thai systems, that are closely related to the Hindu calendar.

22.3.1 The Burmese Calendrical System

The Burmese calendrical system is summarised by Chatterjee (1996), Eade (1995), Gislen and Eade (2019b; 2019d), Htoon-Chan (1918) and Irwin (1909). The fundamental quantity for the Sun is an 800-year period containing 292207 days. If we multiply these numbers by the factor 5400 we regain the *Sûryasiddhânta* (old) values 4320000 years and 1577917800 days. The epoch for the common Burmese/Chulasakarat era is 22 March 638 CE, midnight. These fundamental parameters and the epoch are the same in the Thai calendar. There are several other epochs in use in Thailand: Anchansakarat, Buddasakarat, and Mahasakarat, they use the same scheme for computation but have different starting dates (Eade, 1995).

The names and lengths of the Burmese lunar months are shown below in Table 22.2.

This gives a total of 354 days in a non-intercalary year. For calendrical purposes the number of days since the epoch, the *ahargaṇa*, at the beginning of a given solar year is computed using the formula

$$(\text{year} \cdot 292207 + 373)/800 = \text{integer part} : \text{remainder}$$

$$\textit{ahargana}\ (\text{Sanskrit})/\textit{sawana}(\text{Burmese})/\textit{horakhun}\ (\text{Thai}) = \text{integer part} + 1 = \text{epoch days.}$$

The number 373 is an epoch constant, essentially expressing the solar longitude at epoch. The remainder is the time in units of 1/800 of a day when the mean Sun reaches 0° in longitude. The *kammacubala* is defined as

Table 22.2 Burmese months.

Tagu (တန်ခူး)	29
Kason (ကဆုန်)	30
Nayon (နယုန်)	29/30
Waso (ဝါဆို)	30
Wagaung (ဝါခေါင်)	29
Tawthalin (တော်သလင်း)	30
Thadingyut (သီတင်းကျွတ်)	29
Tazaugmon (တန်ဆောင်မုန်း)	30
Nadaw (နတ်တော်)	29
Pyatho (ပြာသို)	30
Tabodwe (တပို့တွဲ)	29
Tabaung (တပေါင်း)	30

$$\textit{kammacubala} = 800 - \text{remainder}$$

and is what is left of the solar new year day expressed in 1/800 of a day. A normal solar year has 365 days. However, if the value of the *kammacubala* is less than or equal to 207 the solar year will be a leap year with 366 days. This intercalation rule ensures that the length of the solar year on average is correct.

We earlier observed that that the lunar day, the *tithi* is equal to 0.9843529 solar days. Conversely one solar day is equal to 1.015896 *tithis*. This number can quite accurately be written as the ratio 703/692 = 1 + 11/692, telling us that the total number of *tithis* will increase by 11/692 for each solar day. The number expressing this is the *avoman*. It is computed as follows: (*ahargaṇa* · 11 + 650)/692 = *d* : *avoman.*

The letter *d* is the integer number of excess *tithis*, avoman is the excess fraction of *tithis* in units of 1 / 692 *tithi*, and 650 is an epoch constant. The *avoman* increases by 11 modulus 692 each day. So that *d* + *ahargaṇa* is the number of elapsed *tithis* since the epoch. Thus (*d* + *ahargaṇa* + 0)/30 = lunar months (*masaken*) : lunar age.

The early calendrical system in Burma, using the *Makaranta* scheme is, like the Thai scheme, based on the parameters of *Sûryasiddhânta* (old). These parameters were used, before the year 1200 or so in the Burmese Era (1838 CE). The intercalation scheme, however, is based on the ancient 19-year Metonic cycle, known already in Greece and Babylonia. The basis of this cycle is the fact that 19 solar years are rather accurately equal to 235 lunar months.

$$19 \text{ sidereal solar years of } 365.25875 \text{ days} = 6939.916 \text{ days}$$

$$235 \text{ lunar months of } 29.530583 \text{ days} = 6939.687 \text{ days}$$

The Metonic cycle is not very well suited to the sidereal solar year, it works much better for the somewhat shorter tropical solar year: 19 tropical solar years of 365.2422 days equal 6939.602 days

We can write the 235 lunar months as 12 years with 12 lunar months and 7 years with 13 lunar months: 235 = 12*12 + 7*13. The sequence of the 7 intercalary years with 384 days in the 19 year cycled followed a fixed pattern; originally the years 2, 5, 7, 10, 13, 15, 18 in the cycle were intercalary. But 12 lunar years with 354 days plus 7 lunar years with 384 days equal 6936 days, so there is a shortfall of 3.687 days in a 19-year period in relation to the 235 lunar months. Thus, there is a need to insert intercalary days. This is done by intercalating slightly more than 11 days in 3·19 = 57 years, 3.687· 3 = 11.061, the day being added to Nayon. In contrast to the rule in the Thai calendar, the rule in Burma is that an intercalary day is never added except in a year with an intercalary month. The rule determining when to add an extra day is based on the value of the *avoman* on the Full-Moon day of Waso for two consecutive years with an intercalary month (Htoon-Chan, 1918) although there seems to be some differences in what actual rule was used and how consistently it was applied. In this *Makaranta* scheme the intercalated month was an added Waso. These rules will keep the lunar calendar in step with the Moon but not with the solar calendar. The solar new year will slowly move forward in the lunar calendar as there is no rule that locks the lunar and solar calendars relative to one another.

It is interesting to note that the approximation for the *tithi*, 692/703, the use of the Metonic cycle, and the mean length of the lunar year 6939.687/ 19 = 365.24669 days are precisely what is found in the *Romakasiddhā̲nta* (Gislén, 2019; Neugebauer and Pingree, 1970, Part II: 8) with roots in the Hellenistic calendrical tradition. Also the lunar calendar is independent of the sidereal solar calendar, the latter only being used for determining the start of the year.

After about the year 1200 in the Burmese Era (≈1840 CE), the *Makaranta* was replaced by a reformed system. This scheme, the *Thandeikhta,* uses the modern *Sûryasiddhânta* parameters, and the sequence of intercalary years within the 19-year cycle was changed several times in order that the lunar calendar be in pace with the solar one. Actually, the change to the modern *Sûryasiddhânta* aggravated the problem with the alignment between the lunar and solar calendars as the *Sûryasiddhânta* sidereal year is slightly longer than the *Sûryasiddhânta* (old) year. A problem with the Burmese calendar is that at present there seems to be no rigorous scheme for computing the calendar for future years, the details being determined periodically by a commission of calendarists. There have been suggestions for reforming the calendar (Irwin, 1909).

22.3.2 The Thai Calendrical System

The information we have on the Thai/Siam/Laos/Cambodia calendrical system comes mainly from *Astronomie Cambodgienne* (Faraut, 1910), which in spite of enormous gaps and errors in the text, faithfully reproduces the data in the manuscripts. Other useful references for Cambodia and Lao are Dupertius (1981), Eade (1995), Gislén and Eade (2019b) and Phetsarath (1956), while Eade (1995; 2000), Gislén and Eade (2019b) and Wisandarunkon (1997) discuss the Siamese/ Thailand calendar.

The names of the lunar months in the Thai calendar are almost identical to the Pali names, as shown in Table 22.3.

In what follows, we will refer to the months by their Sanskrit names but without the diacritics. The intercalation scheme of the lunar calendar is quite complex. We will use the *suryayatra* rules that seem to be more reliable (Eade, 2000). There is a rule that the solar year can never start earlier than 6 Caitra or later than 6 Vaisakha in a lunar year (see Fig. 22.3). As the lunar year is 11 or 12 days shorter than the solar year, depending on whether the previous solar year is a leap year or not, it means that the solar new year will start the corresponding number of days later in the lunar calendar.

Thus, if a lunar year started on or later than 24 or 25 Caitra, the next year would violate that rule and an intercalary lunar month then has to be inserted, which will move the start of the next solar year back 18 or 19 days in the lunar calendar. A year with an intercalated month is *adhikamas*; the intercalation is effected by inserting a

Table 22.3 Thai months.

Thai name	Days	Pail name	Sanskrit name
Chittra (จิตร)	29	*Citta*	*Caitra*
Wisakha (วิสาข)	30	*Visakha*	*Vaiśâkha*
Chettha (เชษฐ)	29/30	*Jeṭṭha*	*Jyeṣṭa*
Asanha (อาสาฬห)	30	*Âsâḷha*	*Âṣâdha*
Sawana (สาวน)	29	*Sâvana*	*Śravaṇa*
Phatrabot (ภัทรบท)	30	*Poṭṭhapâda*	*Bhâdrapada*
Atsawayut (อัศวยุช)	29	*Assuayuja*	*Aśvina*
Kattika (กัตติกา)	30	*Kattikâ*	*Kârttika*
Mikkasira (มิคสิร)	29	*Mâgasira*	*Mârgaśîrṣa*
Putsa (ปุสส)	30	*Phussa*	*Pauṣa*
Makha (มาฆ)	29	*Mâgha*	*Mâgha*
Phakkhun (ผัคคุณ)	30	*Phagguṇa*	*Phâlguna*

Fig. 22.3 The lunar year start in the Thai calendar.

second Ashada month of 30 days, thus giving a lunar year of 384 days. This rule in effect locks the lunar calendar to the solar one. However, it turns out that this intercalation scheme is not sufficient to keep the lunar calendar in step with the (mean) Moon, and a fine-tuning intercalation of one extra day, *adhikawan*, is required now and then and the extra day is added to Jyesta. The Thai rule is that such an intercalation day can never occur in a year with an intercalated lunar month. This is at odds with the Burmese rule that only years with an extra lunar month can also have an extra day. The insertion of the extra day is governed by the *avoman* as shown below. This seemingly small difference could have material effects as shown in the *Prasert Chronicle* (Frankfurter, 1954), which indicates that the capital of Burma tried to tell the capital of Siam that the year would not have an extra month, "In 943, the year of the snake … a letter was received from Pegu stating that in the year of the snake there would be no leap year. In Siam there was, however, a leap year". Checking on the requirements for this year, one finds that both places were correct by their own systems of reckoning. To defer to Burma, Siam would have had to abandon its own system of reckoning.

The month intercalation scheme will generate on average 7.00776 intercalary months in a 19-year and not in a fixed pattern, so it is only a very approximate Metonic cycle.

The rule for inserting the intercalary day in the lunar calendar is:

IF (solar leap year AND *avoman* ″ 126
OR NOT solar leap year AND *avoman* ″ 137) THEN intercalary day.

This rule will insert the required number of intercalary days. It is easy to calculate, using the probabilities of having a solar leap year or not and having the *avoman* in the specified ranges, that this rule will insert on average 155.091 extra days in an 800-year period or on average 11.0502 days in a 57-year period. This will keep the lunar calendar in step with the Moon. However, this rule would insert an intercalary day in a year that already had an intercalary month, so the intercalary day has to be moved to one of the adjacent lunar years. This leads to the situation that in order to determine the type of year, you have to set up a scheme with five consecutive years with the target year in the middle to ensure that the flow of days in this sequence is correct. Given the complexity of this scheme it is not surprising that there is evidence that at times these intercalation rules were not always strictly adhered to (Eade, 1993).

This calendrical scheme will automatically synchronize the lunar calendar with the solar one and the lunar calendar with the Moon. As the system uses a sidereal year, the solar New Year will slowly drift relative to the Gregorian calendar. From its epoch, the drift is now about 20 days.

22.4 Calculations

22.4.1 Planetary Calculations

In order to compute the true longitude of the Sun, the mean longitude has to be corrected by an equation of centre,

$$\lambda_{true} = \lambda_{mean} - e_{sun} \cdot \sin\left(\lambda_{mean} - 80^{\circ}\right)$$

The parameter e is the eccentricity, its value for the Sun in Southeast Asian astronomy is identical with the *Sûryasiddhânta* (old) value 14/360 as well as 80°, the longitude of the apogee of the Sun.

For the Moon we have

$$\lambda_{true} = \lambda_{mean} - e_{moon} \cdot \sin\left(\lambda_{mean} - \omega_{moon}\right)$$

The value of the lunar eccentricity is the same as in the *Sûryasiddhânta* (old), 31/360. For the Moon the apogee ω_{moon} is a linear function of time, identical with that assumed in the *Sûryasiddhânta* (old).

For the mean longitudes of the other planets, somewhat simplified periods were used as compared with the *Sûryasiddhânta* (old) canon (see Table 22.4).

Table 22.4 Hindu and Southeast Asian periods.

	Mahâyuga revolutions	Period	SE Asian Periods
Mercury	1793700	87.970	8797 = 100·87.97
Venus	7022388	224.698	2247 = 10·224.7
Mars	2296824	687.000	687
Jupiter	364220	4332.321	12997 = 3·4332.33
Saturn	146564	10766.067	10766
Rahu	232226	6794.751	6795
Lunar apogee	488219	3231.988	3232

Rahu is the ascending node of the Moon and is used with eclipse calculations. It was considered to be a monster that devoured the Moon or the Sun during eclipses, very similar to the Dragon's Head in medieval European astronomy.

For computation of the true longitudes, the Southeast Asian astronomers adopted exactly the same procedures as used in India by the *Sûryasiddhânta* (old) canon. Expressed in mathematical form, the procedures used to calculate the true longitude of an outer planet can be summarized as follows (Billard, 1971):

$\gamma_1 = \lambda_{sun} - \lambda_{mean}$, the difference between the longitudes of the Sun and the planet
$\tan \delta_1 = \rho \sin\gamma_1 / (1 + \rho \cos \gamma_1)$, a correction
$\omega_1 = \omega - 0.5\ \delta_1$, first corrected apogee
$\sin \mu_1 = 2e \sin (\lambda_{mean} - \omega_1)$, a correction
$\omega_2 = \omega_1 + 0.5\ \mu_1$, second corrected apogee
$\sin \mu_2 = 2e \sin (\lambda_{mean} - \omega_2)$, a correction
$\lambda_1 = \lambda_{mean} - \mu_2$, corrected mean longitude
$\gamma_2 = \lambda_{sun} - \lambda_1$, corrected elongation
$\tan \delta_2 = \rho \sin \gamma_2 / (1 + \rho \cos \gamma_2)$, a correction
$\lambda = \lambda_1 + \delta_2$, true longitude

Here ω is the longitude of the apogee, ρ and e are parameters, given for the different planets, somewhat resembling the parameters used in the Ptolemaic system, as far as we can see without its geometrical interpretation but with connections to Greek early methods of calculation (Thurston 1992; van der Waerden, 1960). The values of these parameters are the same as in *Sûryasiddhânta* (old). The functions in the second and next to last line are given by two tables, *chaya mangkara* and *chaya korakada*. The sine function in the formulae above is given by another table, *chaya manda*. These tables are given explicitly in Faraut (1910) although with many errors which, however, can be corrected using the formulae in Billard (1971). For an inner planet the longitudes of the Sun and the planet are switched in the formulae above. The accuracy of the planetary values in Thai and Burmese temple horoscopes that survive strongly suggests that these *chaya* tables were handed down across the generations as sets of numbers to be applied by rote. As a system of rote learning it was remarkably stable and efficient.

The Burmese *Thandeikta* system uses different values for apogees, close to the modern *Sûryasiddhânta* values. It also uses the more complicated modern

Sûryasiddhânta system with epicycles and eccentricities that are variable and with corrections to the epoch longitudes. This certainly points to a later import of ideas from India.

The planetary calculations are mainly used with the astrological intent of setting up horoscopes for specific dates. In Southeast Asia the computation scheme was devised as a set of instructions and tables quite similar to a computer program, such that a person could do the calculations without knowing anything about the theoretical astronomical background, only using addition, subtraction, multiplication and division. In Fig. 22.4 the left part of the horoscope shows the position of the planets in the zodiac dated 14 April 1288 CE. The zodiac starts at the top and goes anticlockwise around the circle. 1 = Sun, 2 = Moon, 3 = Mars, 4 = Mercury, 5 = Jupiter, 6 = Venus, 0 = Saturn; in Thai horoscopes Saturn is normally marked with 7. The planet marked with 8 should be Rahu but a computer check shows that the longitude is not correct. L marks the lagna, the current rising sign. The right part shows the true longitudes of the planets. The numbers at the bottom of the big rectangle are the *masaken*, *avoman*, and *ahargaṇa*/*sawana*. The number 650 is the Burmese year. These horoscopes have been of immense value for checking the calendrical and computational procedures in Southeast Asia (Eade and Gislén, 2000).

22.4.2 Eclipse Calculations

There are some examples of calculations of eclipses of the Moon and the Sun in Southeast Asian astronomy. The examples that we have found from Burma (e.g., see one in Fig. 22.5) use the modern *Sûryasiddhânta* parameters for most of the calculations but have quite original and ingenious ways of handling the calculation of parallax that are necessary for a solar eclipse calculation (Gislén, 2015). Special for Burma are the calculations of the shadow of the Sun and the Moon (Gislén and Eade, 2014).

The Thai calculation sheet (Anonymous, ca. 1868) in Fig. 22.6 for the 18 August 1868 solar eclipse follows closely the 62 steps of instruction as given by Wisandarunkon (1997; cf. Gislén and Eade, 2019d). This was one of the most important eclipses in solar physics, the duration of the totality was exceptionally

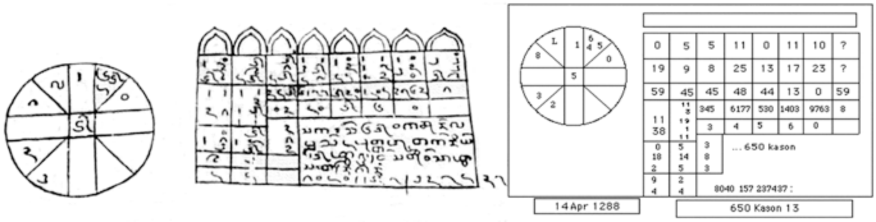

Fig. 22.4 Example of a Southeast Asian horoscope from site 1710 in Bagan (Kubauk-nge at Myinkaba).

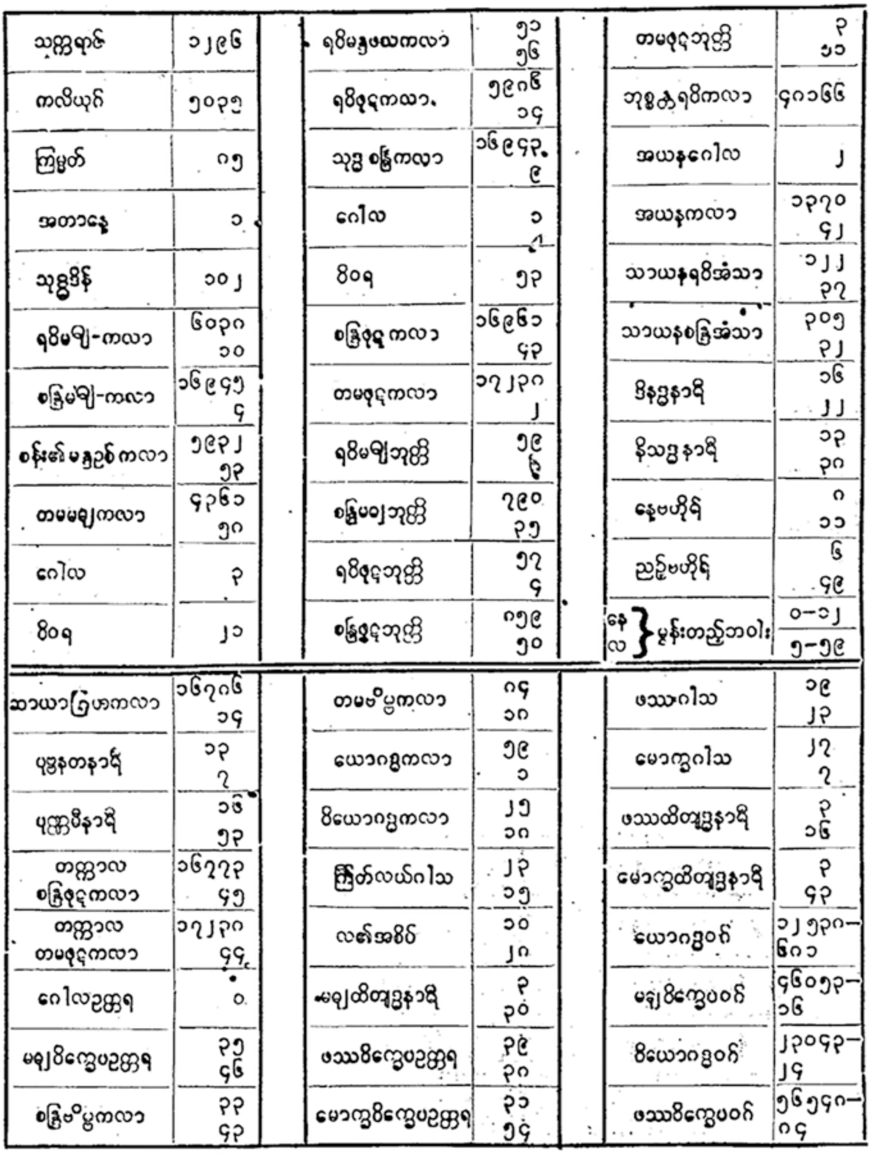

Fig. 22.5 A Burmese lunar eclipse calculation for 26 July 1934.

long and it was the first solar eclipse where spectroscopic observations were made, leading to the discovery of helium (see Orchiston, 2022). It was observed from several locations on the Earth from Aden in the west to the Indonesia in the east by Austrian (Aden), English (India), German (India and Aden), French (Siam), and Dutch (Indonesia) astronomers. The French commission of astronomers observed

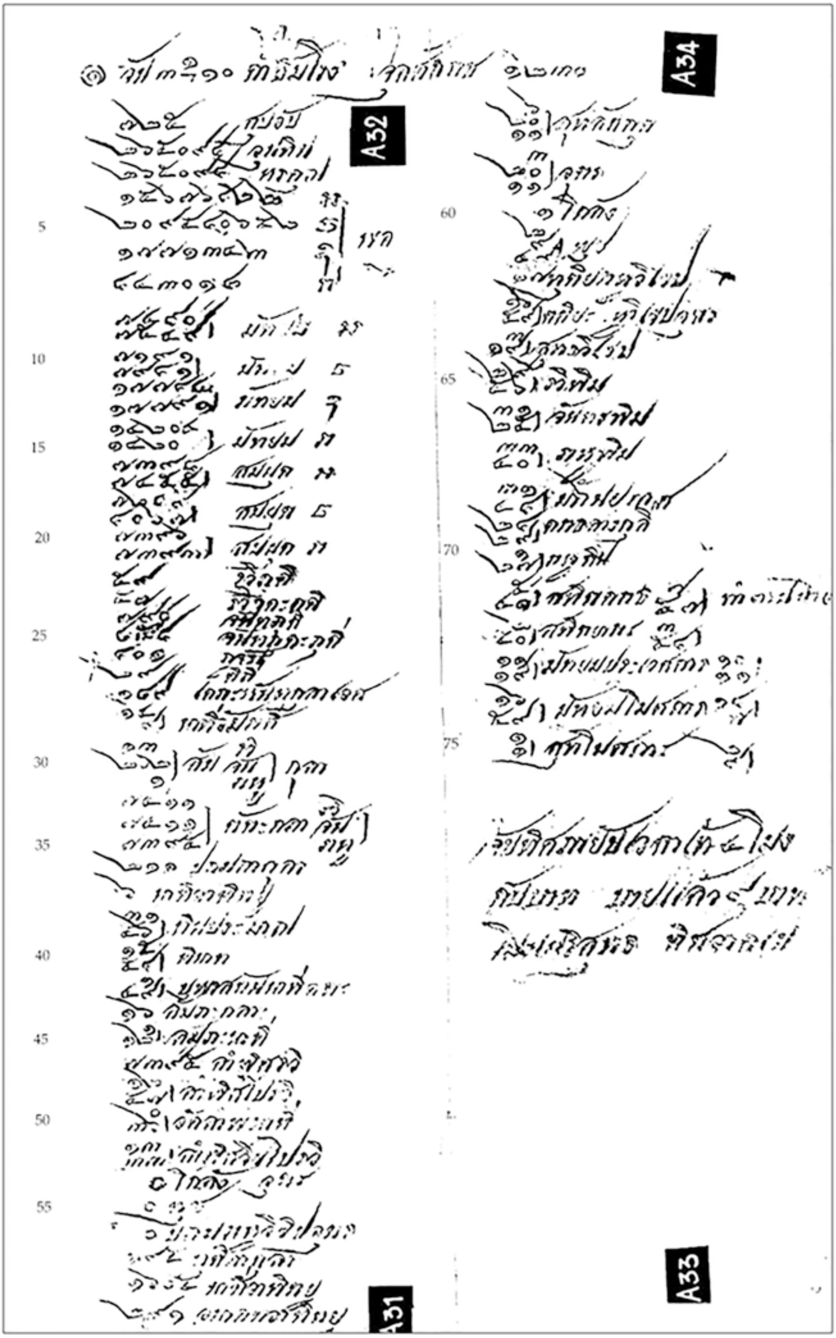

Fig. 22.6 Thai solar eclipse calculation for 18 August 1868.

Fig. 22.7 The path of the 18 August 1868 solar eclipse (map: Lars Gislén).

the eclipse from Wah-koa in Siam (under the white bull's-eye in Fig. 22.7) in the presence of King Rama IV of Siam (Orchiston and Orchiston, 2017; Soonthornthum and Orchiston, 2021).

The examples from Thailand have some interesting features. It turns out that they use the *Âryabhaṭa* parameters for the Sun, and for the Moon an improved version of the *Âryabhaṭa* canon that was introduced in a canon *Grahacaranibandhanasaṃgraha* (Billard, 1971; Haridatta, 1954) dated around 100 CE. These computations also have their own ways of handling the parallax problem in solar eclipses and for the Thai calculations, an original, very rough method of calculating the duration of the eclipses (Gislén and Eade, 2001), possibly being inherited from ancient times. The Thai solar eclipse calculation above is not particularly good, it does not predict a total eclipse, the reason being that the calculation uses a sidereal longitude for the Sun when calculating the parallax.

22.5 Concluding Remarks

In summary for the calendars, the influence from India on Southeast Asia is clear when it comes to the fundamental parameters such as the description of the solar and lunar movements. These influences are dominated by the early Hindu canons from about 500 CE. The first introduction of Hindu-based calendars was around 640 CE and came via Burma and spread from there. However, the intercalation problem has been solved in quite different ways in the different regions of Southeast Asia, in Burma possibly based on the *Romakasidhanta*. In Burma there has lately been a strong influence from the modern *Sûryasiddhânta* canon with the adoption of the *Thandeikta* calendrical system.

As for the calculation of the true longitudes of the planets, the calculation scheme and the parameters are almost identical to the *Sûryasiddhânta* (old) scheme in India.

In Burma the more advanced *Sûryasiddhânta* parameters are used in the *Thandeikta* scheme.

Thai solar and lunar eclipse calculations are based on improved *Âryabhaṭa* parameters but the extant examples from Burma are based on the *Sûryasiddhânta*. The handling of the parallax problem in solar eclipses is different in Thailand and Burma and both differ from the procedures used in India.

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Chapter 23
Investigating the Astronomical Histories of India and Southeast Asia: The Role of Stone Inscriptions

B. S. Shylaja

23.1 Introduction

Stone inscriptions are seen in all corners of India as edicts for grants and donations of land and other possessions to temples and/or individuals, mostly scholars. Many of them are also records of the deaths of great saints, martyrs of war, and heroes who confronted danger, like attacks by wild animals. They also include citations of people who selected self-immolation, for example, windows of war heroes and a section of sun-worshippers.

The grants and donations made for running of temples, sustenance of academic activities and educational institutions were made on copper plates and these were preserved by the individuals and/or institutions, even through to the present today. Many inscriptions have been studied, translated into English and published, as early as in the nineteenth century. Apart from Indian epigraphists, many British scholars also contributed to this voluminous work, which is being continued today by the Archaeological Survey of India. B.L. Rice (1837–1927), L.F. Kielhorn (1840–1908) and J.F. Fleet (1847–1917) converted the dates listed to those of the Western system and prepared a chronological history of South India and elaborate lists of the dates of stone inscriptions.

The tradition of getting the edicts recorded on stone can be traced back to the third century BCE. A stone inscription in Vidisha, Madhya Pradesh, records the visit of a Greek Ambassador named Heliodorus of the second century BCE (Fig. 23.1). The languages in these inscriptions are archaic; however a small percentage of the population was able to read and decipher their meanings.

In all of these cases the dates and timings are meticulously written down; on many records the details of the positions of the planets also are available.

B. S. Shylaja (✉)
Jawaharlal Nehru Planetarium, High Grounds, Bengaluru, India

W. Orchiston, M. N. Vahia (eds.), *Exploring the History of Southeast Asian Astronomy*, Historical & Cultural Astronomy,
https://doi.org/10.1007/978-3-030-62777-5_23

Fig. 23.1 The pillar at Vidisha with the second century BCE inscription of Heliodorus (photograph: B.S. Shylaja).

The languages used in the earliest inscriptions are Páli, Prákrit, Nágari and Sanskrit. Subsequent ones are available in regional languages. In Southern India we also find inscriptions in Tamil, Telugu and Persian. The antiquity of the Kannada language has been established through a stone inscription that dates to about CE 450 (Taranatha, 2001).

The year count is uniform all over South East Asia, and used the *Śaka* era of epoch CE 78. The languages included Sanskrit by default which was copied into regional languages. The dates chosen for making these records were sometimes related to eclipses, which gives the inscriptions astronomical significance.

In the past it required great mathematical expertise to predict the occurrence of an eclipse. Among the early European visitors, the French astronomer Le Gentil (1725–1792), who visited India during 1761–1769 in order to observe a pair of transits of Venus, and the Englishman John Warren (1769–1830), who was in India during 1790–1810, learnt how to make the calculations, and accordingly they enlightened Europeans about the expertise of Indian astronomers. These studies were then continued by others, including John Playfair (1748–1819), Francis Baily (1774–1844) and John Dominique Cassini (1625–1712), who appreciated the mathematical skills involved and reported their interpretations at meetings of the Royal Society.

23.2 The Records on the Inscriptions

Astronomical details contained in the stone inscriptions were used more than 100 years ago to understand the evolution of the calendar (Venkatasubbaiah, 1918). The calendar convention itself is discussed in great detail by Sengupta (1947). Dikshit had discussed these aspects in his Marathi volumes in the late nineteenth century, and the English translations were made available subsequently (Dikshit, 1969), which resolved much confusion. Beer (1967) first noted the mention of an 'invisible planet' in an inscription from Angkor Wat in Cambodia. In preparing their sourcebook on Indian astronomy, Subbarayappa and Sarma (1985) noted the significance of inscriptions, and presented a few examples. The revelation that details like totality are mentioned was first noted by Chidananda Murthi (1980), and subsequent studies led to many more findings (see Shylaja, 1997). We then undertook to scrutinize all inscriptions, which required a knowledge of astronomy as well as a command of the ancient languages (Shylaja and Geetha, 2014a, b and 2016).

Let us now understand how the details of the celestial events recorded in stone inscriptions can be deciphered. Fig. 23.2 shows a typical layout of a stone inscription, with the Sun and the Moon symbolising the validity of the edict.

Most of the stone inscriptions begin with information about the date. In some cases an event (like an eclipse) may be mentioned at the beginning of the text or at the end. The information on the astronomical event may be hidden as an adjective or as a simile in the long-running text covering the praise of the donor and the awardee.

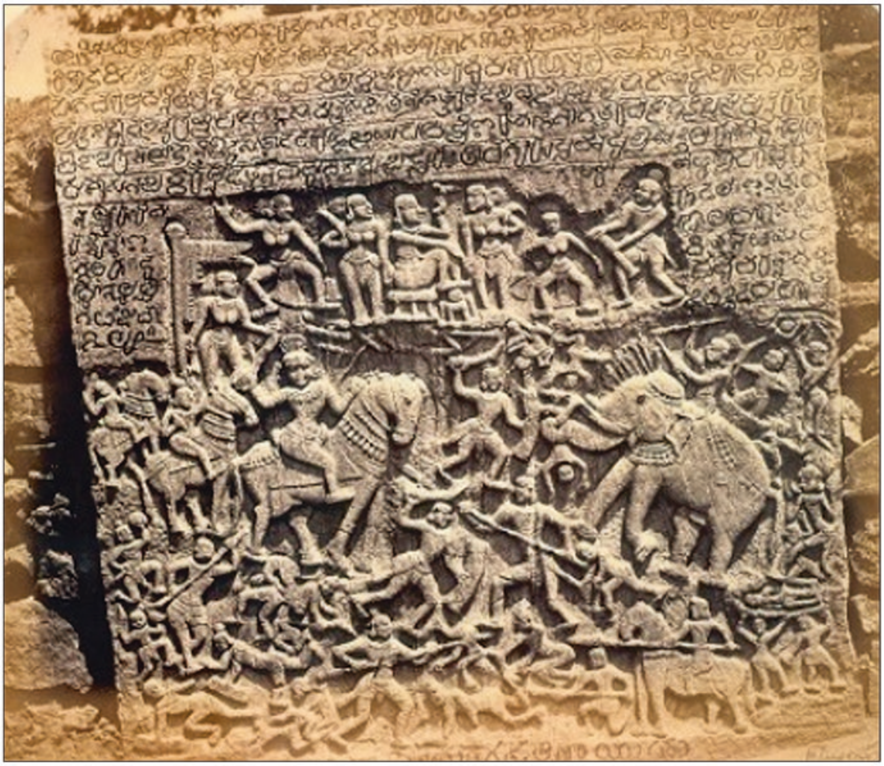


Fig. 23.2 The stone inscription of a war hero in Bengaluru (photograph: B.S. Shylaja).

In the inscriptions, the time markers are *Śaka* Year, *Samvatsara* (a cycle of 60 years), lunar month, *tithi* (the phase of the moon) and *Vāra* (the week day). We see examples of the *nakaśtra* citation (each day is associated with a star, a *nakaśtra*, the one closest to the Moon among the 27), while in some examples *lagna*, the ascendant zodiacal sign is cited, giving the time of the day. It is interesting to note that in the inscriptions of the tenth century and earlier, the *nakaśtra* itself is cited as the ascendant. For example, an inscription states "*Krittika Janane*", meaning "When *Krittika* (Pleiades) is rising", giving the time of the event within a few minutes, and supporting the argument that prior to the introduction of zodiacal constellation names all calculations were made with reference to the asterisms, in tune with the 27-star lunar calendar system (Dikshit, 1969).

There are several ways of stating the year count:

(1) *Samvatsara* is a cycle of 60 years. The commencement of a new *Samvatsara* is on the day of *Yugādi*, the first day after the New Moon in the month of *Caitra*. The name repeats after 60 years and therefore the ambiguity is ±60 years, which can be easily resolved by other details mentioned therein.

(2) Year or day count with the epoch of *Kaliyuga*. The onset of *Kaliyuga* is fixed around 3100 BCE, based on various considerations (for example, a citation in the work of *Āryabhaṭa*) (Balachandra Rao, 2010). In many cases the *Samvatsara* and the *Kaliyuga* day count, as well as the *Śaka*, are mentioned, making the calibration easy.

(3) Among the various *Śaka* counts, the most popular was (is) *Śālivāhana Śaka* which has been operating since CE 78, rendering an easy conversion. The old *Prākrit* inscriptions have the days of *Kaliyuga* mentioned but not the *Śaka* number. Another *Śaka* which is seen often is the *Vikrama Śaka*—of epoch BCE 56.

(4) Other *Śakas*, like the number of years after the coronation of the King, *Hijari Moulūdi*. Recent inscriptions (in nineteenth century) record the Christian Era as 'isvi' (a local word).

(5) In many inscriptions the year is reckoned from the year of incarnation of the King, which also can be converted to the running year count.

There are very interesting ways of representing the numerals of the *Śaka* years. The earliest inscriptions of the third or fourth centuries CE wrote the place values separately. For example 321 was written as 300 20 1. The later inscriptions have the place value system which is being used even now. Later inscriptions used the *Kaṭapayādi* or *bhuta sankhya* systems.

The *Kaṭapayādi* system uses the following scheme (see Fig. 23.3), with the Sanskrit alphabet:

Ka, Kha up to *Jha* are numbered 1,2,3,4 9
Ta, Tha up to *Dha* are numbered 1,2,3,4 9
Pa, Pha, *Ba*, *Bha*, *Ma* are numbered 1,2,3,4,5
Ya, Ra up to *Ha* are numbered 1,2,3,4 9

The nasal sounds represent zero. Very appropriate meaningful words are coined to convey the number. The words are to be read in the reverse order to get the *Śaka* year. For example, consider the word *Rāmalōke,* which means *in the world of Rāma.*

Rā ma lō ke = 2 5 3 1
The *Śaka* year is 1 3 5 2

1	2	3	4	5	6	7	8	9	0
ka क ಕ	*kha* ख ಖ	*ga* ग ಗ	*gha* घ ಘ	*nga* ङ ಙ	*ca* च ಚ	*cha* छ ಛ	*ja* ज ಜ	*jha* झ ಝ	*nya* ञ ಞ
ṭa ट ಟ	*ṭha* ठ ಠ	*ḍa* ड ಡ	*ḍha* ಢ	*ṇa* ण ಣ	*ta* त ತ	*tha* थ ಥ	*da* द ದ	*dha* ध ಧ	*na* न ನ
pa प ಪ	*pha* फ ಫ	*ba* ब ಬ	*bha* भ ಭ	*ma* म ಮ	–	–	–	–	–
ya य ಯ	*ra* र ರ	*la* ल ಲ	*va* व ವ	*śha* श ಶ	*sha* ष ಷ	*sa* स ಸ	*ha* ह ಹ	–	–

Fig. 23.3 The numerals represented in the *Kaṭapayādi* system.

The year of birth of Saint *Rāmānujāchārya* is coined as *Dhirlabhda* (this means intelligence was obtained), which implies the *Śaka* year is 939. [dh (9) la(3) dh (9); the half letter ba is not included].

The *Kaliyuga* days are also mentioned in the same way. For example, *Vishamam Punyamekam* refers to *Va* = 4 *Sha* = 6 *ma* = 5 *Pa* = 1 *Ya* = 1 *Ma* = 5 *Ka* = 1, which read in the reverse order is 1511564 days elapsed in *Kaliyuga*.

The *Bhuta sankhya* system uses the names of objects/mythological characters to represent the numerals. For example:

One – Earth, Moon – several synonyms for these
Two – Eyes, shoulders, hands
Three – *Guṇās* (qualities described as *Satva, Rajas and Tamas* in the *Bhagavad Gīta*) *agni, vahni,* fire (*āhavaniya, dakshināgni and Gārhapatya* as described in *Śulba Sūtrās*), *Rāma* (*Paraśu Rāma, Ayōdhyā Rāma and Bala Rāma*)
Four - Oceans, *Vēdā*
Five - Arrows, elements, sensory organs
Six - Tastes, organs, seasons
Seven - *Rishīs*, islands, horses, vices, serpents
Eight - *Lakshmi*, elephant, *Vasu* (eight of them born to Goddess *Gangā)*
Nine - *Graha* (planets), *Nidhi* (treasure), precious stone *Ratna*, holes (in the human body), *Nandās* (Kings of Magadha whom *Chāṇakya* overthrew)
Zero - Space (*vyoma*), sky, celestial sphere (*kha*)
Eleven - *Rudra* (forms of Lord *Śiva*)
Twelve - *Ādityās,* - names of the Sun
Fourteen - *Indrā*, Lords of the heaven, *Manu* (originators of the human race)

For example, a word like *"Kara Vasu Nidhi"* has meanings as *Kara* (hands) = 2, *Vasu* = 9 and *Nidhi* = 9. This should be read in reverse order as 992, which corresponds to the *Śaka* year and CE 1060. Similarly, *Vasu Vyōma Vahni Indu* is *Śaka* year 1308. Thus, there is no ambiguity in the year count.

The names of the months are also mentioned in the lunar calendar schemes in most of the inscriptions. The lunar months commence on the day after the New Moon. The name of the month is derived from the name of the star which is seen next to the Full Moon in that month. Twenty seven stars, called *yogatārās*, are identified in the sky to mark the position of the Moon each day. The duration is equivalent to the movement of the Moon by about 13°. For time division this interval is further subdivided into four '*Pāda*' (meaning quarter). Just as the Full Moon of March/April seen near the star *Citra* or Spica (Alpha Virginis) gives the name *Caitra* to the month, all other eleven names are derived from the corresponding star names.

The *Taittirīya Samhita* provides a different set of 12 names starting with *Madhu*, corresponding to *Caitra* and so on; both nomenclatures are found in the inscriptions. They are:

Madhu	*Caitra*	March – April
Mādhava	*Vaiśākha*	April – May
Śukra	*Jyēshṭha*	May – June
Śuchi	*Āshāḍha*	June – July
Nabhas	*Śrāvaṇa*	July – August
Nabhasya	*Bhādrapada*	August – September
Īśa	*Āśvayuja*	September – October
Ūrjha	*Kārtīka*	October – November
Sahas	*Mārgaśira*	November – December
Sahasya	*Pushya*	December – January
Tapas	*Māgha*	January – February
Tapasya	*Phālguṇa*	February – March

The lunar calendar has a scheme for introducing an intercalary month once every three years, as per the rules laid down. The corresponding month is recorded as *Adhika.* In the lunar calendar the month is divided into two (bright and dark) fortnights called *pakṣa*. The bright fortnight, called *Śukla, Śuddha, Pūrva or Sita*, ends with the Full Moon. The dark fortnight, called *Apara*, *Bahuḷa or Krishṇa pakṣa*, commences on the day after Full Moon and concludes with the New Moon. The days are identified by the numbers of these days in these *pakṣa*. *Pāḍya (Prathama*) is the first day, which when prefixed by *Śukla or Kriṣṇa* indicates the phase of the Moon or the day of the month. Likewise, the others are simply named *Dwitīya*, *Tritīya* … and so on, until *Caturdaśi*, the fourteenth day. These are generally referred to as the *tithis*.

Some special events have their names prefixed by a *tithi*. For example, one finds the work *Aksha Thadige*, the third day after New Moon in April/May. It is more specifically known as *Vaiśākha Śuddha Thadige*. Even today this day is celebrated with great pomp and show. It is the birthday of the great Saint Basavēśwara, who fought for virtues and eradication of the caste system in the eleventh century, and also of Shivaji, the great Maharshtra King.

In the solar calendar scheme, the name of the zodiacal constellation itself is the name of the month. We find these are used in inscriptions from regions in the extreme south of India, currently identified with Kerala and Tamiḷ Nāḍu. The lunar *tithis* are also included in the inscriptions from these regions.

As a rule, further time divisions, like the hours, general are not found. Some inscriptions provide *Ghaḷige* and *Vighaḷige* (Kannada versions of *ghatika* and *vighatika*) if it corresponds to a ceremony like the establishment of a temple or the coronation of a king. In death records (especially of *Jaina* saints) the time of death is recorded.

In our earlier study (Shylaja and Geetha, 2016), we mainly concentrated on the inscrsiptions found in and around Karnāṭaka, but with the language (not the political boundary) being the key criterion. A good number of Kannaḍa inscriptions are found in the adjoining states of Āndhra Pradēsh, Tamiḷ Nāḍu, Mahārāshṭra and Gōa. Many of the inscriptions are bi-lingual. For example, all the inscriptions at Tirupati have a combination of Kannaḍa, Sānskrit and Telugu, and at times Tamiḷ. The three volumes of inscriptions from Tirupati span the fifteenth, sixteenth and seventeenth centuries, the peak period of the *Vijayanagara* Empire. During the reign of *Krişṇadēvarāya*, every auspicious event was used as an opportunity to offer gifts and donations.

23.3 A Summary of a the Study of the Records from South India

Our study covered 14 volumes of *Ephigraphia Carnatica*, 9 volumes of *Ephigraphia Kannaḍa University*, 3 volumes of *South Indian Inscriptions* and several special volumes compiled on the basis of region or language or recent discoveries (Shylaja and Ganesha, 2012, 2014a, b, 2016). It was confined to South India, although Kannada inscriptions can be traced to as far away as Myanmar. About 38,000 inscriptions ranging from the sixth century to the seventeenth century, were scrutinised, and 1100 examples of useful information about celestial events were gathered. The results include solar eclipses, lunar eclipses, solstices, equinoxes and planetary conjunctions. One inscription showed a record of the 1604 supernova, concealed as a metaphor (Shylaja, 2019).

23.3.1 Solar Eclipses

The records that are engraved on the occasion of solar eclipses can be classified into four categories (omitting a small number of records with a total mis-match of dates). While most of the dates matched the compilation from NASA (https://eclipse.gsfc.nasa.gov/SEpubs/5MCLE.html), some could be corrected for typographical errors. There are some eclipses that were visible just outside the boundary of South India. Five inscriptions specifically mentioned a total eclipse or an annular eclipse. A typical record reads:“*Chalukya Vikrama Śaka 54 Sadharana samvatsara Kartika Shudda Padiva Vaddavara Suriya grahanadallu …*” The number 54 corresponds to the reign of the king of the Chalukya Dynasty; the name of the *samvatsara* is *Sadharana*; the name of the month is *Kartika*; *shudda padiva* implies the first day after New Moon; *Vaddavara* is the local version of Saturday; and *Suriya Grahana* is a solar eclipse.

23.3.2 *Lunar Eclipses*

The lunar eclipses mentioned include partial, total and even penumbral events. This helps us determine the limit of visibility that was accepted in order to declare an eclipse. The astronomical texts declare that if 1/12th part of the Moon is in the shadow it will be considered as an eclipse (for the Sun it was 1/16th part). Some dates of eclipses have been marked as possible penumbral eclipses by current software, such as *Occul*t. A search for discussion on penumbral eclipses showed that they were called *Dipti Hrāsa* (reduction of brightness) eclipses (Naraharaiah, 1912). Thus, these records indicate honest reports of eclipse observations.

A typical record reads as "*Śaka varsha 1098 Durmukhi Samvatsara Karthika Punnami Somoparaga nimitta …"* The *Śaka* count of the year is available; the name of the *samvatsara* is *Durmukhi*; the month is *Kartika*; *Punnami* is the local version of *Purnima* (Full Moon); *Soma* is the Moon; and *Somoparaga* is an eclipse of the Moon.

23.3.3 Vyatipãtha – *A Novel Concept*

A unique concept discussed in all texts on Hindu astronomy is *Vyatipãtha*. We find ample records with this citation. This is the instant corresponding to the equal values of the declination of the Sun and the Moon. It was possible to attribute the need for this as a tool to predict eclipses by fixing the position of the nodes of the Moon's orbit quite precisely (Shylaja and Ganesha, 2016). The records of the equality of the declination of the Sun and the Moon can be extended to predict eclipses. This has been worked out and examples are available. It has been possible to identify the instances where a solar or lunar eclipse was not visible from India but the equality of declination occurred either on the same day, or on the previous day or the next day. This is quite useful when discussing penumbral eclipses. Here is an example: "*Śaka varsha 1136 Bhava Samvatsara Ashadha Shudda 11 Somavara vyatipatha* ..." On 11th day of the bright fortnight of the month os *Ashadha*, in the *Śaka* year 1136 (CE 1214) *samvatsara* named *Bhava,* the declinations of the Sun and the Moon were equal. This is verifiable.

23.3.4 *Planetary Configurations and Special Events*

Some records are available of special occasions when planets and stars were in conjunction with the Moon, that led to occultations. The movement of the Moon is the fastest of all of the regular Solar System bodies, therefore mention of its conjunction with a star, for example, Aldebaran (*Rohiniyuta*), allows us to fix the time very precisely. On the other hand, Saturn being the slowest can be seen near a star for a good number of days but the conjunction refers to a minimum angle of separation. With details of the date, it has also been possible to work back and show that a conjunction indeed occurred on a said date.

Another example is an edict about the gift made by a *mahãraja*. It says that it was a New Moon day; *nakṣatra* was *Bharani*; and Jupiter was in conjunction with Sun and Moon. The year is given as *ashtanavottare*, implying the 198th year of the Gupta era. From *Stellarium* it was possible to verify that on the New Moon day of CE 7 April 517, the Moon, the Sun and Jupiter were within 2° of one another.

23.3.5 Records of Equinoxes and Solstices

A good number of records of solstices (*Uttaryana and Dakshinayana*) and equinoxes (*Vishuva*) are available, enabling us to check the corrections for precession. Here the comparison is easy because the lunar phase for the corresponding date is available. However, one has to take care because the word *uttarayana* is sometimes used to mean the half year when the Sun is moving north. For example that word can appear in the month of March.

A typical record is: "*Śaka varsha 1114 Paridhavi Samvatsara Pushya masa bahula 11 uttarayana sankramana.*" Here the Śaka year count as 1114; the name of the *samvatsara* as *Paridhavi* is used to fix the year; *Pushya masa* is the name of the month; and *bahula* 11implies the 11th day of dark fortnight in December–January.

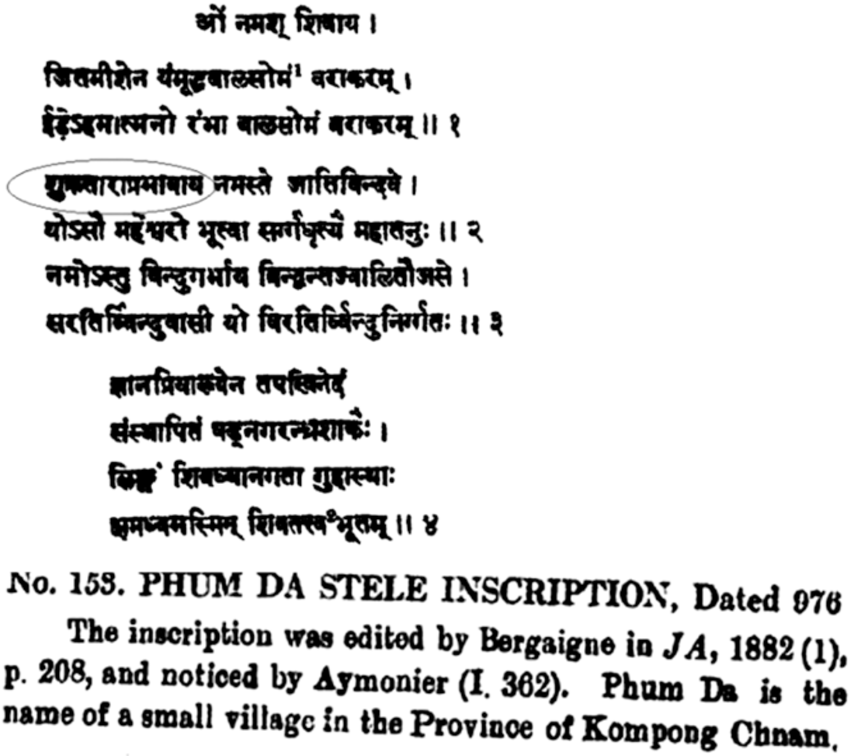
23.4 Records From All Over Southeast Asia

The influence of Hindu culture and tradition is easily recognizable by the facts that the stone inscriptions generally have Sanskrit as one of the languages, and the same *Śaka* count of the years was maintained throughout South East Asia. This makes the study as easy as for any part of India.

The biggest treasure of stone inscriptions is available from *Kambhoja* which comprises parts of present-day Cambodia and Thailand. These inscriptions were first compiled and published by the French archaeologist and historian George Coedès and the Sanskrit texts with English translations are now available thanks to the efforts of R.C. Majumdar (1953). Our study has revealed a record of the CE 1054 supernova (Fig. 23.4) as a metaphor on a stone inscription from Phum Da (Shylaja, 2019). The God has been described as "… one who can make a star shine as bright as Venus." An enquiry on the corresponding text in Khmer revealed an identical phrase (Kunthea Chome, pers. comm., February, 2019).

Another inscription from Angkor Wat dating to 1295CE mentions *Ketu*, which was identified as an invisible planet (Beer, 1967). It reads:

> In the year 1217 (of the Śaka era – corresponding to 1295 AD) on the 12th day of the first half of the month of Vaishakha, on a Thursday, under Citra … the king erected these two statues. Sun and Saturn were in Taurus, Mars and Rahu in Gemini; Moon in Libra; Jupiter in Scorpio; Mercury, Venus and Ketu in Aries. The ascendant being in the sign of Cancer …



No. 153. PHUM DA STELE INSCRIPTION, Dated 976

The inscription was edited by Bergaigne in *JA*, 1882 (1), p. 208, and noticed by Aymonier (I. 362). Phum Da is the name of a small village in the Province of Kompong Chnam.

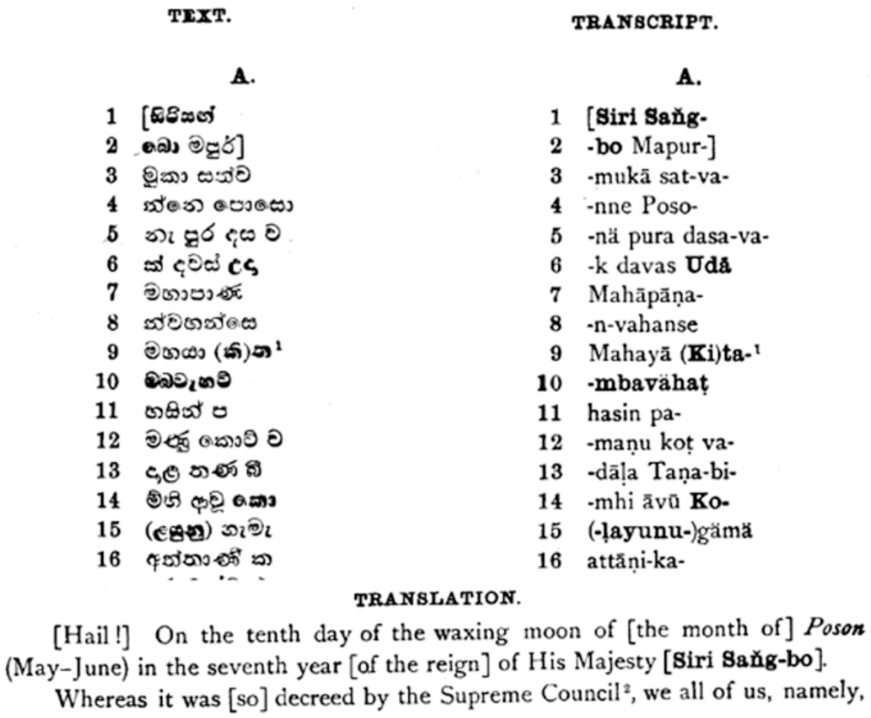
Fig. 23.4 The extract from the volume edited by R.C. Majumdar where the inscription is deciphered. Here the second line in the last verse refers to the year in the Bhuta *sankhya* system as *Shat* (6) *naaga* (serpent, 7) and *randhra* (9), which is Śaka 976.

All the planetary positions agree when compared with calculations as well as *Stellarium*. However, the location of the descending node of the Moon does not agree, since it should be 180° away from *Rahu* (in Gemini). There is no record of any comet. Therefore we had to search for an alternate explanation. We speculate that it may be a transient brightening of a star in the pre-planetary nebula phase (Shylaja and Ganesha, 2014b).

In the case of other countries, most of the records are not yet available in English translations. But a search for on-line records from other countries yielded some quite interesting results (Shylaja, 2018, 2019).

Sri Lanka has several volumes of inscription records that depict mostly the edicts of Buddha. Many of them have been copied in multiple languages, which need to be deciphered. The details of the phase of the Moon and the time of the year are available (e.g. see Fig. 23.5). The year count is not Śaka but is called the Buddha year. Records later than the fifth century CE have eclipses mentioned clearly.

The records from Nepal (e.g. see Fig. 23.6) all have the planetary positions very clearly written down. The introduction of zero in numerals is seen from the third



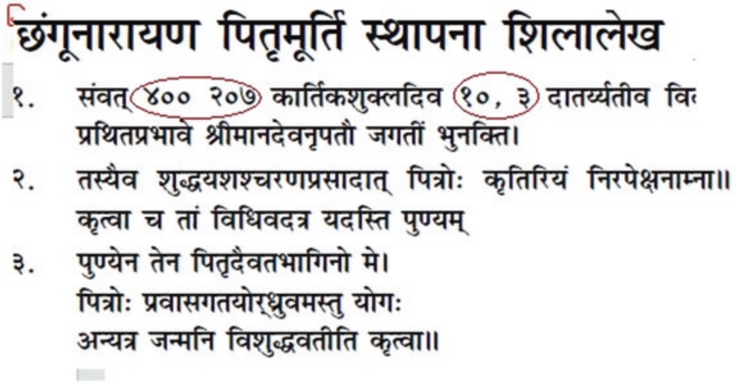
	TEXT.		TRANSCRIPT.
	A.		A.
1	[සිරිසඟ්	1	**[Siri Saňg-**
2	බො මපුර්]	2	**-bo** Mapur-]
3	මුකා සත්ව	3	-mukā sat-va-
4	න්නෙ පොසො	4	-nne Poso-
5	නැ පුර දස ව	5	-nä pura dasa-va-
6	ක් දවස් **උදා**	6	-k davas **Udā**
7	මහාපාණ	7	Mahāpāṇa-
8	න්වහන්සෙ	8	-n-vahanse
9	මහයා (**කි**)**ත**[1]	9	Mahayā (**Ki**)**ta-**[1]
10	**ම්බවැහට්**	10	**-mbavähaṭ**
11	හසින් ප	11	hasin pa-
12	මණු කොට් ව	12	-maṇu koṭ va-
13	දාළ තණ බි	13	-dāḷa Taṇa-bi-
14	ම්හි ආවූ **කො**	14	-mhi āvū **Ko-**
15	(**ළයුනු**) ගැමැ	15	(**-ḷayunu-**)gämä
16	අත්තාණි ක	16	attāṇi-ka-

TRANSLATION.

[Hail !] On the tenth day of the waxing moon of [the month of] *Poson* (May–June) in the seventh year [of the reign] of His Majesty **[Siri Saňg-bo]**.

Whereas it was [so] decreed by the Supreme Council[2], we all of us, namely,

Fig. 23.5 A typical record from Sri Lanka (after *Epigraphia Zylanica*).



छंगूनारायण पितृमूर्ति स्थापना शिलालेख

१. संवत् ४०० २०७ कार्तिकशुक्लदिव १०, ३ दातर्य्यंतीव वि
प्रथितप्रभावे श्रीमानदेवनृपतौ जगतीं भुनक्ति।

२. तस्यैव शुद्धयशश्चरणप्रसादात् पित्रोः कृतिरियं निरपेक्षनाम्ना॥
कृत्वा च तां विधिवदत्र यदस्ति पुण्यम्

३. पुण्येन तेन पितृदैवतभागिनो मे।
पित्रोः प्रवासगतयोर्ध्रुवमस्तु योगः
अन्यत्र जन्मनि विशुद्धवतीति कृत्वा॥

Fig. 23.6 A typical Nepalese Inscription, with the two red ellipses corresponding to the year count and the day count. It is dated 432 Śaka year written as 400 30 7, and the day is 13th day written as 10 3 (http://asi.nic.in/asi_books/6481.pdf).

century CE. The year 321 is written as 300 20 1. Not much of an emphasis is given to eclipses for making the records.

The records from Myanmar, Malaysia and Indonesia are not completely available in English. From a scrutiny of those published in the context of political history of the kings, development of social practices and the like, it can be inferred that they have the time very meticulously recorded. The purpose of these investigators was restricted to establishing the genealogy of the King and hence other details of the time record. Such records may include celestial events, but these are not mentioned in their papers.

23.5 Usefulness of the Study of Inscriptions

As has been discussed in Section 23.3, stone inscriptions contain a wealth of records of celestial events from several centuries BCE to about CE 1800. They need to be studied for possible records of sightings of comets and eruptive events like supernovae.

Another important aspect of the study concerns the detection of changes in the value of ΔT (the rotation rate of the Earth) over the past several millennia. Stephenson et al. (2016) have established this trend using eclipse records from Babylonia and China. The equation from this study is currently being used for the position of the Sun and Moon. The stone inscriptions mention the eclipse but do not give details of the timings. We found that the mention of totality could be used to assign limits to the values of ΔT. This required a very careful study of the text of the inscriptions.

We had found five inscriptions that described total or annular solar eclipses. The adjectives used were *Sarvagrāsi (*captured all over), *sakala kaluṣa* (dirtied all over); an annular eclipse was described as *valaya* (zonal) or *chudāmani* or *kankana* (after an ornament worn around the wrist). These were very useful when it came to establishing limits for values of ΔT. For example, the pillar at the Mallikārjuna Temple in Pattadakallu village shown in Fig. 23.7 contains an inscription about a total solar eclipse that was observed from that site on CE 25 June 754. Fig. 23.8 shows Espenak and Meeus' (2006) prediction of the path of totality of this eclipse, which does indeed cross India. From the latitude and longitude of the temple we can plot a close-up of the site and of the eclipse path across India, and this is shown in Fig. 23.9. Using these data, Ganesha and Shylaja (2019: 159) were able to conclude: "The eclipse date of AD 25 June 754 sets the limits on the value of ΔT, to about 2900 s and 3300 s. Hence this date becomes invaluable to the study of variations in ΔT …" Previously, Ganesha (2017: 16) stressed that "This is a very rare inscription which directly mentions totality of the solar eclipse, which precisely agrees with theoretical predictions."

These studies need to be continued because even now new excavations are bringing to light more and more inscriptions that were hitherto unknown. Last year we found two inscriptions from the ninth and eleventh centuries from South India that mentioned total eclipses, thanks to the availability of new volumes (see the Appendix

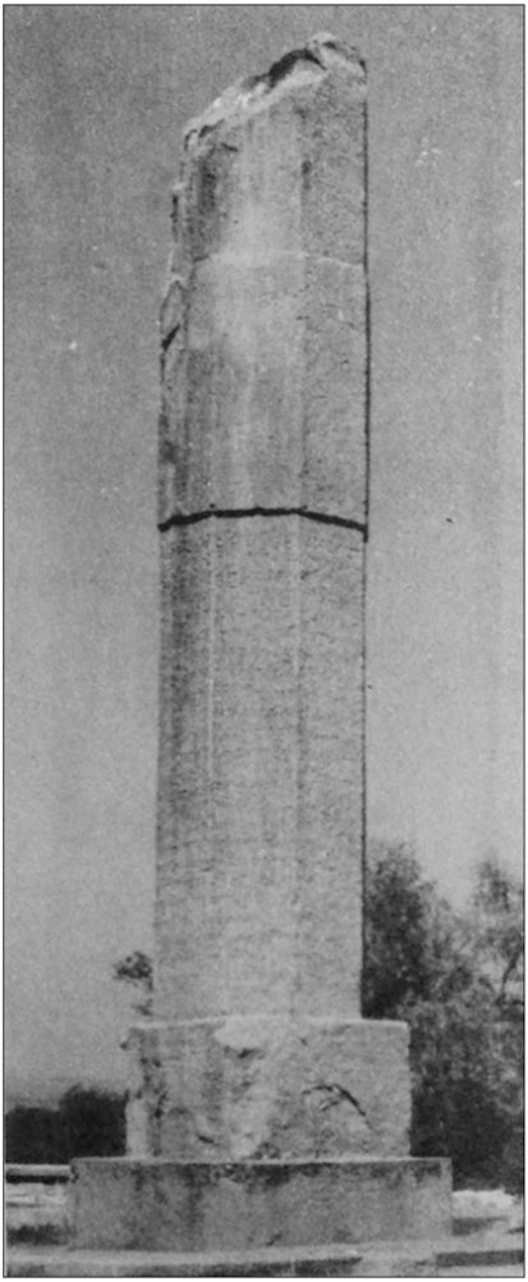


Fig. 23.7 The octagonal pillar with a square base at the Mallikārjuna Temple. The inscription was carved on the sides of the pillar and on the base (after Ganesha and Shylaja, 2019: 158).

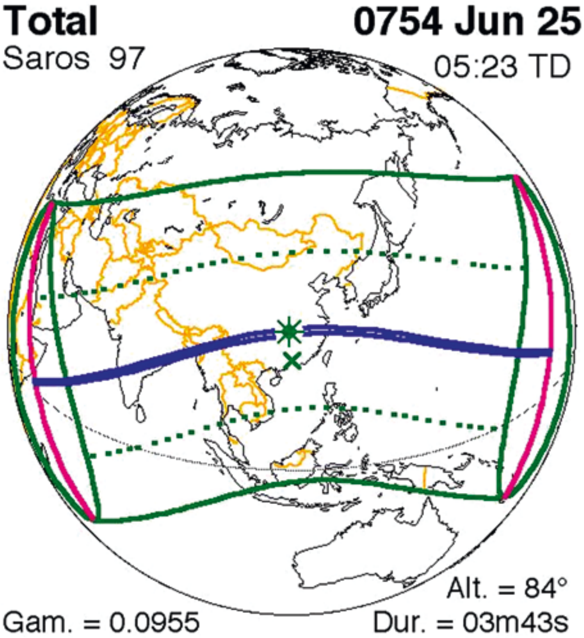


Fig. 23.8 The path of totality of the total solar eclipse of 25 June 754 (after Espenak and Meeus, 2006).

for a listing). Thus, the number of stone inscriptions that has contributed to determining the range for ΔT, has increased to seven (see Tanikawa et al., 2019).

There are two other exciting aspects of this study. One is to try and find observations of the *same eclipse* made from India and some other site or sites, which will significantly help narrow the range of ΔT values. Thus far, no such matches have been made, but as further Indian inscriptions listing solar eclipses are discovered the potential remains.

Yet even more exciting is Kiyotaka Tanikawa's tactic of looking at pairs or groups of total solar eclipses, that occurred within relatively short time intervals (i.e. tens of years) of each other and analysing them collectively. Thus, Tanikawa et al. (2017) compare and contrast the afore-mentioned eclipse 25 June 754 Indian eclipse (shown in Fig. 23.9) with an eclipse observed from China on 5 August 761. As we know, Ganesha and Shylaja (2019) had derived a ΔT value of about 2900–3300 for the Indian eclipse, while Tanikawa et al. obtained a figure of 1700–3270 for the Chinese eclipse. Combining the two results gave a final result of $2900 \text{ s} < \Delta T < 3270 \text{ s}$.

Taking this fruitful approach even further, Tanikawa et al. (2019) made their starting point the total solar eclipse of CE 01 August 1087 where the path of totality crossed northern Africa, the Middle East, India and SE Asia (see Fig. 23.10). This was one of the rare hybrid solar eclipses, where a total solar eclipse was seen along

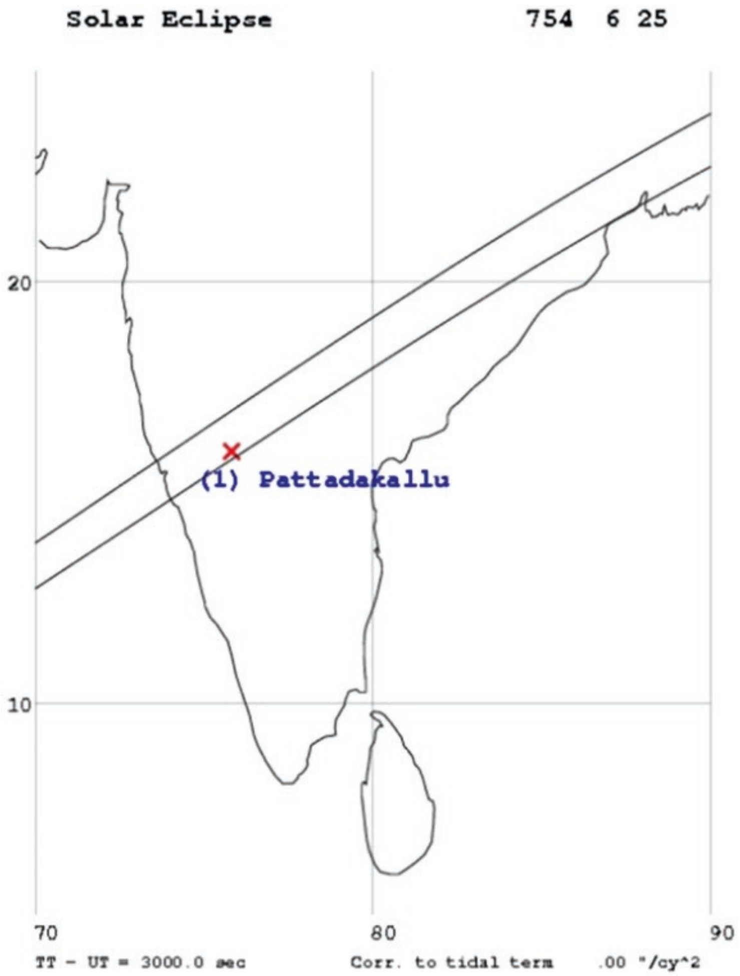


Fig. 23.9 An enlargement of the path of totality showing the location of the village of Pattadakallu and the Mallikārjuna Temple (after Ganesha and Shylaja, 2019: 161).

part of the path of totality, and annular eclipse elsewhere along the path. There were six different Indian inscriptions that mentioned this eclipse (their locations are also shown in Fig. 23.10), and two of them specifically stated that it was a total eclipse. For their analysis, Tanikawa et al. (2019) identified two other eclipses, seen from Baghdad on 20 June 1661 and from Kyoto on 21 July 1669. They then constructed a ‘Sôma Diagram’, an ingenuous diagram developed by Mitsuru Sôma where “The abscissa is the coefficient of the lunar tidal term and the ordinate is ΔT. In general, for a given year, the totality or annularity region of this parameter space for the eclipse is bound by nearly parallel curves.” The Sôma Diagram for this group of eclipses is reproduced in Fig. 23.11, and Tanikawa et al. (2019: 152) report the following results:

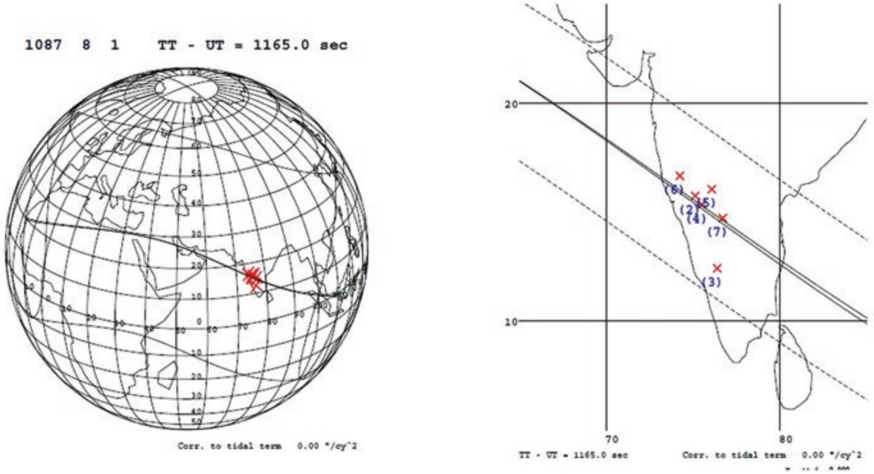


Fig. 23.10 Left: the path of totality of the 1 August 1987 eclipse; Right: a close-up on the eclipse path over India, showing the locations of the six stone inscription sites; two of these sites were on or very near the centreline of the path of totality (after Tanikawa et al., 2019: 149).

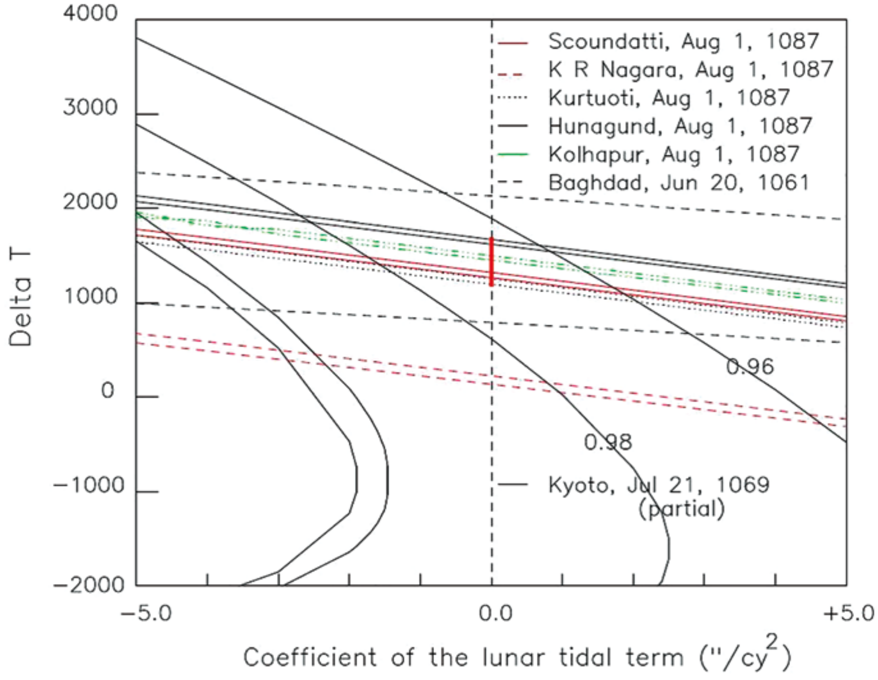


Fig. 23.11 The Soma Diagram for around CE 1087 (after Tanikawa et al., 2019: 153).

> … we obtained the following range of ΔT values. As shown by the red interval in the figure:
>
> $$1197s < \Delta T < 1673\,s.$$
>
> This comes from the lower-most and upper-most boundaries of the five annularity parallels for Indian cities. If we dare to adopt the range of ΔT from the parallels of Soundatti, Raibag, we obtain 1267 s < ΔT < 13123 s.

There are many such instances involving different solar eclipse stations spread across different countries. Therefore the availability of records should indicate an appropriate trend and will help us understand short term variations in ΔT due to tidal interactions. Hopefully there are astronomical inscriptions from SE Asia that also will be helpful in this regard.

Apart from solar eclipses the Indian stone inscriptions record lunar eclipses, while Shylaja and Ganesha (2014a) mention that there also are many records of conjunctions and planetary occultations. Some of these occultations may hold special promise because Sôma and Tanikawa (2016) have shown that when combined with solar eclipse data, they also can be used to research variations in the rotation rate of the Earth.

The Indian inscriptions have some unusual events recorded, like the distribution of alms to people when an epidemic-like plague broke out or when there was an earthquake (although earthquakes are quite rare in southern India).

23.6 Future Work

The stone inscription records of eclipses and other celestial events bear testimony to the observational and mathematical ability of the astronomers of yesteryear. This aspect has not been given much thought so far, whereas their potential as rich resources of social, historical and political upheavals has been researched.

A careful study will reveal not only the astronomical events but the names of the astronomers (to whom grants were made), some of whom may have been forgotten long ago.

An event like a total solar eclipse that was recorded at two or more different geographical locations will serve as a very useful tool for tracking variations in ΔT in the past.

The study of these inscriptions also will throw light on the evolution of calendars and time measurement systems in these countries. The big puzzle about the time of the introduction of the twelve zodiacal constellations in the prevalent lunar mansion scheme may also be solved.

Acknowledgements The invitation by Professor Wayne Orchiston to contribute to this volume is gratefully acknowledged, and I particularly wish to thank him for researching and writing most of Section 23.5 and adding many new references. Thanks are also due to Geetha Kydala Ganesha for having provided the additional volumes of inscriptions which contributed to important inferences.

Appendix: Epigraphy Volumes that have been Studied Since the Publication of our Book (Shylaja and Ganesha, 2016)

1. *Epigraphia Kannada University Volume – 9* – Bagalakote District – published by Prasaranga Kannada University, Hampi, 2006.
2. Epigraphia *Carnatica Volume 15* – Shivamogga District – Hosanagara Taluk and Sagara Taluk – published by Kuvempu Institute of Kannada Studies, Mysore, 2009.
3. *Epigraphia Carnatica Volume 24* – Tumkur District – Tumkur Taluk, Kunigal Taluk, Gubbi Taluk and Chikkanayakanahalli Taluk - published by Kuvempu Institute of Kannada Studies, Mysore, 2009.
4. *Kalyana Chalukyara Shasanagalu Volume-1* – published by Kuvempu Institute of Kannada Studies, Mysore, 2011.
5. *Kalachuri Shasanagalu* – published by Yuvasadhane, Bengaluru, 2017.

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Shylaja, B.S., and Ganesha, G.K., 2014a. Planetary conjunctions and occultation records in stone inscriptions in India. In Sôma, M., and Tanikawa, K. (eds.), *Proceedings of the Intensive Workshop on Ancient and Medieval Data: Compilation of Eclipse Data and Examination of their Reliability*. Tokyo, National Astronomical Observatory of Japan. pp. 43–48.

Shylaja, B.S., and Ganesha, G.K., 2014b. Records of *Ketu* in stone inscriptions. *Current Science*, 107(10), 1751–1753.

Shylaja, B.S., and Ganesha, G.K., 2016. Records of Vyatīpāta in stone inscriptions. *Indian Journal of Hist-orical Sciences*, 51.2.1, 206–216.

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Sôma, M., and Tanikawa, K., 2016. Earth rotation derived from occultation records. *Publications of the Astronomical Society of Japan*, 68, 29(1–8).

Sôma, M., and Tanikawa, K. (eds.), 2017. *Proceedings of the Sixth Symposium on "History of Astronomy"*. Tokyo, National Astronomical Observatory of Japan.

Stephenson, F.R. Morrison, L.V., and Hohenkerk, C.Y., 2016. Measurement of the Earth's rotation: 720 BC to AD 2015. *Proceedings of the Royal Society* (London), A 472: 20160404 https://doi.org/10.1098/rspa.2016.0404

Subbarayappa, B.V., and Sarma, K. V., 1985, Indian Astronomy; A Source Book, Nehru Center, Bomaby.

Tanikawa, K., Sôma, M., Ganesha, G.K., and Shylaja, B.S., 2017. *ΔT* from solar eclipse on 754 June 25 observed in India and solar eclipse on 761 August 5 observed in China. In Sôma and Tanikawa, 46–53.

Tanikawa, K., Sôma, M., Shylaja, B.S., and Vahia, M., 2019. The reliability of the records of observed solar eclipses in India and comparison with contemporaneous eclipse data from other countries. In Orchiston et al., 143–155.

Taranatha, N.S. (ed.), 2001. The Discovery of the Century. Bengaluru, Karnataka Sahitya Academy (in Kannada).

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Chapter 24
The Evolution of Local Southeast Asian Astronomy and the Influence of China, India, the Islamic World and the West

Yukio Ôhashi and Wayne Orchiston

24.1 Introduction (YÔ and WO)

There are several traditional calendars in Asia, and in some regions, they are still used for traditional festivals etc.

For example, there are several Thai traditional calendars that are popular today (see Fig. 24.1), and in 2017 the first author of this chapter also was able to purchase some Burmese calendars at a bookshop in Mandalay where Burmese traditional dates are mentioned (Fig. 24.2).

There are several traditional festivals in Thailand and Myanmar, such as *Songkrān* in Thailand, which corresponds to *Thingyan* in Myanmar, and *Lōy Krathong* in Thailand, which corresponds to the *Tazaungdaing* festival in Myanmar, etc. (for Thai festivals see Gerson, 1996; Kajiwara, 2013).

Songkrān was originally a Sanskrit word *saṅkrānti*, which means the Sun's entrance to a sign of the zodiac. The famous Thai *Songkrān* festival is the Sun's entrance to the sign Aries, that is the vernal equinox. However, *Songkrān* currently

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Unfortunately, Dr Yukio Ôhashi died suddenly on 31 October 2019, so this chapter combines his original manuscript and additional material provided by Wayne Orchiston. The editors of this book felt it essential that Yukio's chapter be included in the book, in order to round out the discussion and close off the book. But there were legal issues, and the only way we could address these was by adding a co-author and substantially expanding Yukio's original manuscript. To indicate authorship, the following code is used after each heading: (YÔ) = prepared by Yukio Ôhashi; (WO) = prepared by Wayne Orchiston; and (YÔ and WO) = prepared by both authors.

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https://doi.org/10.1007/978-3-030-62777-5_24

Fig. 24.1 Recent Thai traditional calendars (Ôhashi Collection).

is celebrated during 13–15 April in Thailand, because the Indian sidereal year is used for the traditional Thai calendar. Meanwhile, according to Ma Thanegi (2014: 51), Burmese New Year falls on 17 April, and *Thingyan* is celebrated for five days prior to that date. *Lōy Krathong* is on the Full-Moon day of the 12th month of the traditional Thai luni-solar calendar.

We shall come back to the relationship between the Indian sidereal year and lunar months in the traditional Thai calendar in Sub-section 24.2.2, later in this chapter.

In several areas of Asia, traditional astronomy has a 'multiplex structure' consisting of local original astronomical knowledge plus the influences of China, India, the Islamic World and the West. For example, Tibetan traditional astronomy (Ôhashi, 2000) and related Mongolian astronomy are a kind of multiplex astronomy consisting of local knowledge, Indian Classical astronomy, certain information derived from the Islamic calendar and Chinese traditional astronomy. Iran also was a kind of crossroads of traditional astronomy, as indicated by some recent studies (e.g. see Isahaya, 2009, 2013).

In this chapter, we shall see that there are several different kinds of multiplex astronomy in Southeast Asia. This long chapter is a substantially revised and greatly expanded version of the papers that the first author (YÔ) presented at the meeting of the Southeast Asian Astronomy Network's History & Heritage Working Group on "Researching the History of Astronomy in Southeast Asia" in Ao Nang, Thailand in 2015 and the Working Group's second meeting in Mandalay, Myanmar in 2017, along with a range of additional material provided by the second author (WO). After

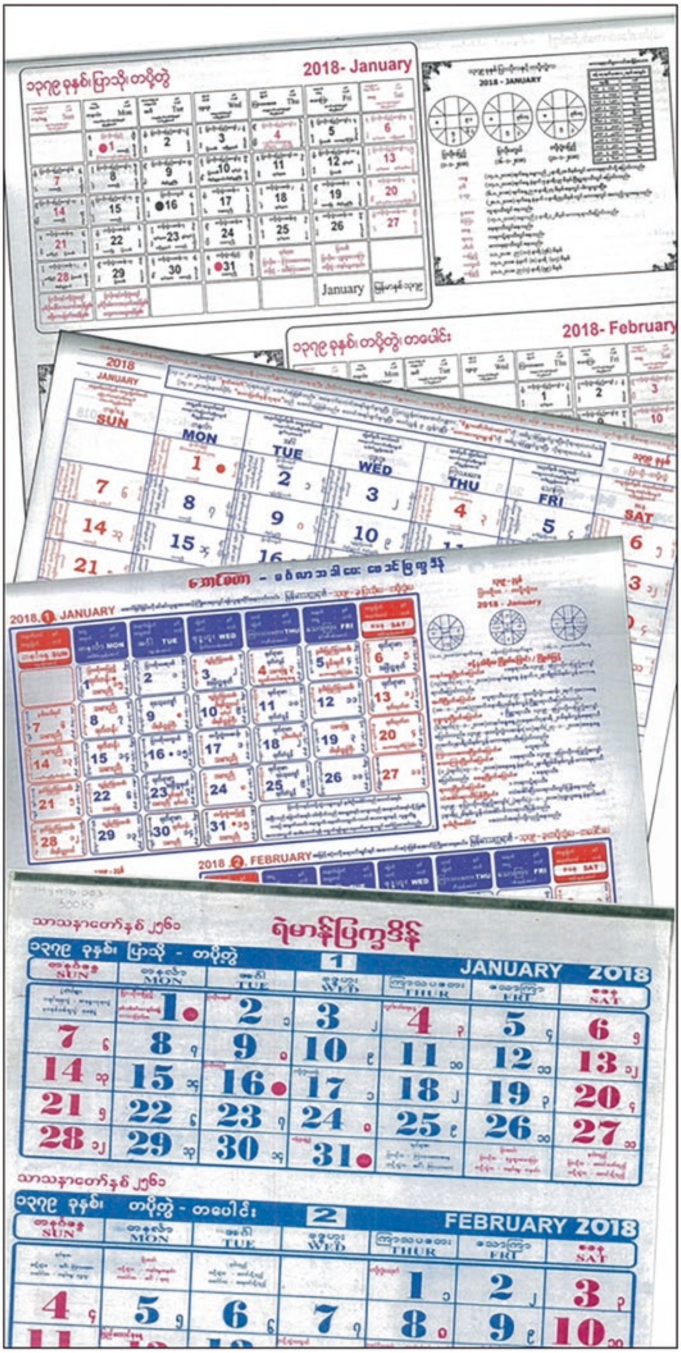


Fig. 24.2 Recent Burmese calendars (Ôhashi Collection).

the Ao Nang meeting, YÔ also presented an overview of Southeast Asian astronomy in Japanese in Tokyo, and later this was published (Ôhashi, 2016b). After the Mandalay meeting, he also presented a paper in Japanese (Ôhashi, 2018) at a research seminar in Japan. This chapter also draws freely on some of the material prepared by WO when researching Chapters 1, 2 and 19 in this book.

24.2 Geographical Overview: Mainland Southeast Asia

Mainland Southeast Asia can be divided into Vietnam, where Chinese astronomical influence was strong, and other areas, where Indian astronomical influence was strong. For the history of Mainland Southeast Asian astronomy in general see Ôhashi (2005, 2008, 2011).

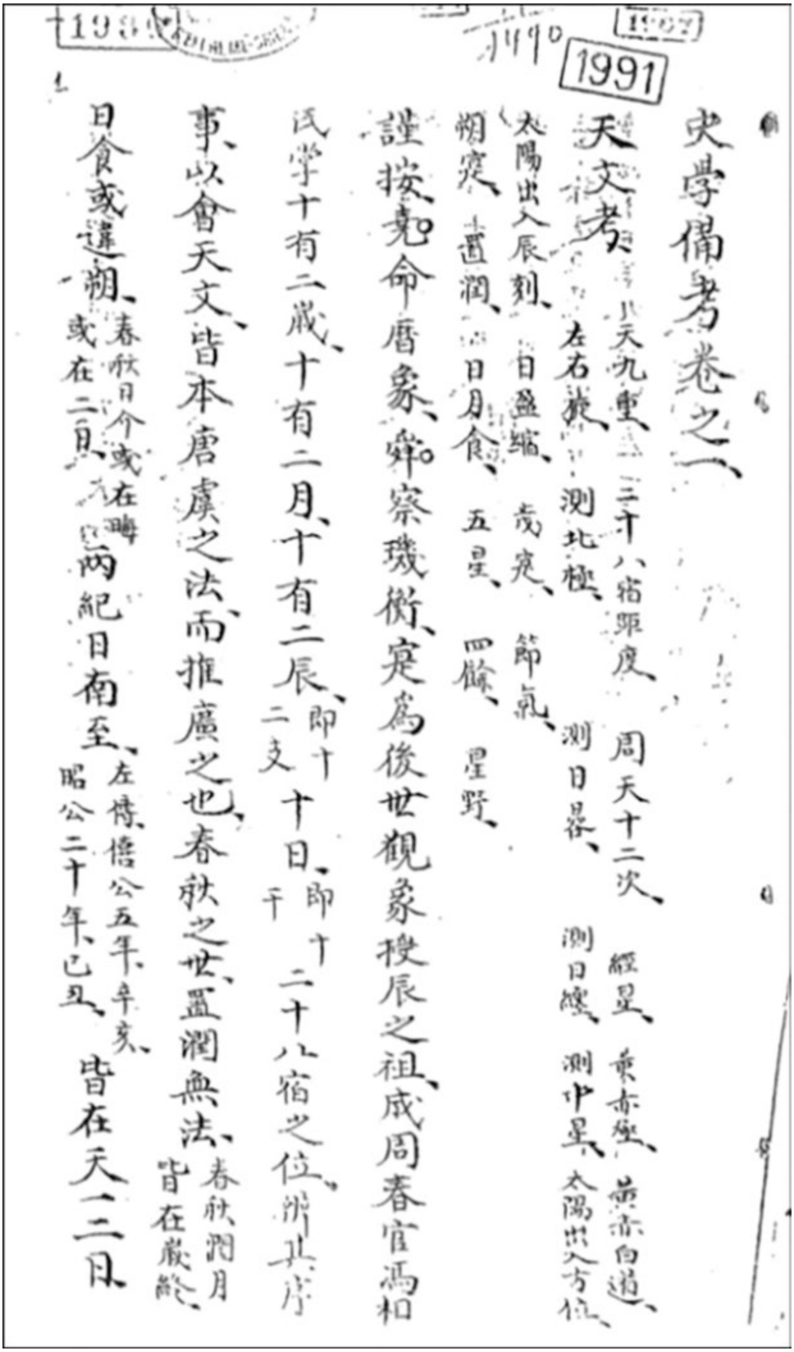
24.2.1 Vietnam (YÔ and WO)

Chinese classical calendars were used in Vietnam. Sometimes, Vietnam continued to use the old Chinese calendar even after the introduction of a new calendar in China, which led to certain differences between Vietnamese and Chinese astronomy. Most pre-modern Vietnamese astronomical works were written in Classical Chinese. Fig. 24.3 is an example of a manuscript on Vietnamese astronomy (*Thiên-văn khảo* (天文考, *Study of Astronomy*) written in classical Chinese language, which is Volume 1 of the *Sử-học bị-khảo* (史学備考) of Dặng Văn-phủ (鄧文甫) and is preserved in the Institute of Sino-Nom Studies in Hanoi.

From around CE 1300 to CE 1812, the Chinese theory of the Shoushi-li (授時曆) Calendar and its successor, the Datong-li (大統曆) Calendar were basically used in Vietnam, but it seems that the calculations were done in Vietnam. Even after the Shixian-li (時憲曆) Calendar was adopted in China, the Datong-li Calendar continued to be used in Vietnam until CE 1812 (Ôhashi, 2016a).

From CE 1813, the Shixian-li Calendar was adopted in Vietnam. At the time of Emperor Minh-mạng (明命) (reign 1820–1840) of the Nguyễn Dynasty, calendar reform was carried out, and it was declared in 1837 that the prime meridian for Vietnam passed through its capital, Hue. After 1841, the longitudinal difference between Beijing and Hue was taken into consideration during the calculation of the calendar. So, from that time on, the Vietnamese classical calendar differed from the Chinese classical calendar (Ôhashi, 2004, 2005).

After World War II, before the reunification of Vietnam, North Vietnam decided to use UTC+7 as standard time in 1968, while South Vietnam used UTC+8, which was the same as Chinese standard time. Since the reunification in 1975, UTC+7 has been used. So, Vietnamese traditional New Year's Day *Tết* sometimes differs from Chinese traditional New Year's Day. For example, Chinese traditional New Year's Day in 1985 was 20 February, but Vietnamese traditional New Year's Day was 21



史學備考卷之一

天文考（九天九重、二十八宿距度、周天十二次、經星、黃赤極、黃赤白道、左右旋、測北極、測日晷、測日躔、測中星、太陽出入方位、太陽出入辰刻、日盈縮、歲寔、節氣、朔寔、置閏、日月食、五星、四餘、星野、）

謹按堯命曆象、舜察璣衡、定為後世觀象授辰之祖、成周春官馮相氏掌十有二歲、十有二月、十有二辰、（即十二支）十日、（即十干）二十八宿之位、（辨其序）事、以會天文、皆本唐虞之法而推廣之也、春秋之世、置閏無法、（春秋閏月皆在歲終、）日食或違朔、（春秋日食或在晦或在二日、）而紀日南至、（左傳僖公五年辛亥、昭公二十年己丑、）皆在天一二日

Fig. 24.3 A manuscript of a work on Vietnamese astronomy (courtesy: Institute of Sino-Nom Studies, Hanoi).

January (Takeuchi, 1987). There are papers about traditional Vietnamese calendars and Vietnamese astronomy by Lê (2010, 2019), Lê and Trường (2017), Okazaki (2017, 2021) and Phâm and Lê (2021), while Nguyen and Nguyen (2004) report on the bamboo stick calendar of the Muong people of Vietnam.

We also need to consider the Champa Kingdom, which existed in present-day central and south Vietnam until 1932. It was much influenced by Indian culture, and dates in inscriptions using the Śaka Era were mentioned in Indian style from the sixth century onwards (see Sugimoto, 1956). The present-day *Cham* people in Vietnam are Austronesian speakers, are said to be the descendants of the Champa Kingdom, and have their own distinctive calendrical system (see Nakamura, 1999, 2009; Sakaya, 2016; Yoshimoto, 2000, 2003, 2011). Their calendars are discussed further in *Sub-subsection 24.9.3.1* below.

24.2.2 Thailand, Laos, Cambodia and Myanmar (YÔ and WO)

Traditional astronomy in this area is a combination of local indigenous astronomy, Chinese influence and Indian influence. For traditional calendars in this area see Eade (1995) and Gislén and Eade (2019a, 2021), and for Indian astronomy viewed from a Southeast Asian perspective see Ôhashi (2009, 2016b).

The *Tai* (傣, *Dai* in Chinese pinyin transliteration) people in Sipsong-panna (西双版纳, Xishuang-banna in pinyin transliteration) in Yunnan (云南) Province of China are closely related to the Thai people, and have traditional astronomical texts. There are detailed studies of the astronomy of the *Dai* people by Zhang and Chen (1981) and Zhang (2013: Volume 3). The traditional culture of the *Ahom* people (one of the *Tai* peoples) in Assam, India, is also close to this area. For their astronomical knowledge, see Terwiel and Wichasin (1992). The *Cham* people (mentioned above) also are culturally similar.

In Thailand, Chinese influence and Indian influence can be seen in an early inscription. In the inscription of King Ram Khamhaeng of the Sukhothai Dynasty of Thailand (see Chamberlain, 1991), a year is mentioned as "In 1214 Śaka, year of the Dragon", which corresponds to CE 1292. Both the Indian year (1214 Śaka) and the Chinese year (year of the Dragon) are used. Then in the fourteenth century, King Lithai of the Sukhothai Dynasty wrote the *Trai-phūm (Three Worlds)* which described Buddhist cosmology in detail (for the English translation of this work see Reynolds and Reynolds, 1982). Then during the Ayutthaya Dynasty de La Loubère (1693) provided a detailed record of Siamese culture, including traditional astronomy, which was examined and explained by Paris Observatory's first astronomer Jean-Dominique Cassini (1625–1712). This marked the first time that information about an Indianized calendar was introduced to European astronomers. For information about the traditional Thai calendar see Gislén and Eade (2019b, 2019d), Komonjinda et al. (2017), Nonaka (1987) and Suehiro (1987).

Some different eras were used in Thailand. In the Sukhothai inscriptions, the Śaka Era, which is called *Mahā-sakkarāt* in Thai, was used, of which the best known is that of King Ram Khamhaeng. Its 0th year began in CE 78 (so, CE 78/79 = *Mahā-sakkarāt*). Then, *Junla-sakkarāt*, which is the same as the Burmese Era, was used through to March of CE 1889. Its 0th year began in CE 638 (so, CE 638/639 = *Junla-sakkarāt*). Until March of CE 1889, the luni-solar calendar was used officially in Siam. Since 1889, the Gregorian Calendar has been used, but each year began from April (instead of January) up until 1940. From April 1889 to March 1912, the Rattanakosin Era, or *Rattanakōsin-sok* in Thai, was used. Its 1st year began on CE 1782 (so, CE 1781/1782 = *Rattanakōsin-sok*). From April 1912, the Buddhist Era, which is called *Phuttha-sakkarāt* in Thai, has been used. Its 0th year began in 544 BC (so, CE + 542/543 = *Phuttha-sakkarāt*). From 1941, the Thai year began in January, and *Phuttha-sakkarāt* has been commonly used until now (now, CE + 543 = *Phuttha-sakkarāt*). Eade (1996) gives several examples of dated inscriptions and chronicles using *Mahā-sakkarāt*, *Junla-sakkarāt* and *Phuttha-sakkarāt*.

For Thai folk-astronomy, see Maison (2013), Phengkaew (2009) and Saibejra (2012). There are some Thai original asterisms (see Sub-subsection *24.4.1.1* below). The National Astronomical Research Institute of Thailand (NARIT) has published a series of books on traditional Thai astronomy in the Thai language, namely, Phumphongphaet (2013) on Thai archaeoastronomy, Maison (2013) on Thai folk-astronomy, and Sawasdee and Maison (2013) on Thai calendrical astronomy.

There was an independent Lanna Kingdom in northern Thailand from the end of the thirteenth century to the beginning of the twentieth century, and the *Lanna* people had their own astronomical systems and beliefs which were based on Indian astronomy (see Soonthornthum 1998, 2006). For the northern Thai calendar, see Davis (1976).

There are a number of Chinese ethnic minorities found in the mountainous regions of northern and north-western Thailand that have their own distinctive astronomical systems. According to Iijima (1971: 81 and 109), who studied the *Karen* people of northern Thailand in 1963–1964 and 1964–1965, the *Karen* calendar begins from the month *Tale* (mid-December to mid-January in the Gregorian Calendar), and the months *Teku*, *Tepe*, *Lasa*, *Denya*, *Lanwe*, *Laxo*, *Laku*, *Chimú*, *Chicha*, *Lano* and *Laplu* follow.

The *Mon* people are an ethnic minority group with Myanmar origins who are now also resident in central Thailand, and speak the Mon language which is one of the Austro-Asiatic languages. The *Mon* have their own literature, including astronomical texts. When King Rama IV (r. 1851–1868; Soonthornthum and Orchiston, 2021) predicted the total solar eclipse in 1968, he used astronomical texts written in Siamese, Mon and English. According to Thongchai (1994), King Mongkut used a Mon text *Saram*, one of the two Mon treatises for planetary calculation known in Siam; the other text, more conventionally used by astrologers at that time, was *Suriyayat*. Komonjinda et al. (2017) state that King Rama IV created the *Pkakanana* system of luni-solar calendar following the *Saram*, which is complicated but more accurate than the usual Thai luni-solar calendar that follows the *Suriya-yatra*. According to Komonjinda et al. (*ibid.*), the *Pkakanana* system is now used only in *Dhammayuttika Nikaya*, which is an order of Theravada Buddhism in Thailand.

Lao people are closely related to the Thai people, and their traditional luni-solar calendar is described by Dupertuis (1981) and Phetsarath (1940, 1959).

In Cambodia there are inscriptions using the Indian Śaka Era dating from the seventh century CE (Barth, 1885). There is a well-known inscription dated Śaka 605 (= CE 683), which is one of the earliest inscriptions that have numerals with the symbol for zero (Aczel, 2015; Cœdès, 1931; Hayashi, 2018: 31).

There is a Chinese record of the Angkor period of Cambodia titled *Zhenla-fengtuji* (真臘風土記) written by Zhou Daguan (周達觀), who in CE 1296–1297 visited Cambodia (which was called *Zhenla* in Chinese at that time). Zhou's account (2000) includes a section on the calendar: the first month of the Cambodian calendar corresponded to the tenth month of the Chinese calendar and was called *jiade* (佳徳). However, this term *jiade* originated from the Sanskrit word *Kārttika*, so we can see the influence of the Indian calendar in Cambodia.

According to Porée and Maspero (1938), there were four astrologers called *hora* in the Cambodian court, and they made calendars and predicted auspicious times etc. For details of Cambodian astronomy see the monograph by Faraut (1910).

The Kingdom of Pagan, the earliest kingdom of the Burmans, existed in present-day Myanmar from the mid-eleventh century to the thirteenth century CE. Luce (1969-1970) tells how Pagán became the Buddhist capital of a united Burma, including Mons and Burmans, from about CE 1060, and he discusses the Old Burma Calendar used in Old Mon and Old Burmese inscriptions dating to the Buddhist, Śaka or Burmese Eras (Luce, 1970(II): 327–337). There are early records of Burmese culture, including cosmology, by Sangermano (1833/1893) and Shway Yoe (1882/1910), while Leider (2005-2006) discusses the function of court astrologers during the Konbaung Dynasty (i.e. from 1752 to 1885).

Burma has its own asterisms, which are described by Buchanan (1799: 195–202), and partially in Khin Zaw (1937). There are some star maps in Burma, the most interesting being three drawn on the ceilings of corridors in the Kyauktawgyi Pagoda at Amarapura, near Mandalay, which was built in 1847 (see Nishiyama 1997). A detailed discussion of these star maps is presented below in Sub-subsection *24.4.1.2*.

For information about the traditional Burmese calendar and astronomy see Clancey (1906), de Silva (1914), Gislén and Eade (2019b, 2019d, 2021), Htoon-Chan (1918), Irwin (1909) and Kiryū (1987), while Furnivall (1922) discusses the Indian Jovian 12-year cycle in Burmese inscriptions. In the traditional Burmese calendar the Burmese Era is used, where the 0th year corresponds to CE 638. Note that the Burmese Era corresponds to the *Junla-sakkarāt* of the Thai calendar.

Irwin (1909) reports the difference between the Burmese calendar and the Arakanese (Rakhine) calendar in the early twentieth century. The Burmese calendar used the *Makaranta*, which probably followed the original *Sūrya-siddhānta*, until the nineteenth century. The *Thandeikta*, which chiefly followed the present *Sūrya-siddhānta* and is said to have been composed in about CE 1738 or CE 1838, was used in the Burmese calendar thereafter. Meanwhile, the *Makaranta* was still used by the Arakanese. There have been recent studies of Burmese astronomy by Gislén (2015, 2018) and Gislén and Eade (2014).

24.2.3 The Malay Peninsula (YÔ and WO)

Early records of astronomical knowledge in the Malay Peninsula were collected by Skeat (1900: 532–566). According to this work, the Malay people in the Malay Peninsula used a 5-day cycle and a 7-day week. The signs of the zodiac had Arabic names. One lunar month was divided into days that seemed to have originally corresponded to the Indian lunar mansions, but their number was usually raised to 30 so as to fit a lunar month. Both the solar year (= tropical year) (365 days) and the lunar year (= 12 synodic months) (354 days) were used. For the calculation of the Islamic lunar year, the 120-year cycle (= 1440 synodic months = 42,524 days) and the 8-year cycle (= 96 synodic months = 2835 days) were used. They were the usual simplified methods for calculating Islamic lunar years.

In modern Malaysia, there is a controversy regarding the Islamic calendar. According to Horii (1987), who studied in Malaysia, some people prefer the actual observation of the crescent Moon (*rukyah*) while others prefer calculations (*kiraan falak*) to determine the first day of an Islamic month. For example, Horii reports that in August 1981, the Sultans of Perak State and Johor State decided the day of the festival Hari Raya Aidilfitri (the first day of the month Syawal after the end of the month Ramadan) by actual observations of the crescent Moon, and it was one day earlier than in other states in Malaysia.

The indigenous minorities in the Malay Peninsula are called *orang asli* (the original people) and consist of the ‘Semang’ (negritos), ‘Senoi’ (who speak Austroasiatic languages) and Proto-Malays. Their cultures are described by Skeat and Blagden (1906). According to this work, the Proto-Malay people denote seasons by the north and south monsoons, and also the harvesting of rice and the ripening of fruits. They know time by the inclination of a stick directed to the Sun (Skeat and Blagden, 1906(I): 393). Semang people think that the Sun and the Moon are female, and each has a husband, while the stars are the Moon’s children. Eclipses are attempts by a gigantic serpent or dragon to cover or swallow the Sun, and there is great fear (Skeat and Blagden, 1906(II): 202–203). Recent studies of indigenous Malaysian astronomical systems are reported elsewhere in this book (see Jaafar and Khairuddin, 2021a, 2021b; Khairuddin and Jaafar, 2021).

24.3 Geographical Overview: Island Southeast Asia (YÔ and WO)

Traditional astronomy in Island Southeast Asia is based on local original astronomical knowledge and Indian, Islamic and sometimes Western influences.

For information about the Indianized calendar in this region see Casparis (1978), Damais (1967), and Eade and Gislén (2000). In Java, there are inscriptions dated by the Indian Śaka Era from the eighth century (Nakada, 1982), and there is also an inscription dated to Śaka 605 (= CE 683) in Sumatra, which is one of the earliest inscriptions that has numerals with the symbol for zero (Cœdès, 1931; Hayashi, 2018: 31). For details of the Islamic calendar in this area see Gislén and Eade (2019c) and Proudfoot (2006). For the astronomy of this region in general see Ammarell (2008), Hidayat (2000) and Maass (1924-1926).

Although the Andaman and Nicobar Islands belong politically to India, their traditional cultures are close to those of island Southeast Asia. For information on the astronomical knowledge of the negritos of the Andaman Islands see Radcliffe-Brown (1928: 141–150), and the indigenous groups of the Nicobar Islands see Man (1897; Vahia et al., 2018).

There also were Austronesian people in Taiwan who were culturally close to the inhabitants of Island Southeast Asia, and there were several studies made by Japanese ethnologists early in the twentieth century (see Ôhashi, 2017b).

We also should note that there are cultural links between Island Southeast Asia and the Polynesian, Melanesian and Micronesian inhabitants of the Pacific islands (e.g., see Bellwood, 2017; Carson et al., 2013).

24.3.1 Sumatra (YÔ)

Marsden (1811: 193–194) records that the Malays used the Islamic calendar (where one year is 354 days), but the original Sumatrans estimated their annual periods from the revolution of the seasons. To denote the time of day, they pointed with their finger to the height of the Sun. They noticed the planet Venus, but did not imagine that the morning Venus and the evening Venus were the same. During an eclipse, they made a lot of loud noise with percussion instruments to frighten off the snake or dragon intent on devouring the Sun.

In Sumatra, there are Batak and Nias peoples etc. (who are Proto-Malays), and Acehnese, Minangkabau and Lampung peoples, etc. (who are Malays).

There is a detailed work on Acehnese culture by Hurgronje (1906, cf. Kurata, 1982), and the Acehnese calendar is described on pages 194 ff. According to this work, the Islamic lunar year is used by Acehnese people (who live in northern Sumatra). Although the commencement of each month should basically be determined by observation, in many districts the calculation is adhered to, and the 8-year cycle and the 120-year cycle are used. There are three intercalary years (355 days) in eight years. In this method, there is a 1-day excess every 120 years, but Hurgronje was not been able to discover whether the Acehnese people corrected for this at the end of every 120 years by skipping a day. The Acehnese are agricultural people, and a seasonal calendar is needed. For this purpose, stars are used. Acehnese people know the three stars in Orion's Belt, Venus (they consider the 'Morning Star' and the 'Evening Star' to be two different stars), the Southern Cross, the Scorpion, the Pleiades, etc. The line joining the three stars in Orion's Belt was thought to point to Qibla, and this idea also prevails in Java. Conjunctions of Scorpion and the Moon are considered to regulate the seasons—there are 13 (sometimes 14) conjunctions in a solar year. Sometimes conjunctions of the Pleiades and the Moon are also used. The Acehnese people used the N.E. and S.W. monsoons for navigation.

Kiyono (1943: 492–497), referring to the works of the German ethnologist A. Maass, mentions some astronomical knowledge of the Minangkabau people of central Sumatra. Time was determined from the altitude of the Sun. At 1 p.m. a vertical rod was erected, and the prayer ‘Asr’ had to be completed before the length of the shadow exceeded the height of the rod. One month is from a New Moon to the next New Moon, as per the Islamic calendar. The seasons were known from the south, east, west and north monsoons, and there are also rainy (wet) and dry seasons. The Minangkabau people knew the Morning Star, Evening Star, the three stars in Orion’s Belt, and the Scorpion, while specialists also knew the Pole Star, comets, planets, the Great Bear, Virgo, the Magellanic Clouds, and more.

The Lampung people in southern Sumatra used the usual Islamic calendar, and they also had a 30-day month (Ginzel, 1906: 426ff).

According to Loeb (1935: 139–140), the people who lived on the island of Nias (off the northwest Sumatran coast) begun their year with the rising of the Pleiades, and planting began one month later. A year was divided into 12 numbered lunar months, and a month was divided into the waxing and the waning of the Moon. There was a story that seven children (the Pleiades) went up to the sky, and their parents and a slave (Orion) followed. There was also a story that at one time there were two Suns and no Moon, and the stars were the children of the Sun and Moon. According to Loeb (1935: 172–173), people living on the Mentawai Islands also used the position of the Pleiades to mark the beginning of the new year in June.

The Batak people who live around Lake Toba have an interesting traditional calendar (see Kimball, 1989-1993; Shinotsuka, 1987; Winkler, 1913/1989-1993). The Batak calendar is called *porhalaan* and is engraved on a bamboo cylinder. There are 12 or 13 columns (for the months) by 30 row rectangular grids (for the days). A year begins when Orion disappears in the western sky and Scorpio rises in the eastern sky. When the rising crescent Moon passes Orion immediately after sunset the Batak year begins. Although modern Batak people use Indonesian day-names of the week that are of Arabic origin, the traditional Batak calendar uses day-names of the week that are of Sanskrit origin.

24.3.2 Java and Madura (YÔ and WO)

In Java, there are Javanese people in central and eastern Java, Sundanese people in western Java, and Madurese people in eastern Java and on the island of Madura. They are all Malay people.

There are several dated inscriptions in Java that use the Indian Śaka Era (see Damais, 1967; Eade and Gislén, 2000; Nakada 1982) while Raffles (1817: 473–479) and Ginzel (1906: 414ff) give early descriptions of astronomy in Java. Igarashi (1987) gives a detailed description of the Javanese calendar (cf. Takahashi, 1987), and Geerts (1960: 77–81) discusses its religious aspects.

The Javanese lunar calendar was established by Sultan Agung (the third King of the Mataram Sultanate) who reigned between 1613 and 1645. It is a combination of the traditional Javanese calendar and the Islamic calendar. The day begins at sunset. Besides the 7-day week, the 5-day cycle *pasaran* is used. One year of the Javanese calendar is a lunar year, and the 8-year and 120-year cycles are used for calculation. One usual year is 354 days, but there are three 355-day years every 8 years. And also, one day is omitted in every 120-year cycle. For counting years, the Indian Śaka year is used instead of the Islamic Hijri year, and CE 1633 was Javanese year 1555. As one lunar year is shorter than one solar year, the Javanese year is now different from the Śaka year of the solar calendar.

In CE 1855 the traditional Javanese solar calendar was reformed by Pakubuwono VII, a ruler of Surakarta who reigned from 1830 to 1858. It begins from the summer solstice, and there was considerable variation in the length of each month. This system of calendar is called *Pranotomongso* (or *Pranatamangsa*), and was linked to certain asterisms (Dardjoeni and Hidayat, 1987). There is a detailed discussion about *Pranotomongso* by van den Bosch (1980). One year consists of 12 months, which consist of 41, 23, 24, 25, 27, 43, 43, 26 or 27, 25, 24, 23 and 41 days respectively. This calendar is based on observations made using a gnomon like the one shown in Fig. 24.4a (Maass, 1924-1926; see also Ammarell, 2008: 326; cf. Fig. 24.4b

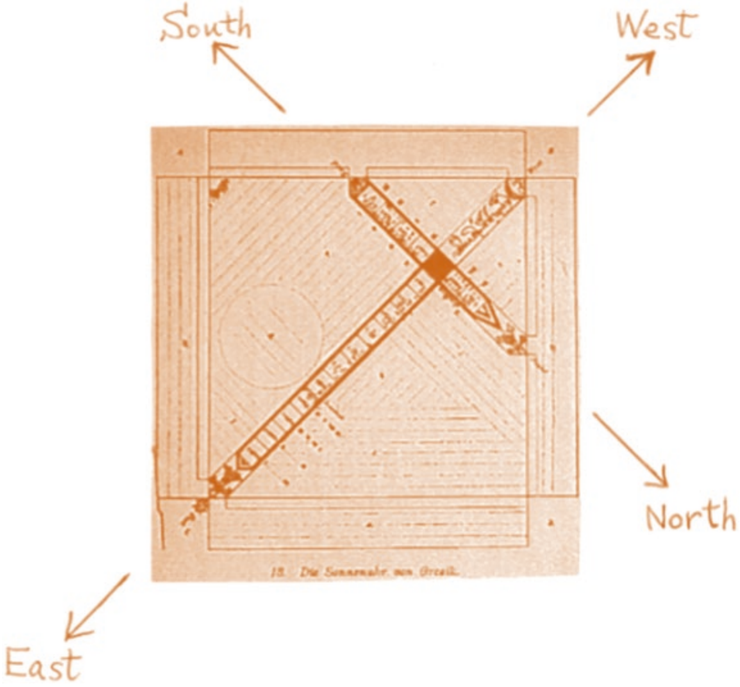


Fig. 24.4a Gnomon from Gresik Regency in Java (after Maass, 1924-1926: Figure 13, with modifications by Yukio Ôhashi).

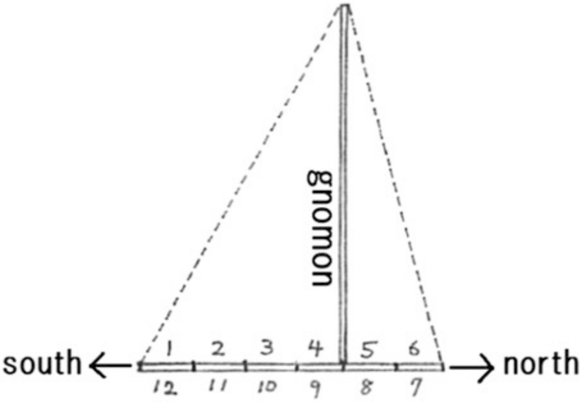


Fig. 24.4b The gnomon used in Java for determining the months in the *Pranotomongso* calendar (diagram: Yukio Ôhashi).

later in this chapter). The noon shadow is observed by its North-South scale. A rectangular gnomon is erected at the square of the intersection of the North-South scale and the East-West rod. The North-South scale is divided into six equal segments (two in the North, and four in the South), and one segment corresponds to a month. As the change of solar declination is not uniform, and the equal segments of the flat scale do not correspond to equal angles, the length of a month is not uniform.

Recently, Ali Sastramidjaja (1935–2009) reconstructed the Sunda Calendar (also called the *Kala Sunda*; see Sastramidjaja 1991/1998). There are separate Sunda solar and lunar calendar systems. In the Sunda solar calendar system, one year ends with the summer solstice, and one month consists of 30 or 31 days. A typical year consists of 365 days, while a leap year has 366 days. A leap year occurs once in four years, but it becomes a common year once in 128 years. In the Sunda lunar calendar system, a half month begins with a half bright Moon and is called *sukla paksa*, and another half month begins from half dark Moon and is called *kresna paksa*. So, one month consists of 29 or 30 days. There is no intercalary month. The 8-year cycle and the 120-year cycle are used to regulate a short year (354 days) and a long year (355 days). The 5-day cycle, 7-day week etc. are also used. Sastramidjaja (ibid.) says that the rules were unknown until he rediscovered them during research that he carried out between 1983 and 1991.

Meanwhile, the inhabitants of the island of Madura, just off the north-eastern coast of Java, … have their own ideas about the night sky, and they used the appearance or the presence of different stars or groups of stars (asterisms) in everyday life, especially during farming and fishing, or voyaging to other Indonesian islands. The Madurese also had their standard cultural responses to unexpected astronomical phenomena such as solar and lunar eclipses. Before the advent of 'modern education', villagers did not understand the scientific reasons for these dreaded events. Even today, many villagers still behave in the traditional way when eclipses occur. (Fatima et al., 2021).

24.3.3 Bali (YÔ)

Bali has an interesting tradition of calendar, which is relatively well known. There was a detailed study in 1930's by Covarrubias (1937), and Eiseman (1990, Volume I) also has a detailed description. Eiseman (1990, Volume II) describes star lore in Bali. There are also studies by Japanese: Nagata (1985) and Igarashi (2008). Igarashi (2008) is a very detailed study; also see Emas et al. (2021) and Ginzel (1906, 424–426).

There are two traditional Bali calendars. One is the 'Saka calendar' which was derived from the Indian calendar, and the other is the 'Pawukon calendar' which is a unique calendar introduced from Java.

According to Covarrubias (1937: Chapter 9), the Saka calendar was used by the 'Bali Agas' (the original Bali people). There are some differences in the calendar according to the calendar makers (Igarashi, 2008). In the 'Saka calendar', one day begins from sunrise, and one month begins from the next day of the New Moon. One month is divided into two halves: from the first day of the New Moon to the day of the Full Moon is the white half month (*sukla paksa*), and from the day after Full Moon to New Moon is the black half month (*kresna paksa*). This method is similar to the Hindu calendar. The 0th year of the Saka era is CE 78, and the 1st day of the 10th month (Kadasa) (according to Igarashi, 2008), or the 1st day of the 9th month (according to Covarrubias (1937), is the beginning of a year called 'nyepí' around the vernal equinox. One month consists of 30 lunar days (*titi*), and one day is jumped over every 63 days. One lunar day is 1/30 of a lunar month, and 64 lunar days = 63 civil days in this method. The *titi* corresponds to the *tithi* in the Hindu calendar. For intercalations, there are two methods. One method is to add an intercalary month every 30 months, and the other method is to add 7 intercalary months every 19 years. Now the method of 7 intercalary months in 19 years is used (Igarashi, 2008).

It is said that the 'Pawukon calendar" probably came into use at the time of Majapahit's domination of South Bali (i.e., in the fourteenth century CE). It is made by the cycles of 1 day, 2 days, 3 days, 4 days, 5 days, 6 days, 7 days, 8 days, 9 days and 10 days. One 'wuku' year in this calendar consists of thirty 7-day weeks, that is 210 days.

24.3.4 The Lesser Sunda Islands (YÔ)

Bali island (see above) in an island belonging to the Lesser Sunda Islands. There is some information about other islands.

For the calendar of Savu Islands see Cuisinier (1956).

Uno (1941: 120), referring to Dutch literature, tells that in the Ende area of Flores island, when a star called 'red pig' (probably Antares) is seen around altitude 30 degrees from the western horizon around 7 pm, the cultivation season begins. The 'red pig' star belongs to an asterism that is considered to be a balance. During this season the Pleiades are seen in the eastern sky.

Maass (1924-1926: 347–357) gives information about astronomy on the island of Timor. Some information about the calendars of Timor and of Letti (now Leti, included in the Moluccas) is mentioned by Ginzel (1906: 430–431).

24.3.5 Borneo (YÔ)

The island of Borneo consists of Kalimantan (belonging to Indonesia), Sabah and Sarawak (which are part of Malaysia), and the nation of Brunei. Around coastal areas there are mainly Malay people, while in the mountainous interior there are Proto-Malay people, often referred to as the 'Dayaks'.

Transilvano, who was a member of Magellan's voyage (1519–1522), records that when they visited the island of Borneo in 1521 the local people thought that the Sun and the Moon were major gods. The Sun was male and the god of the day-time, the Moon was female and god of the night-time, and the stars were small gods who were related to the Sun and the Moon, and belonging to the Sun and the Moon (Chōnan, 2011: 313). This must be one of the earliest records of the astronomical folklore of Island Southeast Asia.

Hose and McDougall (1912) described some astronomical knowledge in Borneo. They divided the Dayak people into six main groups: the Sea Dayaks (= Ibans), Kayans, Kenyahs, Klemantans, Maryts and Punans. Hose and McDougall (1912(1): 105–111) tell that the Kenyah people erect a vertical wooden gnomon in the ground, whose verticality is ascertained by a plumb, and the length of the midday shadow is measured by a stick with marks on it in order to know the season for agriculture. Some Kayan people observed the position of mid-day sun through a hole in the roof of a chamber. The Klemantan people directed a bamboo cylinder filled with water towards a certain star, and knew the season of planting by the remaining water. The Sea Dayak people knew the seasons by the direction of the Pleiades. Hose and McDougall (1912(2): 139) also mention that the Klemantan people considered that the Great Square of Pegasus was a storehouse; the Pleiades a well; the constellation that included Aldebaran a pig's jaw; and Orion the figure of a man.

Ammarell and Tsin (2015) report on sky lore in South Kalimantan, where the local people use the three stars in Orion's Belt to determine the direction of Qibla.

According to Lumholtz (1921(2): 441–444), who carried out research in central Borneo from 1913 to 1917, the Katingan people (one of the Dayak groups in south-west Borneo) used seven inclined gnomons, and when the Sun was above the central gnomon at noon (when the Sun was at or very close to the zenith), they considered that it is the best season for sowing their crops (see Fig. 24.5).

King (1985: 156) records that the Maloh people (who belonged to the Klemantan group of Proto-Malays) also used the stars to determine the times for commencing the agricultural cycle and planting their crops. The most important constellation was 'bintang tuju' (Pleiades). The constellation 'bintang talu' (Orion) also was recognized.

For the traditional astronomy of the people of northern Borneo see Evans (1922, 1923, 1953).

Freeman (1970: 171–172) reported that the Iban (Sea Dayaks) of Sarawak used 'bintang banyak' (Pleiades), 'bintang tiga' (Orion) and 'bintang tangkong peredah' (Sirius) to track the seasons. The Iban agricultural year was signaled by the rising of the Pleiades at dawn.

24.3.6 Sulawesi (YÔ and WO)

On the island of Sulawesi there are Makassar and Bugis people, both of whom are Malays, in the south-west area, Mandar peoples on and near the west coast in the central area (they also are Malays), and the Toraja (Proto-Malay) people in the central area.

Wallace (1869), a noted British naturalist, recorded an interesting navigational aid seen on a local Makassar vessel. It was a floating bowl type of water clock (see

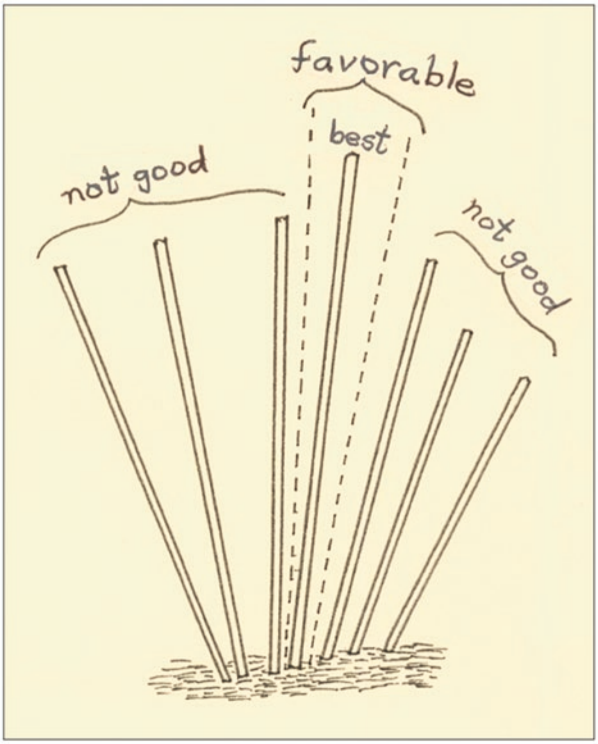


Fig. 24.5 The seven gnomons of the Katingan people in Borneo (after Lumholtz, 1921).

Fig. 24.33). For Bugis navigation, see Ammarell (1999) and Wakita (2010). Ammarell (1999: 127) gives a table of asterisms with identifications. And also, Pelras (1987: 27–32) and (1996: 231 and 264) mentions the constellations of the Bugis people that were used for agriculture and navigation (also see the 'Cultural Overview' section below).

Yamashita (1988: 81) records that the Toraja people used stars to track the seasons, and that a year was divided into three seasons. Observation of the stars in order to determine the season was called 'pentiro taunan'. Stars used included 'Lemba' (Ursa Major), 'Bunga' (the Pleiades) and 'Manuk' (Crux). The three seasons were: the season when these stars were visible in the dawn (i.e., from the end of November until the end of March); the season when they were visible in the evening sky (i.e., from the end of March until the end of September); and the season when they were invisible (i.e. from the end of September until the end of November).

Neighbouring the Bugis on the west coast of Sulawesi is another celebrated maritime group, the Mandar. Just like the Bugis, the Mandar "… developed a body of knowledge involving key stars and star patterns, that traditional navigators passed down from generation to generation." (Rasyid et al., 2021: 550). In all, ten different stars or asterisms were involved, but they are presently unknown to most young Mandar seafarers. This sad situation is found throughout Southeast Asia, where education and 'modernisation' have had a profound impact on indigenous cultures. Consequently, traditional astronomical knowledge is being lost at an alarming rate as old people die without passing on their knowledge to younger generations. As ethnoastronomers we recognize the urgently of our task if we are to capture surviving remnants of these astronomical systems, before it is too late. Hence our motto, inspired by the late great American singer, Elvis Presley, "It's Now or Never".

24.3.7 Moluccas (Maluku Islands) **(*YÔ*)**

In the records of Magellan's voyage (1519–1522), which was continued after Magellan's death, there are some records from the Moluccas. Pigafetta writes that the King of Tidore Island was a Muslim and an astrologer (Chōnan, 2011: 166). Transilvano writes that the King said that he knew that the fleet was coming by their observation of the stars (Chōnan, 2011: 324). This was an astrological rather than astronomical observation, but it does show that there was an interest in the stars.

For astronomical knowledge in the Moluccas also see Maass (1924-1926: 364–375).

24.3.8 The Philippines (YÔ)

In the present-day Philippines the Gregorian calendar is officially used, but until the end of 1884 the Gregorian day was one day earlier because the Spanish rulers considered that Philippine time was 16 hours later than Spain time. So, 31 December 1884 does not exist in the Philippines, and the next day after 30 December 1884 was 1 January 1885 (Umehara, 1987).

There is some information about traditional calendars in the Philippines in Zaide (1961: 38) and Umehara (1987). According to an early Spanish record dating to CE 1582 the ancient calendar of the Visayans (on the islands between Luzon and Mindanao) had 12 months in a year, among which eight months had names, and the beginning of a year was the time when the Pleiades made their appearance. Zaide tells us that each month had 30 days, except for the last month that only had 26 day, making a year with 356 days. The calendar of the Ifugaos (an ethnic group that lives in the northern part of Luzon Island) contained 13 months (each of 28 days), so one year was 364 days, but a further day was added to the 13th month.

Gōda studied the Bontok people in the northern mountainous area of Luzon Island from the 1970's to 1980's, and he reports on their calendar (Gōda, 1989: 56–71). There, a new year began after the rice harvest, when they were going to start new cultivations, i.e. around October or November. The year was divided into four seasons, and the calendar was not related to the phase of the Moon, although lunar phases were recognized by them.

For the astronomical knowledge found in the Davao district of the island of Mindanao see Cole (1913). Meanwhile, Schlegel (1987–1988) reports on the celestial calendar of the Tiruray, hill people found in Mindanao Island.

For the folk astronomy of the Philippines, see Ambrosio's (2010) monumental work.

24.4 Indigenous Astronomy: A Cultural Overview

24.4.1 Local Names and Folklore of the Stars and Asterisms (YÔ)

There are some Southeast Asian groups of stars, or asterisms, which are not found in other areas, and many Southeast Asian asterisms do not correlate with Western constellations.

24.4.1.1 Thai Asterisms

Saibejra (2012), in quoting from the epic *Phra Aphay Manī* written by Sunthorn Phū (1786–1855), mentions the following Thai asterisms:

- Orion: the ‘turtle’ and the “plough” (*Dāw-tau*, *Dāw-thai*).
- Hyades: the ‘flag’ (*Dāw-thong*).
- Pleiades: the ‘children of the hen’ (*Dāw-lūkkai*).
- Gemini: the ‘coffin’ (*Dāw-lōng*).
- Cassiopeia: the ‘crow’ (*Dāw-kā*).
- Argo: the ‘junk’ (*Dāw-duang-lam-samphau*).
- Big Dipper: the ‘alligator’ (*Dāw-jōrakhē*).
- Arcturus: the ‘summit of great Buddhist tower’ (*Dāw-yōt-mahā-culāmanī*).
- Crux and α and β Centauri: the ‘beam balance’ (*Dāw-khanchang*).
- Great Square of Pegasus: the ‘carrying corpse’ (*Dāw-hām-phī*).

Phengkaew (2009) and Maison (2013) also describe several other Thai astronomical folklores, etc. Fig. 24.6 is an overview of Thai asterisms drawn by the first author of this chapter but based on Saibejra (2012).

24.4.1.2 Burmese Asterisms

Burma has its own asterisms. The earliest description of Burmese asterisms in a Western language is probably by Buchanan (1799, particularly pages 195–205). He says that during his stay in Amarapura, he saw several treatises on astronomy, besides almanacs, including a plan of ‘twenty-seven signs’ and a plan of ‘nine signs’ (see Fig. 24.7), and also a delineation of the sixty-eight Burma asterisms (Fig. 24.8) with a short explanation in the Burmese language.

The small plan in Fig. 24.7 represents the nine northern Burmese asterisms, and the large plan in Fig. 24.7 represents the Burmese northern asterisms (the outer circle) and the 27 Indian lunar mansions (the inner circle).

Fig. 24.8 gives figures of 68 heavenly bodies (the nine northern Burmese asterisms, 27 Indian lunar mansions, other Burmese asterisms, the Sun, Venus and Jupiter). In Fig. 24.8, the first author of this chapter (YÔ) added the blue frame for the nine northern Burmese asterisms, the red frame for 27 Indian lunar mansions, and the yellow background for the Sun, Venus and Jupiter. Following the arrangement of the words in the original, Buchanan gives a verbal English translation, along with a Burmese explanation and his notes. Some asterisms are related to certain cities or countries. Following is a list of Buchanan’s translation of the heavenly bodies (but YÔ has excluded his notes). The first numerals correspond to the numbers given in Fig. 24.8. In Buchanan’s translation, a ‘circle’ means a star. As it is a ‘verbal translation’, the word order is different from the usual English word order. YÔ rearranged and divided Buchanan’s ‘heavenly bodies’ into four groups. The nine northern Burmese asterisms could be identified by their names, and their figures by comparison with Fig. 24.7. It seems that the 27 Indian lunar mansions could not be fully identified with the heavenly bodies in Buchanan’s list, but YÔ could identify them by their names and their figures when compared to the figures of the Burmese lunar mansions quoted by Nishiyama (1997). Most of the Burmese asterisms were not correlated with modern Western constellations by Buchanan.

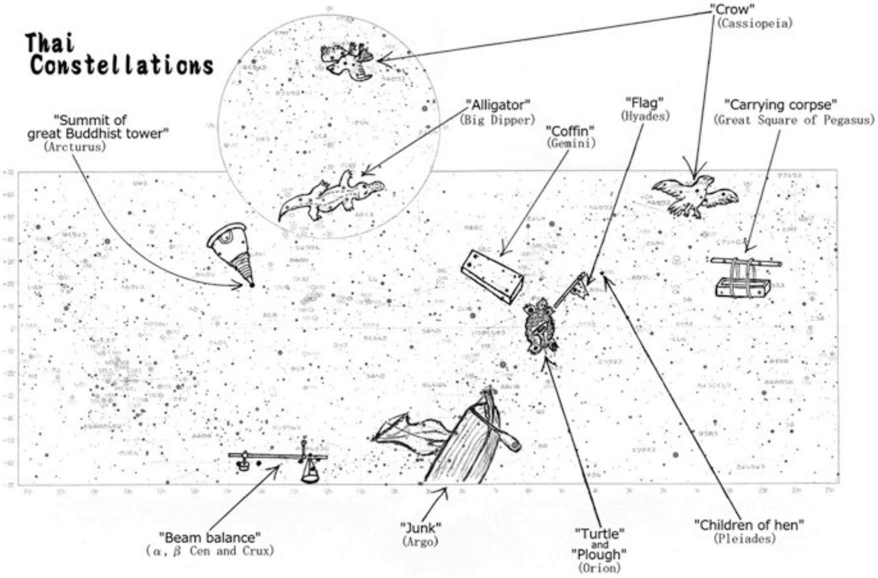


Fig. 24.6 Thai asterisms, drawn by the first author of this chapter, but based on data in Saibejra (2012).

Here is a list of the sixty-eight heavenly bodies mentioned in Buchanan's paper (1799), as re-arranged by YÔ:

(a) The nine northern Burmese asterisms (i.e. 'constellations'). YÔ re-arranged the order in accordance with the prograde order in Fig. 24.7, and he added some notes in brackets. He also added corresponding Roman numerals with his own identifications):

41. "The crow constellation eleven circles has, and the *Thayndua* country" (II).

43. "*Hayntha*, a constellation of seven circles, belong to *Radanapura*". (III)

32. "The crab constellation of ten circles has, *Rasagyol* country". (Buchanan says that no.34 is the Burmese asterism, but no.34 is actually an Indian lunar mansion, and no.32 should be the Burmese asterism.) (IV)

56. "The balance constellation, four circles has". (V)

61. "Of *Thanliœk*, a constellation of three circles, *Kothambe* is the country". (VI)

23. "The *Brahmen* constellation of eight circles, *Kaleingareet* country governs". (Buchanan says that no.15 is the Burmese constellation, but no.15 is actually an Indian lunar mansion, and no.23 should be the Burmese asterism.) (VII)

22. "The *Shan* country the elephant constellation with six circles has". (VIII)

10. "The horse constellation has eleven circles, *Europe* is its country". (IX)

2. "The *Pyain* constellation five circles has, of *Thoukkada* country the constellation". (I)

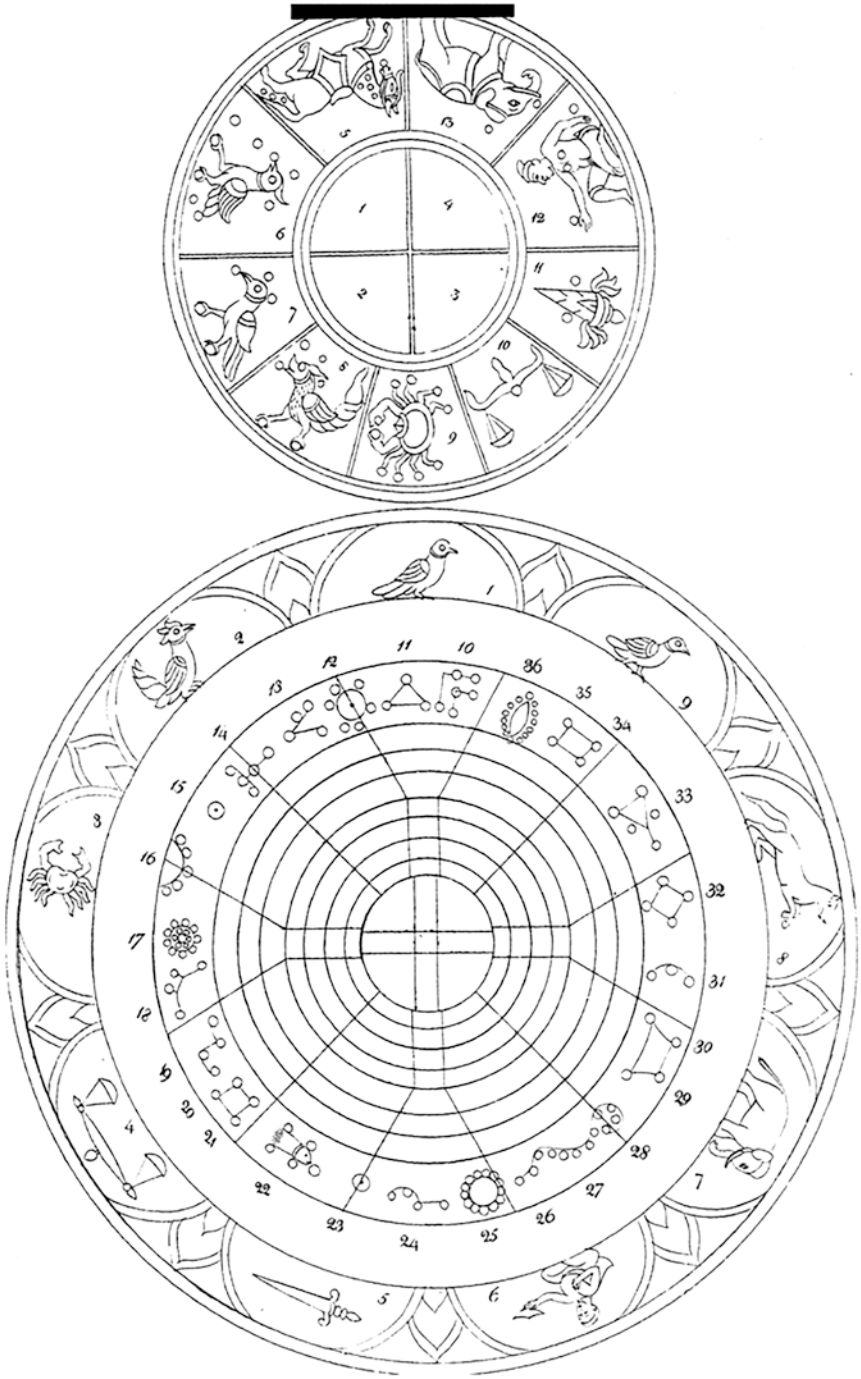


Fig. 24.7 Plans of the 27 Burmese lunar mansions and the nine northern asterisms (after Buchanan, 1799).

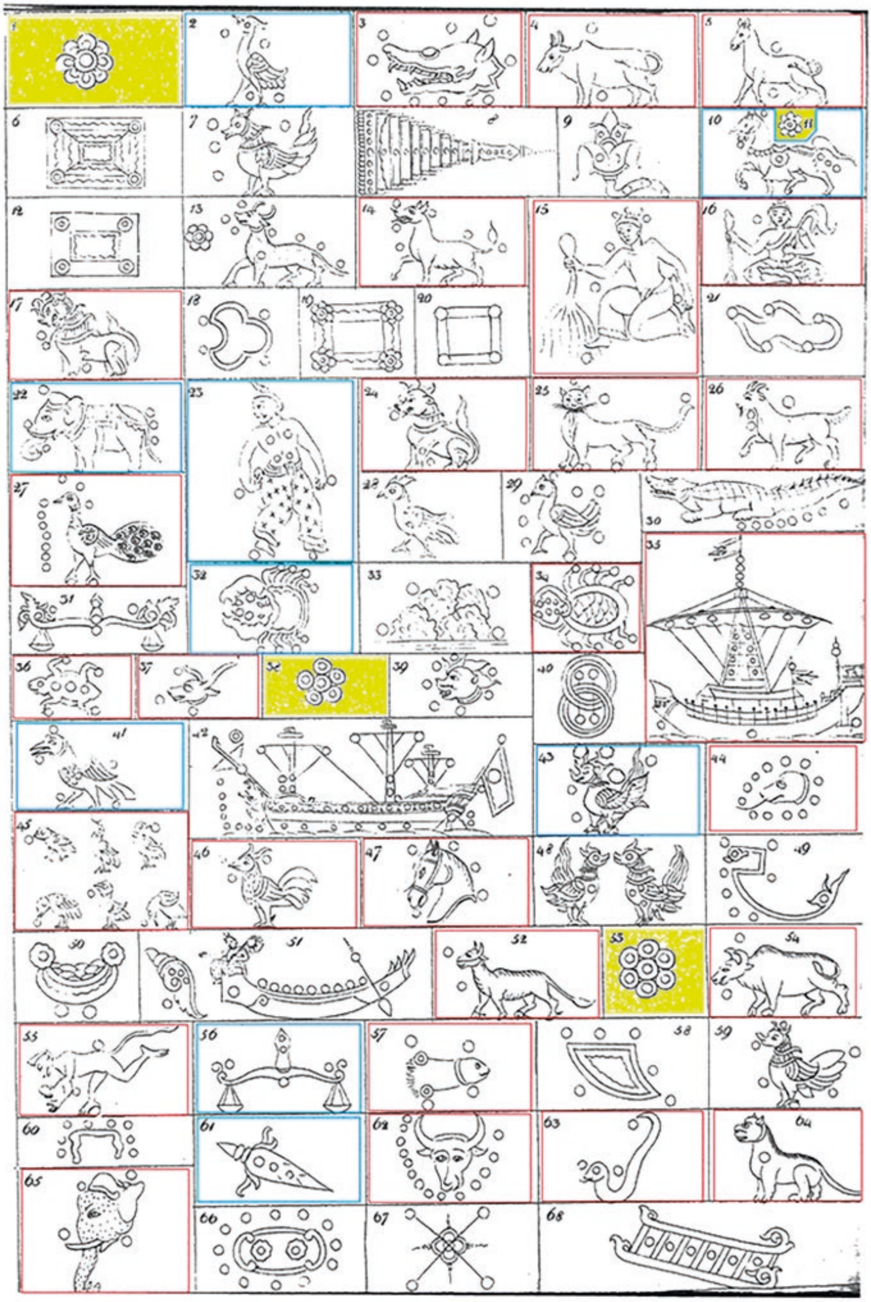


Fig. 24.8 Figures of the 68 Burmese heavenly bodies (after Buchanan, 1799) with the addition by YÔ of blue frames for the nine northern asterisms, red frames for the 27 lunar mansions, and yellow backgrounds for the Sun, Venus and Jupiter (diagram: Yukio Ôhashi).

(b) The 27 Indian lunar mansions (YÔ re-arranged the order in accordance with the usual order of Indian lunar mansions, and added Sanskrit names in brackets):

47. "Of *Athawane* the horse's head picture has six circles, and the *Rakain* country". (Aśvinī)

46. "*Pagan* country is governed by the old cock's figure". (Bharaṇī)

45. "*Kiatteka* has a fowl's picture, and six circles". (Kṛttikā)

44. "Of *Rohane* the snake's-head figure has ten circles". (Rohiṇī)

37. "*Mecathe* has of an antelope's head the picture, three circles, and *Haynthawade* country". (Mṛgaśiras)

36. "Of *Adara Daway* is the country". (Ārdrā)

35. "The *Brahmen's Buchia* has a boat's picture, and the *Dagoun* country". (Punarvasu)

34. "*Buchia* the crab constellation ten circles has". (Puṣya)

57. "Of *Athaletha* the horse's-yard picture, four circles has, and the *Thattoun* country". (Āśleṣā)

55. "*Matha* has of a monkey the figure, four circles, and the *Baranathe* country". (Maghā)

54. "Of *Pyouppabaragounne* the cow's picture three circles has". (Pūrva-Phālgunī)

52. "Of *Uttarabaragounne* the bullock's picture two circles has". (Uttara-Phālgunī)

65. "*Hathadda* of an elephant's head the picture has, *Dhagnawade* is its country". (Hasta)

64. "Of *Zeittara* the tiger's picture, has one circle, and the *Wethale* country". (Citrā)

63. "Of *Thuade* a great snake's-head picture, has three circles, and the *Thayndua* country". (Svātī)

62. "*Wethaga* has of a buffalo's head the picture, and fourteen circles". (Viśākhā)

27. "Of *Anurada* the peacock's picture has fifteen circles, and the *Zedouttara* country". (Anurādhā)

26. "Of *Seitta* the goat's picture five circles has, *Zedouttara* is its country". (Jyeṣṭhā)

25. "Of *Mula* the cat's picture five circles has, *Peenzalareet* is its country". (Mūla)

24. "Of *Pyouppathan* the lion's picture two circles has, *Mouttama* country it governs". (Pūrva-Āṣāḍhā)

17. "Of *Uttara* the lion's picture two circles has, *Moranun* country governing". (Uttara- Āṣāḍhā)

16. "*Tharawun* constellation a hermit's picture three circles has". (Śravaṇa)

15. "Of *Danatheidha* the fisherman's picture four circles has". (Dhaniṣṭhā)

14. "*Thattapescia* with a leopard's picture six circles has". (Śatabhiṣaj)

5. "*Pyouppa parabaik* of a cow the picture has, and two circles, *Patanago* country it governs". (Pūrva-Bhādrapadā)

4. "*Uttara-parabaik* a cow's figure has, and two circles, and the *Kappelawut* country". (Uttara-Bhādrapadā)

3. "*Rewade* an alligator's figure has, *Kutheinnaroun* country, and nine circles it has". (Revatī)

(c) Other Burmese asterisms:

6. "A couch is *Sataga* constellation, four circles it has, and the *Kathee* country".

7. "The *Pyathat* of twenty-four circles, is of *Kieen* country the constellation".

8. "The duck constellation, five circles has, *Shan* is its country".

9. "The *Kyabuayn aroo* leaf is the *Talain* country constellation, it has seven circles".

12. "The table constellation four circles has, of the *Kiayn* country the constellations".

13. "*Zain* constellation eleven circles has".

18. "The *Pangiayn* mountain constellation four circles has, of *Rakain* country the constellation".

19. "*Tareindane* constellation four circles has, of *Yoodaya* country the constellation".

20. "A couch is *Pagan* constellation with four circles, of *Shethœk* country

21. "The cloud constellation has five circles, of *Thulabe* the constellation".

28. "The fowl male of *Peenza* constellation circles fifty has, of *Sawa* country the constellation".

29. "The fowl female of *Utta* constellation eight circles has, of *Uzaung* country the constellation".

30. "Of an alligator the *a-me-kah-han* is the picture of *Uttara* constellation with eight circles, and the *Lahu* country".

31. "The balance constellation".

33. "The mountain constellation four circles has".

39. "*Buchia* constellation has eight circles, and *Yun* country".

40. "*Zaduka* constellation four circles has, in a pair of fetters, of *Giun* country the constellation".

42. "The *Kyay* ship of twenty-eight circles".

48. "*Pozoke* a constellation of eight circles belongs to the *Talain* country, like the *Hayntha* male and female".

49. "*Putthata* constellation seven circles has, of the *Raneezee* tree the fruit".

50. "*Aykatheitta* a constellation of four circles of *Kale* country the constellation, is like a basin".

51. "*Tarouttara* constellation two circles has, and the *Taroup* country".

58. "The flag is *Pathatta* constellation, six circles it has".

59. "*Eessa* constellation six circles has, of *Momain* country the constellation".

60. "Of *Akap*, a constellation of eight circles, *Daway* is the country".

66. "*Kobiape* constellation with eleven circles has, the *Myamma* country".

67. “A fowl’s foot is *Thareiddha*, a constellation of four circles, of *Laynzayn* country the constellation”.

68. “A boat’s ladder is *Tareiddha*, a constellation of six circles, of *Kula* country the constellation”.

(d) The Sun, Venus and Jupiter:

1. “Of *Sunday* the star”.
11. “The morning constellation one circle has, of *Dunwun* plant the fruit”.
38. “Of *Friday* the Star”.
53. “Of *Wednesday* the Star”.

There is also a paper by Khin Zaw (1937). Khin Zaw used a star map in the form of a parallelogram in the ‘Bernard Free Library’, and he identified 27 Indian lunar mansions and eight (out of the nine) inner northern Burmese asterisms with modern Western constellations. There were already studies of Indian lunar mansions in Indian Sanskrit texts, but there were some differences between India and Burma as Khin Zaw pointed out, and this paper is an important early contribution.

In Myanmar, there are some star maps, among the most famous of which are the three star maps (two circular and one rectangular) drawn on the ceilings of corridors at the Kyauktawgyi Pagoda. This Pagoda was built in 1847 by King Pagan of the Konbaung Dynasty, and is located at Amarapura (near Mandalay). Fig. 24.9 shows an external view of the Pagoda.

The Kyauktawgyi Pagoda star maps include several asterisms that are not found elsewhere. The existence of these star maps was known to researchers of Burmese Buddhism, and a photograph of one of the star maps was published by Ōno and Inoue in 1978. This inspired both authors to visit the Pagoda. The first author (YÔ) visited the Pagoda twice, the first time in 1984. At the time, the taxi driver who accompanied YÔ was very helpful, and his hobby happened to be photography. Luckily, he had the same camera, so YÔ sometimes borrowed his wide-angle lens for some of the photographs.

Subsequently, YÔ was informed that the Japanese astronomical historian Minewo Nishiyama was interested in the Burmese asterisms, so he presented his photographs to him and Nishiyama started studying the asterisms, with help from some specialists in the Burmese language. In 1997 he published a paper in English (Nishiyama, 1997) and other papers in Japanese. In his 1997 paper Nishiyama presented a list of 161 heavenly bodies on the star map in the southern corridor of the Pagoda. He tried to identify the Burmese asterisms with modern Western constellations, but many of the asterisms included in the 27 Indian lunar mansions and in the nine northern Burmese asterisms could not be identified. Later, in 1996, Mr Nishiyama visited the pagoda to see the star maps for himself and to take his own set of photographs. Then, after the November 2017 SEAAN History and Heritage Working Group Meeting in Mandalay, the first author of this chapter (YÔ) was able to visit the Kyauktawgyi Pagoda again, after a break of 33 years, this time in the company of Visanu Euarchukiati (who also has chapters in this book). Generally, speaking, YÔ found the star maps were well preserved and looked almost the same as 33 years earlier, but there were some small areas with damage.

Fig. 24.9 The southern entrance to the Kyauktawgyi Pagoda at Amarapura (photograph: Yukio Ôhashi, 2017).

Figs. 24.10, 24.12, 24.14 and 24.16 are YÔ's photographs taken in 2017, while Figs. 24.11, 24.13, 24.15 and 24.17 are his tentative (partial) identifications of asterisms (with the 27 Indian lunar mansions numbered with red numerals, and the nine northern Burmese asterisms with blue Roman numerals). In the case of Star Map 'B' (in the northern corridor), they are all asterisms with Burmese captions. In the case of the Star Maps 'A' (in the southern corridor) and 'C' (in the western corridor), there were other asterisms with Burmese captions, and further research is needed. Some asterisms without captions were identified by their figure and position. The identification of 27 Indian lunar mansions is not necessarily the same as the usual Indian identifications, but is YÔ's tentative identification based on the Burmese star maps. He referred to the identifications in Khin Zaw (1937) and Nishiyama (1997), but his identifications are not necessarily the same as theirs. Regarding the Roman numerals of the nine northern Burmese asterisms, YÔ tentatively followed Nishiyama's Japanese listing which was previously circulated through the internet. YÔ first presented his own identifications in Ôhashi (2018).

Fig. 24.10 Star map 'A' in the southern corridor of the Kyauktawgyi Pagoda, Amarapura (photograph: Yukio Ôhashi, November 2017).

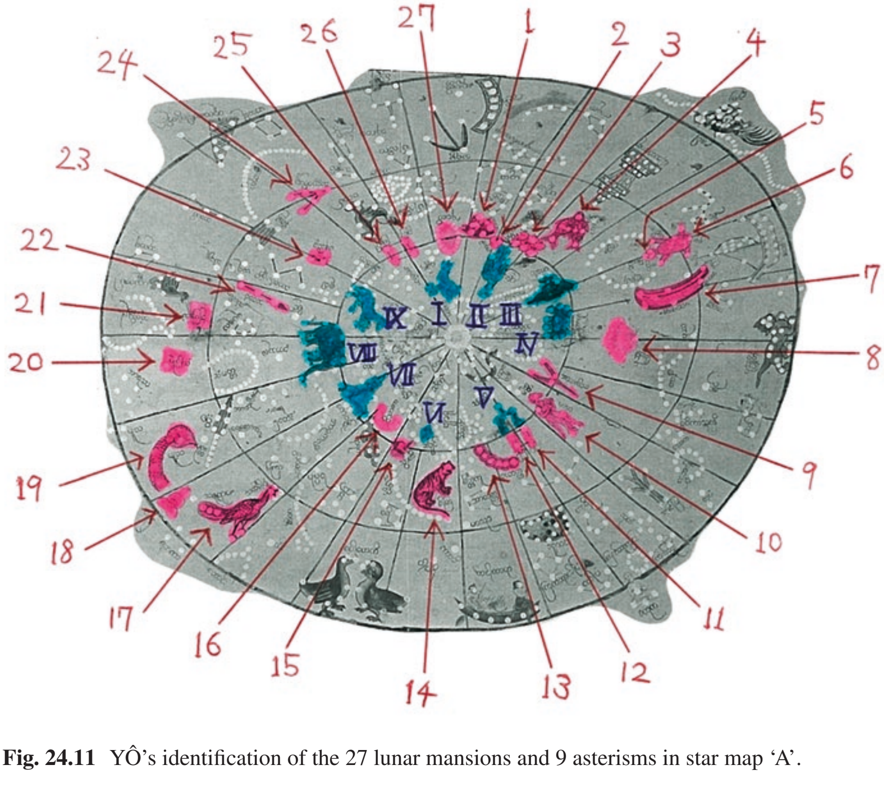


Fig. 24.11 YÔ's identification of the 27 lunar mansions and 9 asterisms in star map 'A'.

Fig. 24.12 Star map ‘B’ in the northern corridor of Kyauktawgyi Pagoda, Amarapura (photograph: Yukio Ôhashi, November 2017).

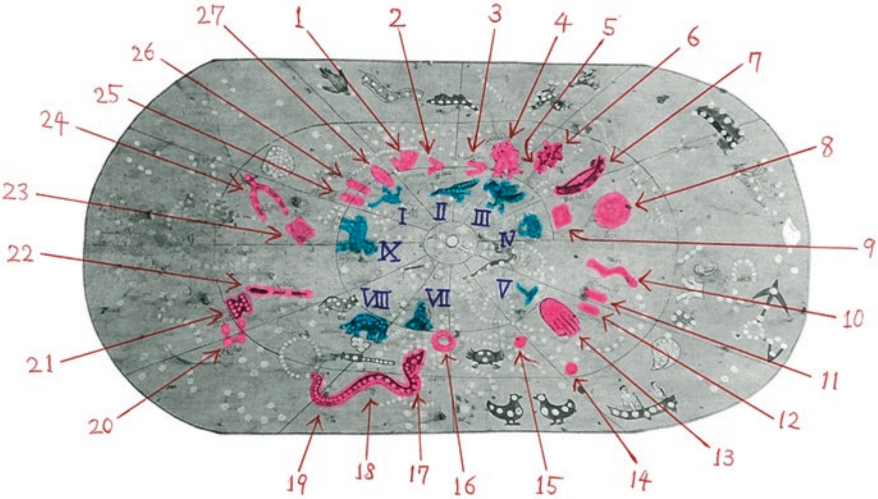


Fig. 24.13 YÔ’s identification of 27 lunar mansions and 9 constellations in star map ‘B’.

Fig. 24.14 Star map ‘C’ in the western corridor of Kyauktawgyi Pagoda, Amarapura (looking from its inner side) (photograph: Yukio Ôhashi, November 2017).

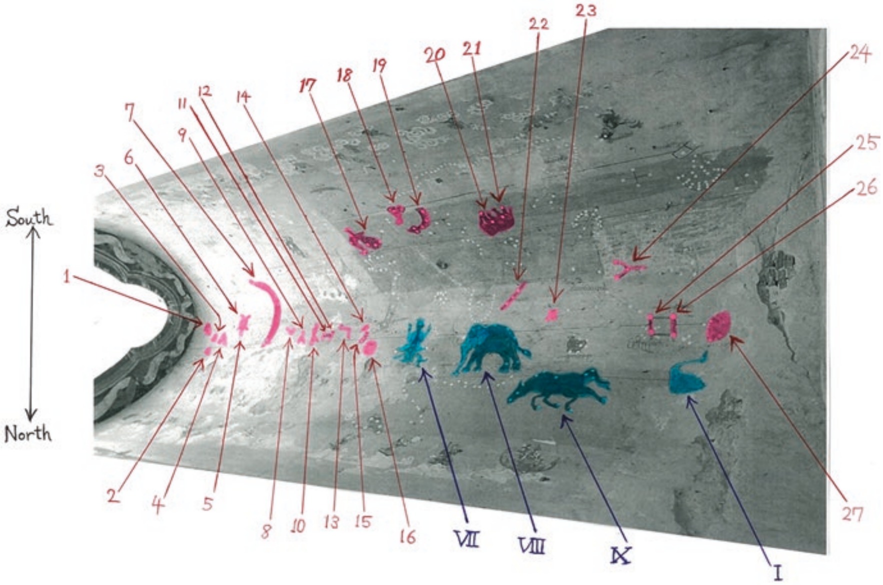


Fig. 24.15 YÔ’s identification of 27 lunar mansions and some asterisms in star map ‘C’ (looking from its inner side).

Fig. 24.16 The star map ‘C’ in the western corridor of Kyauktawgyi Pagoda, Amarapura (looking from its outer side) (photograph: Yukio Ôhashi, November 2017).

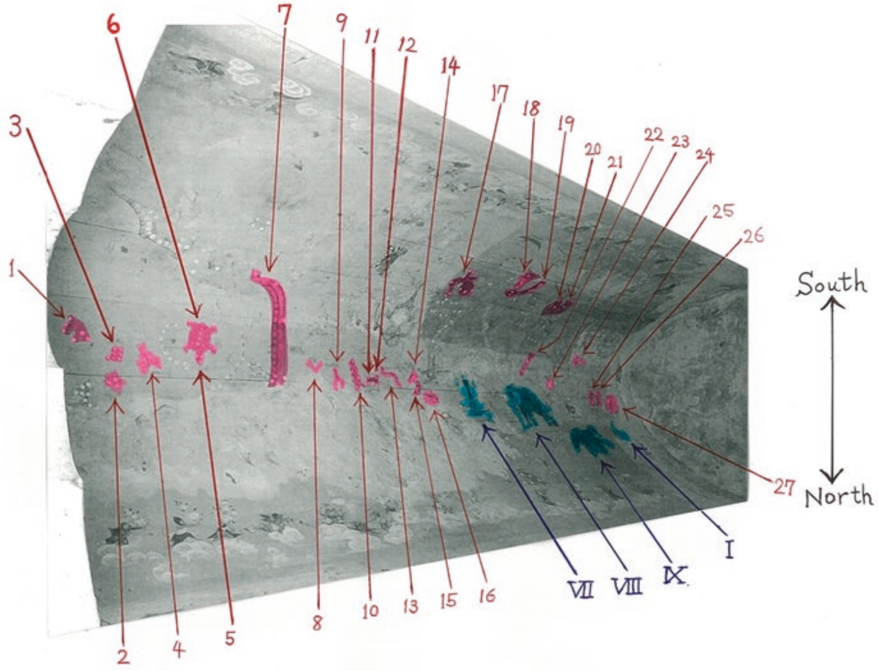


Fig. 24.17 YÔ’s identification of 27 lunar mansions and some constellations in star map ‘C’ (looking from its outer side).

Following are YÔ's identifications of the 27 lunar mansions and 9 northern asterisms shown in the Burmese star maps:

The 27 Indian lunar mansions:

1. *Aśvinī* (α, β, γ Ari)
2. *Bharaṇī* (35, 39, 41 Ari)
3. *Kṛttikā* (Pleiades)
4. *Rohiṇī* (Hyades)
5. *Mṛgaśiras* (λ, φ^1, φ^2 Ori)
6. *Ārdrā* (Orion)
7. *Punarvasu* (Gemini)
8. *Puṣya* (Cancer)
9. *Āśleṣā* (Western part (κ, λ, ε, μ) of Leo ?)
10. *Maghā* (α, η, γ, ζ Leo)
11. *Pūrva-Phālgunī* (δ, θ Leo)
12. *Uttara-Phālgunī* (β, 93 Leo)
13. *Hasta* (Northwestern part of Virgo ?)
14. *Citrā* (Spica)
15. *Svātī* (Arcturus)
16. *Viśākhā* (Corona Borealis)
17. *Anurādhā* (Northwestern part (β, δ, π) of Scorpius)
18. *Jyeṣṭhā* (α, σ, τ Sco)
19. *Mūla* (Southeastern part of Scorpius)
20. *Pūrva-Āṣāḍhā* (δ, ε (and γ, η ?) Sgr)
21. *Uttara-Āṣāḍhā* (ς, σ (and τ, φ ?) Sgr) (* *Abhijit* (Disused in Burma))
22. *Śravaṇa* (α, β, γ Aql)
23. *Dhaniṣṭhā* (α, β, γ, δ Del)
24. *Śatabhiṣaj* (Western part of Aquarius)
25. *Pūrva-Bhādrapadā* (α, β Peg)
26. *Uttara-Bhādrapadā* (γ Peg, α And)
27. *Revatī* (Northeastern part of Pisces)

The 9 northern Burmese asterisms:

I. *Byai*n 'Heron', (Cassiopeia).
II. *Kyi* 'Crow', (Perseus).
III. *Hindha* 'Ruddy Sheldrake (duck)', (Auriga).
IV. *Puzun* 'Crab', (head and forelimbs of Ursa Major).
V. *Khyein* 'Balance (scales)', (hindlimbs of Ursa Major).
VI. *Hsankyin* 'Hairpin', (Coma Berenices).
VII. *Tanga* 'Fisherman', (Hercules).
VIII. *Hsin* 'Elephant', (Cygnus).
IX. *Myin* 'Horse', (Cepheus).

Since there are some small areas of damage on the innermost part of the star map 'C' when YÔ visited the Pagoda in 2017, he now presents some of his photographs taken in 1984 and 2017 as Fig. 24.18 and 24.20 (taken in 1984) and Fig. 24.19 and 24.21 (taken in 2017) for comparison.

Fig. 24.18 The outer part of star map 'C' (photograph: Yukio Ôhashi, 1984).

Fig. 24.19 The outer part of star map 'C' (photograph: Yukio Ôhashi, November 2017).

Fig. 24.20 The inner part of star map "C" (photograph: Yukio Ôhashi, 1984).

Fig. 24.21 The inner part of star map "C" (photograph: Yukio Ôhashi, November 2017).

24.4.1.3 Bugis Asterisms

There are several original asterisms in Indonesia. Ammarell (1999: 122–142) gives the following Bugis asterisms, found in southern Sulawesi:

A. *bintoéng balué* ‘widow-before-marriage’, (α, β Cen).
B. *bintoéng bola képang* ‘incomplete house’, (α~δ, μ Cru).
  B.1. *bembé’ é* ‘goat’, (Coal Sack nebula in Crux).
C. *bintoéng bale mangngiweng* ‘shark’, (Scorpius (south)).
D. *bintoéng lambarué* ‘ray fish, skate’, (Scorpius (north)).
  D.1. (identified without name) ‘lost Pleiad’, (Antares).
E. *bintoéng kappala’ é* ‘ship’, (α~η UMa).
F. *bintoéng kappala’ é* ‘ship’, (α~η UMa; β, γ UMi).
G. *bintoéng balu Mandara’* ‘Mandar widow’, (α, β UMa).
H. *bintoég timoro’* ‘eastern star’, (Altair).
J. *pajjékoé* (Makasar term) or *bintoéng rakkalaé* ‘plough stars’, (α~η Ori).
J.1. *tanra tellué* ‘sign of three’, (δ, ε, ζ Ori).
K. *worong-porongngé* or *bintoéng pitu* ‘cluster or seven stars’, (Pleiades).
M. *tanra Bajoé* ‘sign of the Bajau’, (Magellanic Clouds).

Pelras (1987: 27–32) gives the following Bugis asterisms that relate to agriculture. The Roman capital letters indicate the corresponding asterisms in Ammarell’s list, while the corresponding Makassar names are shown in square brackets (the Bugis and Makassar languages are closely related).

1. (= K) *worong-mpolong* ‘Tuft’, [*borong-borong*], (Pleiades).
2. *wara-wara* ‘Burning Coal’, [*bara-bara*], (Aldebaran).
3. (= J.1) *tanra tellu* ‘Triple Beacon’, [*tanra tallu*], (δ, ε, ζ Ori).
4. *manu’* ‘Chicken’, [*jangang*], (Canopus, Sirius and Procyon).
5. *watang-mpata* ‘Job’s Tears Stalk’, [*batang-bata*], (α, β Leo)
6. (= B) *éppang* ‘Lame’, [*balla’ képpang* “the Crooked House”], (Crux).
7. (= A) *walu* ‘Widow’, [*balu*], (α, β Cen).
8. (= D) *lambaru* ‘Rayfish’, [*lambaru*], (Scorpius (north)).
9. *tékkoroso* ‘Pushed Plough’, (Triangulum?).

Fig.24.22 is an overview of Bugis asterisms drawn by the first author of this chapter but based on Ammarell (1999) (indicated by Roman letters) and Pelras (1987) (indicated by numerals).

24.4.1.4 Philippines Asterisms

Ambrosio (2008a) lists the following Philippine asterisms:

Batik (Orion’s Belt)
Mupu (Pleiades)
Bubu (Big Dipper)
Paliyama (parts of Aquila)
Mamahi Uttara (North Star)

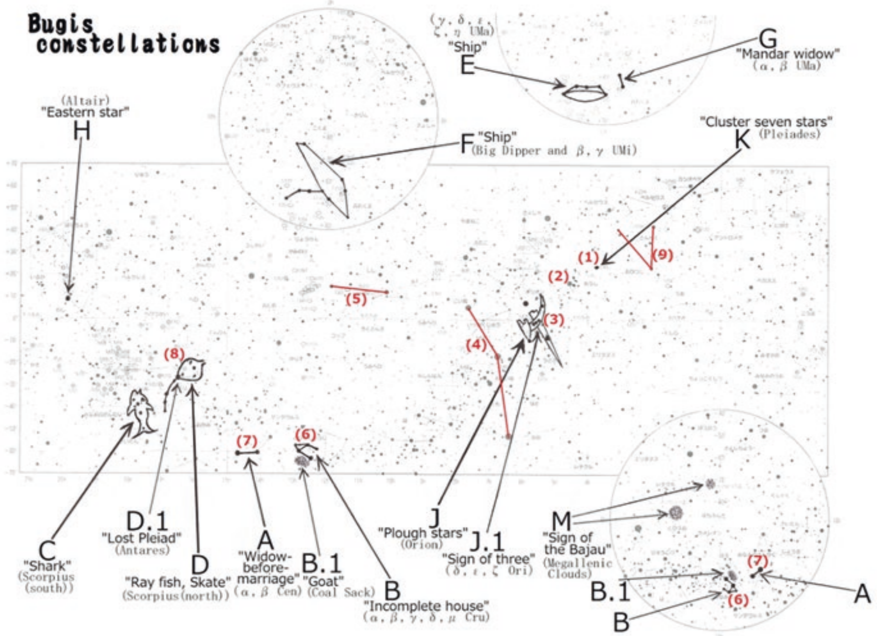


Fig. 24.22 Bugis asterisms, drawn by the first author of this chapter but based on Ammarell (1999) and Pelras (1987).

Saloka (Scorpius)
Anakdatu and *Sahapang* (Alpha and Beta Centauri)
Bunta (Southern Cross)
Lakag or *Maga* (morning star)
Mamahi Kagang,
Mamahi Pagi

Ambrosio (2008b) also mentions that *Balátik* (Orion) and *Moropóro* (Pleiades) were very important in the Philippines. As there are different names for asterisms in different languages in the Philippines, these names are different from those in the above list (see, also Ambrosio, 2010).

24.4.1.5 Additional Remarks

There are some similar asterisms in Southeast Asia. Fig. 24.23 shows Southeast Asian asterisms corresponding to Orion. In Fig. 24.23, A and B are from the Burmese star maps at the Kyauktawgyi Pagoda (Figs. 24.10 and 24.12) which depict a 'turtle'; C is the Thai asterism based on Saibejra (2012) which is a combination of the 'turtle' and 'plough', and D is the Javanese asterism based on Ammarell (1996) which is a 'plough'. By the way, in the Philippines, Orion is a 'trap' for hunting, as is shown on the front cover of Ambrosio (2010)—see Fig. 24.24).

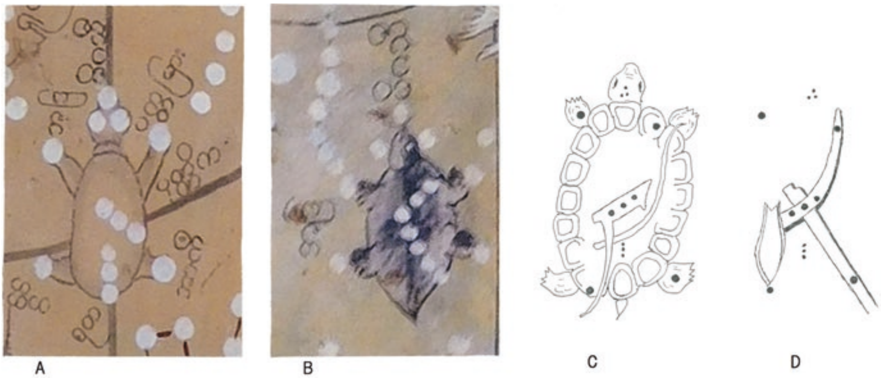


Fig. 24.23 Some similar of Southeast Asian constellations (diagram: Yukio Ôhashi).

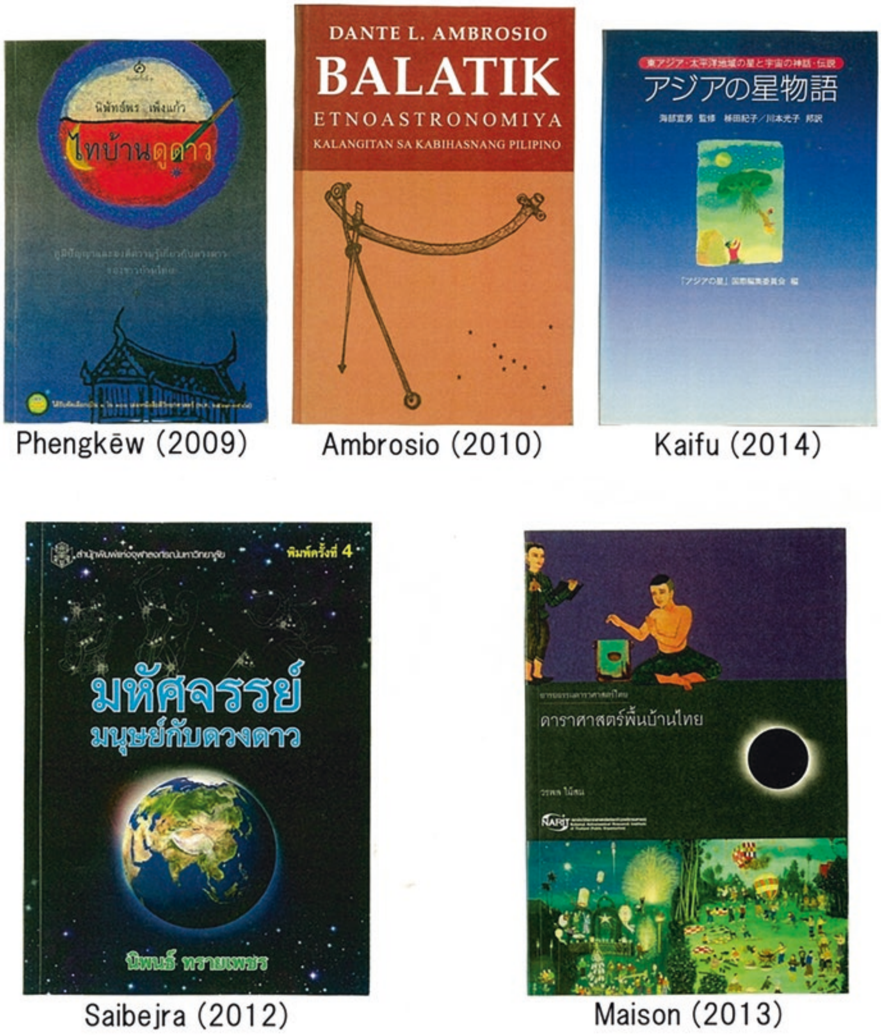
Here are some recent works on folk-astronomy in Asia. Fig. 24.24 shows the front covers of Phengkaew (2009), Saibejra (2012) and Maison (2013) in Thai, Ambrosio (2010) in Filipino, and Kaifu (2014) in Japanese. It will be fruitful to discuss them at international seminars in the future.

24.4.2 Timekeeping: The Pranotomongso *Calendar of Java (YÔ)*

Various kinds of sun dials were used in several places. As they depend on local latitude, they are indigenous. We already saw some examples in the Geographical Overview section above. One interesting example is the gnomon that was used in Java in connection with the *Pranotomongso* calendar (see Fig. 24.4b). It was used to determine the months by observations of the noon shadow. The latitude of Java is around 7° S or so. The solar mid-day zenith distance varies from 30.5° N to 16.5° S, so, if we assume that the length of the vertical gnomon is 1, the length of the shadow (the tangent of the zenith distance of the Sun) varies from 0.589 south to 0.296 north. If the scale is divided into six equal segments, the lengths will be 0.589, 0.442, 0.294, 0.147 north, 0 (the root of the gnomon), and 0.148, 0.296 south. Then, considering the zenith to be 7° S, the Sun's zenith distance in each division will be approximately 23.5°, 16.9°, 9.4°, 1.4°, –7.0°, –15.4° and –23.5°. Then, using the formula

$$\sin\lambda = \sin\delta / \sin\varepsilon \qquad (1)$$

where λ is the solar longitude, δ is the solar declination, and ε is the obliquity of the ecliptic, the longitudinal differences of each segment are approximately 43°, 23°, 21°, 21°, 24° and 48°. In the actual observation, the equation of the centre should also be considered but this is disregarded. In the *Pranotomongso* calendar, one year has 12 months from the summer solstice, which consist of 41 days, 23 days, 24 days, 25 days, 27 days, 43 days, 43 days, 26~27 days, 25 days, 24 days, 23 days and 41 days respectively. This calendar must have been based on traditional astronomical knowledge that could only have been accumulated for a particular terrestrial latitude.



Phengkēw (2009) Ambrosio (2010) Kaifu (2014)

Saibejra (2012) Maison (2013)

Fig. 24.24 Front covers of some recent books on the folk-astronomy in Asia (Ôhashi Collection).

24.5 Chinese Influences on Southeast Asian Astronomy (YÔ)

24.5.1 *The Twelve Animal Names of the Year*

The Chinese 12-year cycle of animals (the rat, ox, tiger, rabbit, dragon, snake, horse, goat, monkey, cock, dog and pig) is very popular in several parts of Asia, but with some local variations. Thus, in Vietnam the ox usually is replaced by the buffalo and the rabbit by the cat (see Fig. 24.25).

As there are Indian Jovian 12-year and 60-year cycles that are independent of the Chinese cycle, we should distinguish them carefully. For the Indian 12-year cycle in Burmese inscriptions see Furnivall (1922).

The Chinese 12-year animal cycle is widely used in Thailand. We have seen that it was used in the inscription of Ram Khamhaeng, along with the Indian Śaka Era. And also, the Chinese 60-year cycle (a combination of the 10-year cycle and the 12-year cycle) was used in the Vietnamese traditional calendar, and also by Thai people outside the Central region—for the case of the Thai calendar see Eade (1995: 24–25).

Fig. 24.25 is an example of the figures of the 12-year animal cycle used on modern Vietnamese postage stamps to celebrate traditional New Lunar Year's Day 'Tết', while Fig. 24.26 is an example of the figures of the 12-year animal cycle used on modern Thai postage stamps.

24.5.2 *The Chinese Luni-solar Calendar*

Serial numbers are used to denote lunar months in Thailand. De La Loubère (1693: 168–169) recorded that this method was used during the Ayutthaya Dynasty of Siam, and Eade (1995: 28–29) mentions some variations of this method in Thailand.

This method is not found in India, where the names of the lunar mansions are usually used to denote lunar-months. The first author of this chapter (YÔ) suspects that the idea of using serial numbers might be of Chinese origin.

In ancient China, the 19-year cycle was used for intercalation. This 19-year cycle was not popular in ancient India, but was very popular in ancient China. YÔ suspect that the 19-year cycle used in Southeast Asia derived from China (and see examples of what we call 'multiplex astronomy' in Subsection 24.9.3 below).

24.6 Indian Influences on Southeast Asian Astronomy (YÔ)

The initial influence of India on East and Southeast Asian astronomy occurred with the spread of the Hindu religion, followed soon after by Buddhism (Ôhashi, 2017a). Various aspects of this influence are discussed below.

Fig. 24.25 Figures of the 12-year animal cycle used on modern Vietnamese postage stamps (Ôhashi Collection).

24.6.1 The Zodiac

The 12-sign zodiac originated in Mesopotamia, and was widely used throughout the Hellenistic World. Then it was introduced to India, the Islamic World, and the West.

The 12 zodiacal signs were introduced into India in around the third century CE from the Hellenistic World, and then introduced into Southeast Asia, as well as East Asia, from India. As the zodiac also is used in the Islamic World, the names of the signs of the zodiac have an Arabic origin in some areas of Southeast Asia, while the names derive from Sanskrit in other areas.

In India, the zodiacal signs were usually fixed to their sidereal positions around the second half of the sixth century CE. These Indianized zodiacal signs are used to regulate some Southeast Asian calendars. For example, the Thai festival of 'Songkrān' is held when the Sun enters Aries. As the signs are fixed to their sidereal positions, the Sun's entrance to the sign Aries, which corresponds to the vernal

Fig. 24.26 Figures of the 12-year animal cycle used on modern Thai postage stamps (Ôhashi Collection).

equinox, is now different from the usual (Western tropical) vernal equinox, due to precession. So 'Songkrān' is now celebrated on 13–15 April.

In present-day Thailand, the Sanskrit names of zodiacal signs are used for the names of the 12 months of the Gregorian calendar. Fig.24.27 is an example of the zodiacal signs from the front page of a modern Burmese calendar that the first author of this chapter purchased at a book shop in Mandalay at the time of the November 2016 Working Group meeting.

24.6.2 Lunar Mansions

India has 27 or 28 lunar mansions, and China has 28 lunar mansions. Originally, they probably were independent (see Chakravarty, 1987; Nakamura, 2017). Eade (1995: 31–37) discusses how the 27 lunar mansions were used in Thai and Burmese traditional calendars. In the Thai traditional calendar the position of the Moon is indicated by the Indian 27 lunar mansions as well as the 12 zodiacal signs. And as we have seen, the 27 lunar mansions also are shown on the star maps at the Kyauktawgyi Pagoda in Amarapura, Myanmar (see Figs. 24.10, 24.12, 24.14 and 24.16).

24.6.3 The Seven-day Week

The 7-day week originated in the Hellenistic world, and was then introduced to India, the Islamic World, and the West. The 7-day week was introduced into India in around third century CE from the Hellenistic World, and then introduced into Southeast Asia and East Asia from India. In Thailand and Myanmar, the day of the week of one's birth is considered to be very important. As the 7-day week also is used in the Islamic calendar, the name of the days of the week originates with Arabic in some areas and from Sanskrit in other areas.

In Thailand, there are symbolic colours for the days of the week. Sunday is red, Monday is yellow, Tuesday is pink, Wednesday is green, Thursday is orange, Friday is blue, and Saturday is purple (Saibejra, 2012: 10; Segaller, 2005: 195). In Thai astrology, Wednesday is divided into day-time and night-time (after 6pm), and night-time corresponds to Rāhu. Sometimes, the symbolic colour of the night of Wednesday is considered to be black.

In Myanmar, Sunday is symbolized by the Garuda; Monday by the tiger; Tuesday by the lion; Wednesday (forenoon) by the elephant with tusks; Wednesday (afternoon) by the elephant without tusks; Thursday by the rat; Friday by the guinea-pig; and Saturday by the dragon. Sunday, Monday, Tuesday etc. usual relate to the Sun, Moon, Mars etc. In Myanmar, Wednesday (forenoon) usually relates to Mercury and Wednesday (afternoon) to Rāhu. Usually, the first letter of one's name is related to the day of the week of one's birth. Shway Yoe (1910: 4–6) and Meiji Soe (2012: 57–69) give detailed descriptions. Fig. 24.28 is an example of the figures of the days of the week on a modern Burmese calendar that the first author purchased in a bookshop in Mandalay at the time of the November 2016 SEAAN History and Heritage Working Group Meeting.

24.6.4 Indian Eras

There are several eras in India. We have seen that the Indian Śaka Era was used in the inscriptions in Champa, Thailand (particularly that of King Ram Khamhaeng), Cambodia, Burma, Indonesia, etc. Also, the Buddhist Era is used in some regions of Mainland Southeast Asia. In Thailand, the Buddhist Era ('Phuttha-sakkarāt' in Thai) is usually used (Buddhist Era = CE + 543). It should be noted that the 0th year of the Buddhist Era begins from 544 BC in Thailand, Laos and Cambodia, while the 1st year of the Buddhist Era begins in 544 BC in Burma and Sri Lanka.

Fig. 24.27 Figures of zodiacal signs from the front page of a modern Burmese calendar (Ôhashi Collection).

24.6.5 The Sidereal Year

The traditional calendars of Mainland Southeast Asia (except for Vietnam) use the sidereal year, and this is of Indian origin. This is the result of the zodiacal signs being fixed in their sidereal positions around the second half of the sixth century CE, as we saw above in the section on the 'zodiac'.

24.6.6 The Indian Luni-Solar Calendar

Hindu traditional calendars are mostly luni-solar calendars, and they were introduced into Southeast Asia. Since the Chinese traditional calendar is also a luni-solar calendar, it is sometimes difficult to distinguish Indian and Chinese influences in this respect.

One Indian specialty is the Hindu method of dividing one synodic month into a white half month (from New Moon to Full Moon) and a black half month (from Full Moon to New Moon). This method also is used in some Southeast Asian calendars. This division is absent in the Chinese luni-solar calendar. Another Indian specialty is to use the Sanskrit names of the lunar mansions as the names of the lunar months.

And also, one synodic month is divided into 30 *tithi*s in the Hindu calendar. In the Hindu calendar, one *tithi* (or lunar day) is usual a period during which the longitudinal difference between the Sun and Moon changes by 12°. This kind of lunar day is also used in some Southeast Asian calendars.

The Indian Jovian 12-year cycle, which is independent of the Chinese 12-year cycle of animals, was used in Burmese inscriptions (Furnivall, 1922).

In India, there are several traditional astronomical calendars in different geographical areas and written in different languages. Fig. 24.29 shows some examples of Indian traditional astronomical calendars in the Hindi language, and Fig. 24.30 shows an example of a page in a Hindi traditional astronomical calendar.

Fig. 24.31 is an example of a traditional Thai astronomical calendar. Here, we can see that the positions of the Sun, Moon, planets and the ascending node of the lunar orbit at the end of the day (24:00) are given in sidereal signs, degrees and minutes. We also can see that the Sun enters sidereal Aries in 14 April 1999, which is the day of Songkrān. Ketu usually means the descending node of the lunar orbit or, sometimes, comets or meteors in Hindu astronomy, and usually means Neptune in Thai astrology (see Suriyā'ārak, 1983), but the position of Ketu in Fig. 24.31 is different from these, and its meaning is not clear. We can see that the Thai traditional luni-solar date has a maximum on the 15th, because one sidereal month is divided into two half months. This is Indian style.

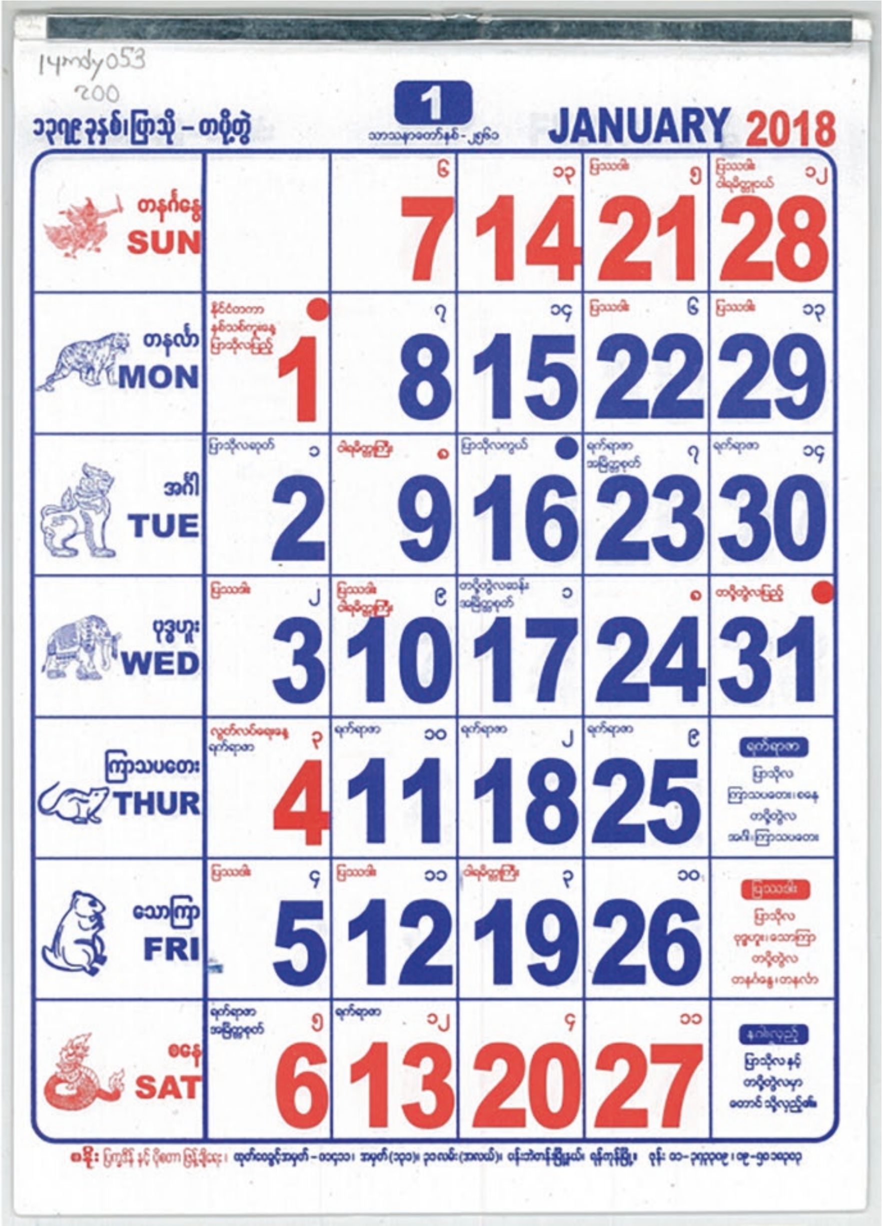


Fig. 24.28 Figures of days of a week in a modern Burmese calendar (Ôhashi Collection).

24.6.7 Time-keeping

Wallace (1869: Chapter 28) recorded a water clock used on a local Makassan ship (Fig. 24.32, C is a drawing by the first author of this chapter based on Wallace's description). This floating type of water clock was used in India from the end of the fifth century or so, and was very popular (Fig. 24.32, A and B are photographs of the water clock in the Rao Madho Singh Museum, Kota, Rajasthan, India). For details of Indian water clocks see Ôhashi (1994).

24.6.8 Horoscopes

Horoscopes are found in inscriptions throughout Southeast Asia (e.g., for Thailand, see Eade, 1996). And also, there are several other examples that are popular till now (see Fig. 24.1, Fig. 24.2 and Fig. 24.32 in Thai and Burmese calendars).

Fig. 24.29 Some Indian traditional astronomical calendars in the Hindi language (Ôhashi Collection).

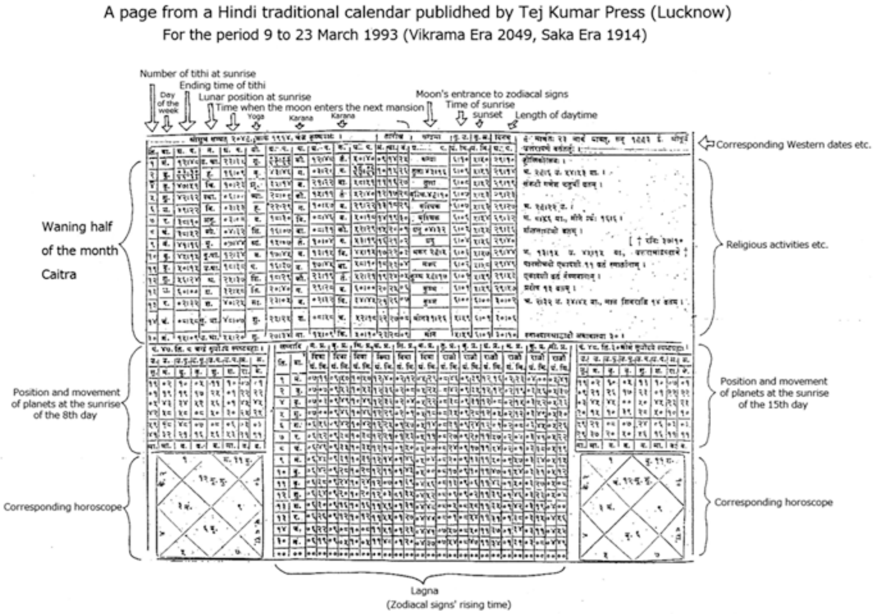


Fig. 24.30 A page from a Hindi traditional astronomical calendar, with comments by Yukio Ôhashi.

24.6.9 *Rāhu: The Demon Who Produces Eclipses*

In Indian astronomy, the ascending node and descending node are called Rāhu and Ketu. The legend of Rāhu is found widely throughout Southeast Asia (Fig. 24.33).

24.6.10 *Cosmology: Mount Meru, etc.*

The influence of Indian cosmology is found at several places in Southeast Asia (Quaritch Wales, 1977) and Swearer (2010). Bogle (2016) explains the Buddhist cosmology in Burma with several beautiful figures. Buddhist cosmology (the Mount Meru model) is mainly based on the *Abhidharma-koṣa* of Vasubandhu (ca. fourth–fifth centuries CE). There are several traditional pictures of Mount Meru in Thailand. And also, it is said that the central tower at the Angkor Wat temple complex in Cambodia symbolizes Mount Meru.

King Lithai of the Sukhothai Dynasty of Thailand wrote the *Trai-phūm* (Three Worlds) in the mid-fourteenth century (Reynolds and Reynolds, 1982). This is a celebrated text of traditional Thai cosmology, and some information about traditional astronomy is also found there.

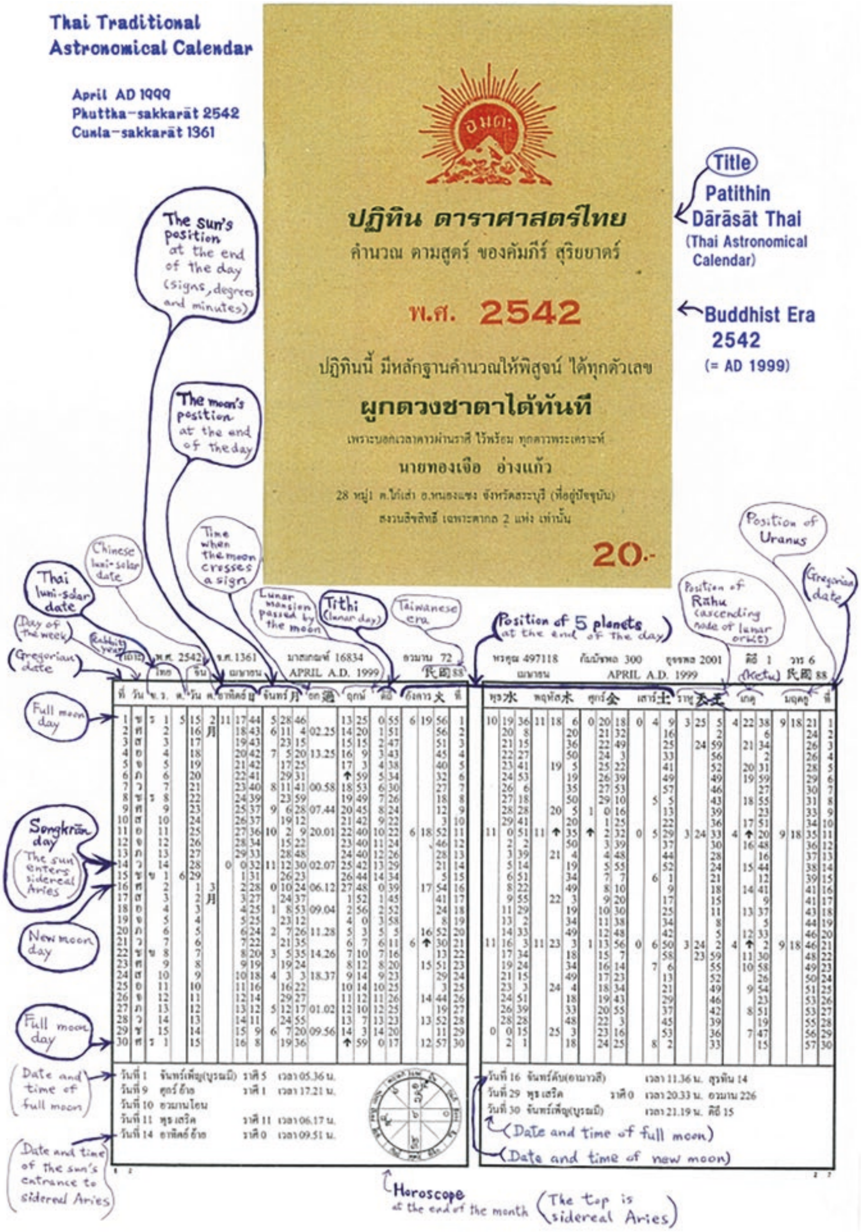


Fig. 24.31 An example of a Thai traditional astronomical calendar, with comments by Yukio Ôhashi (Ôhashi Collection).

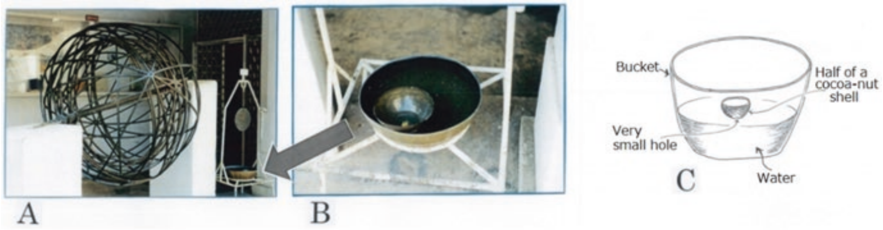


Fig. 24.32 Indian water clock (A and B) and a drawing (C) of a Makassan water clock (photographs and drawing: Yukio Ôhashi).

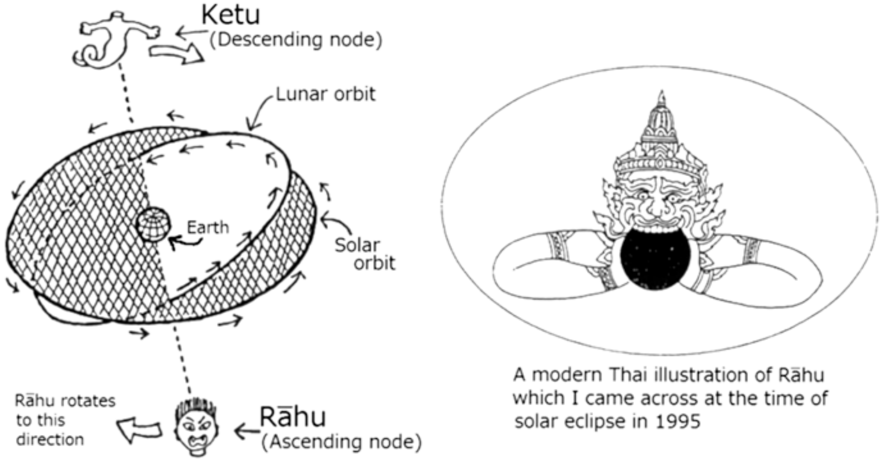


Fig. 24.33 Rāhu and Ketu (original artwork: Yukio Ôhashi).

24.6.11 Architecture

The Indian traditional science of architecture is called 'Vāstu-śāstra' in Sanskrit. For the determination of directions, astronomical methods were used. An interesting paper about the application of this principle in the planning of Chiang Mai city in Thailand was presented at the February 2020 H&H Meeting (see Saelee et al., 2021).

24.7 The Influence of Islam (YÔ)

Islam spread through island Southeast Asian between the thirteenth and sixteenth centuries, and quickly became the primary religion of what are now known as Malaysia and Indonesia. The astronomical impact of this newly-introduced religion is discussed below.

24.7.1 The Islamic Lunar Calendar

Basically, when the new crescent Moon is observed in the western sky in the evening, a new Islamic lunar month begins from sunset. So, the length of a month (29.530589 days) is exact. One year is 12 lunar months regardless of the season.

There are some simplified methods to predict lunar visibility. Proudfoot (2006) discussed the methods used in early island Southeast Asia. One method is trigesimal calendars that use a 30-year cycle (360 months), which has 11 leap years. This means that one lunar month is (30 × 6 × (29 + 30) + 11) / (30 × 12) = 29.530556 days. A simpler method is octaval calendars that use an 8-year cycle (96 months), which has 3 leap years. It means that one lunar month is (8 × 6 × (29 + 30) + 3) / (8 × 12) = 29.53125 days. Proudfoot says that the octaval calendar was widely used in pre-nineteenth century Southeast Asia. And we saw in the Geographical Overview Section that there is also a 120-year cycle (1440 months) with 44 leap years, which consists of 42,524 days. This is actually just four times the 30-year cycle.

At present, the visibility of the crescent Moon is still very important (for the case of India, see Ôhashi, 2006b), and there are several reports about it. In Japan, meanwhile, Kawada (2008) reports that there is a 'Ruyat-e-Hilal Committee-Japan' that observes the crescent Moon at the beginning and the end of the month Ramadan (the month of fasting), and if it is not observed then they follow the decision of the Malaysians. However, there are some Muslims in Japan who follow Turkey's decision. So, sometimes there may be a difference of one day in different Islamic calendars from the same area.

According to Horii (1987) who studied in Malaysia, some people prefer to make actual observations while others prefer calculations, so sometimes different states of Malaysia use slightly different Islamic dates.

24.7.2 Time-keeping and Qibla

There are five prayers called 'ṣalāt' daily, and time-keeping is very important for Muslims. There was an interesting record of the prayer time in the Dutch East Indies (now Indonesia) in the early twentieth century (Izutsu, 1942: 29–30), as follows:

(1) *ẓuhr* (after the time when the Sun is going to move from its highest point and before the shadow becomes the same length (or double length) as the height of itself): starting from 12 noon in the Dutch East Indies (while starting shortly after 12 am in Mecca).
(2) *'aṣr* (in the afternoon after *ẓuhr* and before the Sun is going to set): done around half past 4 pm in the Dutch East Indies (while done about 3 hours after *ẓuhr* in Mecca).
(3) *maghrib* (after complete sunset within evening twilight): done around 6 pm in the Dutch East Indies (while done right after sunset in Mecca).

(4) ishā (at night after evening twilight and before morning twilight (before sleeping): done around half past 8 pm in the Dutch East Indies (while done about two hours after *maghrib* in Mecca).
(5) *ṣubḥ* (after *ishā* and before sunrise): done between 4 am and 5 am in the Dutch East Indies (while done about one and a half hour before sunrise in Mecca).

The method of determining time in the pre-modern Southeast Asian Islamic world needs to be studied further.

The direction of the Kaaba in Mecca is called 'Qibla', and prayers should be done in this direction. According to Hurgronje (1906), Acehnese people and Javanese people considered that the rising three stars of Orion indicate Qibla. Ammarell and Tsing (2015) say that Banjar wet-rice farmers (in South Kalimantan) also saw the three stars of Orion's Belt as pointers to Qibla.

Lunar visibility, prayer times and the direction of Qibla are all very important in Islamic daily life, and there have been several attempts to modernize them. One attempt was made by the well-known Malaysian astronomer Mohammad Ilyas (1984, 1997).

24.8 Western Astronomers and Astronomy (YÔ and WO)

From the mid-sixteenth century Jesuit missionaries visited Southeast Asia, and Western astronomy was introduced into Asia through them. For example, on CE 11 December 1685 King Narai of Siam observed a lunar eclipse with Jesuits sent by the French King Louis XIV (Gislén et al., 2018; Orchiston et al., 2016). This event is depicted in Fig. 24.34. Later, Siam's King Rama IV studied Western astronomy as well as traditional Siamese and Mon astronomy, and he predicted and observed the total solar eclipse of AD 1868 (Soonthornthum and Orchiston, 2021) from Wah-koa, a coastal locality in southern Siam.

It should be noted that NARIT (the National Astronomical Research Institute of Thailand) has published the following series of books on the history of modern astronomy in Siam/Thailand in the Thai language: the reign of King Narai of the Ayutthaya Dynasty by Phumathon (2012a); the reign of King Mongkut (Rama IV) by Phumathon (2012b); the reigns from King Rama V to King Rama VIII by Euarchukiati (2015); and the reign of King Bhumibol Adulyadej (Rama IX) by Soonthornthum and Thajchayapong (2012). Meanwhile, for English-language overviews of the history of Thai astronomy see Soonthornthum (2017) and Orchiston et al. (2019).

During the nineteenth and twentieth centuries, Southeast Asia also was host to Western expeditions intent on observing the total solar eclipses of 1868 (Mumpuni et al., 2017; Orchiston and Orchiston, 2017a; Orchiston et al., 2021c); 1871 (Mumpuni et al., 2017); 1875 (Euarchukiati, 2021; Kramer and Kramer, 2017); 1901 (Pearson and Orchiston, 2017); and 1929 (Noor and Orchiston, 2021; Soonthornthum et al., 2021). Fig. 24.35 shows the eclipse camp at Wah-koa, Siam, where a French expedition successfully observed the total solar eclipse of 18 August

Fig. 24.34 A drawing supposedly showing King Narai (in the pavilion) and French Jesuit astronomers using telescopes to observe the 11 December 1685 lunar eclipse from the King's country retreat near Lop Buri, but as Orchiston et al. (2016) have shown, this contains considerable artistic license (after Tachard, 1686).

1868 at the invitation of King Rama IV (Orchiston and Orchiston, 2017a). King Rama IV's own eclipse camp was located nearby.

We also should consider Western influence on the traditional astronomy of Asia. For example, the last Chinese traditional calendar, the *Shixian-li* (時憲暦) (which was used in China from CE 1645) was based on Western astronomy. Subsequently, the *Shixian-li* calendar was adopted in Vietnam in CE 1813. In Vietnam, in CE 1837 the prime meridian was declared to pass through its capital Hue, and the longitudinal difference between Beijing and Hue was determined in 1841. At that time, longitude was measured from Paris. Here, also, we can see Western influence on the traditional astronomy of Vietnam (cf. Phâm and Lê, 2021).

Finally, the history of recent astronomy in some areas of Southeast Asia after the introduction of Western astronomy has been recorded in various chapters in the books edited by Batten (2001), Hearnshaw and Martinez (2007) and Nakamura and Orchiston (2017).

Fig. 24.35 A photograph of the 1868 French eclipse camp at Wah-koa, Siam, showing instrument huts and the 40-cm (left) and 20-cm (right) reflecting telescopes set up outdoors (courtesy: Archives, Observatoire de Marseille, 132 J 84).

24.9 Expanding on the Concept of 'Multiplex Astronomy'

24.9.1 Introduction: Changing Astronomical Systems (WO)

Near the start of this chapter we introduced the concept of 'multiplex astronomy', where there is evidence that the original local astronomical knowledge system has been modified by the later superimposition of other astronomical influences from China, India, the Islamic World, the West, or any combination of these. In mainland Southeast Asia the oldest known astronomical systems usually date to the local arrival of farming communities, and given this comparatively short time frame it is relatively easy to identify the external astronomical influences, as we have seen in Sections 24.4–24.7 above.

However, the situation in island Southeast Asia and the Malay Peninsula tends to be much more complicated, given that the existing negrito populations of southern Thailand, the Malay Peninsula and various islands in the Philippines archipelago possess astronomical knowledge bases that evolved from the ancestral astronomical system that was introduced 60,000–70,000 years ago when the first *Homo sapiens* settled this region.

Then around 4000 years ago Austronesian populations from Taiwan spread throughout much of island Southeast Asia, imposing their language and their culture—including their astronomical beliefs and practices—on the existing negrito (Australo-Melanesian) populations, before many negrito groups withdrew, or were driven, into the heavily-forested mountainous interiors of the islands in the Philippines archipelago, where they could maintain their identities in cultural and genetic isolation.

Around 3000 years ago Austro-Asiatic populations from South China and Vietnam settled the Malay Peninsula and southern parts of island Southeast Asia, bringing their own distinctive astronomical knowledge systems, which were closely linked to rice-cultivation. They in turn imposed their astronomical beliefs and practices on the existing negrito populations of southern Thailand and Malaysia, and on the Austronesians. Meanwhile, their own ecologically-related astronomical beliefs and practices soon evolved as they adjusted to successfully growing rice in localised tropical environments dominated by monsoons. It is also possible that some Austro-Asiatic groups chose to adopt various astronomical beliefs of the negritos and Austronesians, and incorporate them into their own astronomical knowledge systems.

Later, the Hindu religion and Islam spread throughout much of island Southeast Asia, introducing their own distinctive astronomical concepts and practices, and leaving their imprints of the daily lives of the local people. Then within the past 500 years the Malay Peninsula and all of the islands of Southeast Asia have experienced colonialism, with each of the European occupying nations (Great Britain, the Netherlands, Portugal, Spain and the United States of America) having its own established reputation in scientific astronomy and—in more recent years—in astrophysics.

Finally, we should note that in addition to the astronomical beliefs and practices introduced over the millennia to the Malay Peninsula and island Southeast Asia by different ethnic groups, religions and perhaps colonialism, astronomical knowledge systems also were liable to undergo change through cultural evolution and adaptation (cf. Orchiston and Orchiston, 2017b), and in response to major environmental changes—and especially those that occurred in sea level, temperature and rainfall over the last 20,000 years (following the last phase of glaciation).

When viewed from a chronological perspective, we can see that the Malay Peninsula and island Southeast Asia experienced a succession of ‘notable events’, each of which had the potential to impact significantly on existing astronomical systems. In chronological order, these events were:

(1) Occupation of the region by Australo-Melanesians 70,000–60,000 years ago
(2) Rapid and sustained post-glacial sea level rise between 22,000 and 6000 years ago
(3) Occupation of the region by Austronesians, beginning about 4000 years ago
(4) Occupation of part of the region by Austro-Asiatics, beginning about 3000 years ago
(5) The spread of Hindu religion throughout much of the region, beginning about 1200 years ago
(6) The spread of Islam throughout much of the region, beginning about 800 years ago
(7) The spread of Western colonialism throughout the region, beginning about 500 years ago

Let us now examine this interplay of changes in human populations, the environment, religion and colonialism in the Malay Peninsula and island Southeast Asia and their likely impacts on local astronomical systems. Since topics (5) and (6) and have already been discussed earlier in this chapter, in Sections 4.6 and 4.7, they will only be examined briefly here. Therefore, our emphasis will be on topics (1) through (4) and (7). Note that all of these have also been discussed elsewhere in this book, particularly in Chapters 2 and 19.

24.9.2 The Potential Impact of Environmental Change, Migrations, Religions and Colonialism on Island SE Asian Astronomical Systems (WO)

24.9.2.1 Australo-Melanesian Occupation of the Southeast Asian Region and Emerging Astronomical Systems

The earliest inhabitants of the Southeast Asian region were hominids belonging to *Homo erectus* (e.g. see Sémah, et al., 2000; Zaim, et al., 2011) and later *Homo Floresiensis* (Brumm, et al., 2010; Sutikna et al., 2016), and we can assume that some of these ancestral populations would have been encountered when the first anatomically modern humans, belonging to the species *Homo sapiens*, migrated into the region between 70,000 and 60,000 years ago (see Dennell, et al., 2014; Swisher III et al., 1996). They originated in northern Africa, and it is thought they probably followed the coast on their journey eastward. Known now as Australo-Melanesians, they settled Southeast Asia and also Australia and New Guinea (O'Connell et al., 2018). Although sea levels (Voris, 2001) during the period 70,000–60,000 BP[1] were significantly lower than those of today (see Fig. 24.36), these newcomers still had to successfully negotiate challenging water crossings in order to reach the Philippines region (Heaney, 1985), and Sahul—the enlarged Australia-New Guinea continent (e.g., see Kealy et al., 2016, 2017; O'Connor, 2015; O'Connor et al., 2017).

We see evidence of the Australo-Melanesians today in archaeological sites and human skeletal remains found throughout Sahul, Sundaland (the enlarged SE Asian land mass) and the Philippines (see Fig. 24.36) and, indeed, the earliest dated evidence of this population influx is from Callao Cave in the northern Philippines, where human skeletal remains have been dated to 67,000 BP (Mijares et al., 2010). Other early human skeletal remains have been recovered from Tabon Cave on the island of Palawan (Détroit et al., 2004; Dizon, 2003; Dizon et al., 2002; Fox, 1970),

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[1] In this section the term BP refers to 'before the present', where 'present' by international definition is the year 1950. Geological time, for the period we discuss in this Sub-Section, is covered by two epochs, the Pleistocene (from 2.58 million years BP to 11,700 BP) and the Holocene (from 11,700 BP to the present day). The Pleistocene has Early, Middle and Late stages, with the Late Pleistocene from 126,000 to 11,700 BP (Gibbard et al., 2010). Sometimes it is convenient to express these dates as 126 kyr BP and 11.7 kyr BP, while the Pleistocene began at 2.58 myr BP. The Pleistocene was characterized by continuous glacial and interglacial phases, but only the Late Pleistocene is relevant here, and most of our discussion in this Sub-Section will focus on the Holocene.

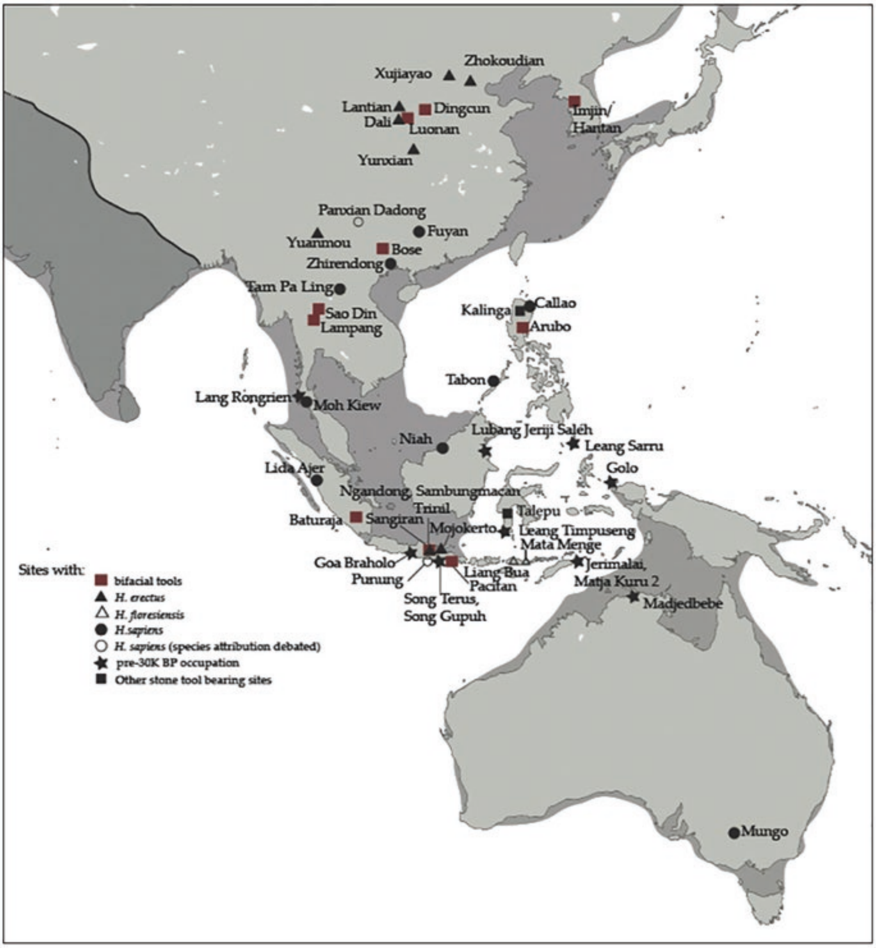

Fig. 24.36 A map showing East and Southeast Asian sites with bifacial tools, and human skeletal remains; the dark shading shows the land areas of 'Sundaland' (an enlarged mainland Southeast Asia) and 'Sahul' (conjoined Australia and New Guinea) when the seas were 110 m below current levels (after Roberts and Amano, 2019: Fig. 1).

and Niah Cave (Barker, et al., 2013; Curnoe et al., 2019; Hunt and Barker, 2014) in what is now northern Borneo.

The other even more conspicuous evidence of the Australo-Melanesian influx is the current existence of 'negrito' populations on the Andaman Islands in the eastern Indian Ocean (e.g. see Radcliffe-Brown, 1928), in southern Thailand, throughout the mountainous forested interior of the Malay Peninsula (Carey, 1976), and on various islands in the Philippines archipelago (e.g. Griffin and Estioko-Griffin, 1985; Rahmann and Maceda, 1955; Reid, 2013; Samson and Vitin, 2019). Their geographical distribution is shown in Fig. 24.37). The negritos are distinguished from other indigenous ethic groups by their short stature, dark skin and dark hair, but in Malaysia and the Philippines in particular they display considerable phenotypical heterogeneity. This is supported by genetic evidence. Studies using mtDNA (inherited through females) and Y chromosomes (inherited through males) show that as a group, the Philippines negritos can be clearly distinguished from the Malaysian negrito populations, which also differ significantly from the Andaman negritos (e.g. see Fig. 24.38). This would suggest that there were two or more different waves of Australo-Melanesians who settled mainland and island Southeast Asia (cf. Corny et al., 2017). Be that as it may, what these negrito groups offer us is an opportunity to possibly identify elements of the original Australo-Melanesian astronomical systems that were introduced to Southeast Asian with the first *Homo sapiens*. Studies conducted among the Aboriginal Australians (e.g. Hamacher and Norris, 2009); Nunn and Reid, 2016) show that astronomical and geomythological information can successfully be passed down from generation to generation for tens of thousands of years.

Fig. 24.37 The current geographical distribution of negrito ethnic groups in the Southeast Asian region; the larger circles in Malaysia and the northern Philippines indicate the presence of many negrito groups in these two areas (map: Wayne Orchiston).

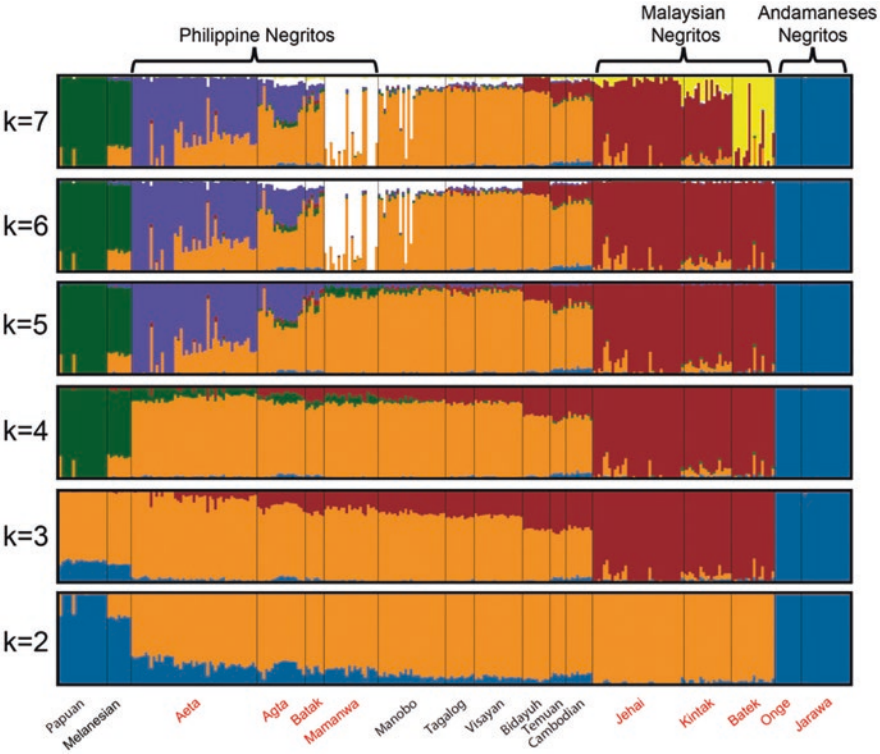

Fig. 24.38 A diagram showing the distinctive genetic signatures of the Andaman, Malay Peninsula and Philippine negrito groups (after Jinam et al., 2017: 2017).

Macaulay et al. (2005) and Oppenheimer (2012) have both reviewed the genetic evidence, and concluded that anatomically modern man, *Homo sapiens*, exited East Africa on a single occasion, and took a route that crossed the entrance to the Red Sea, and ran along the coast of the Arabian Peninsula, round the coast of the Indian Subcontinent, into mainland and then island Southeast Asia. However, Petraglia et al. (2010: 305) believe this is an over-simplification:

> Based on our review of the fossil, genetic, and archaeological evidence, we argue that the expansion of *H. sapiens* out of Africa was a complex process, and not simply the consequence of a single, rapid coastal expansion at 60 ka ago. We argue that that modern human expansion into Arabia is probably coincident with the ages of 130–70 ka for H. sapiens in the Levant, with populations reaching South Asia by 78 ka, and perhaps earlier.

These new inhabitants of Southeast Asia must have brought with them ancestral astronomical systems that formed part and parcel of their evolving cultural complexes. These Australo-Melanesians were hunter-gatherers and if later Aboriginal Australian ethnographic analogies are any indication we can assume that there were close correlations between human ecology and astronomy—so what was of prime importance here on the Earth often was projected into the sky and associated with specific stars or asterisms, or even with dark lanes in the Milky Way (e.g. see Clarke, 2014, 2015; Fuller et al., 2014; Gullberg et al., 2020; Hamacher, 2015).

At this time sea levels were lower than today (see Fig. 24.39) and the Malay Peninsula, Sumatra, Borneo and Java all formed part of an extended SE Asian continent, with the area referred to as Sundaland. This is indicated by the dark grey areas in Fig. 24.36, but this map is to some extent misleading because the position of the coastline was constantly changing, sometimes even on a decade-by-decade basis—therefore within the span of a normal human lifetime—as sea levels oscillated between 70 kyr and 40 kyr. This obviously impacted on coastal exploration of the region, as did the presence of dense tropical rainforest, though Bird et al. (2005) and others have suggested that an E-W ‘savannah corridor’ across Sundaland helped facilitate the dispersal of populations throughout Sundaland, to the Philippines, islands in the Lesser Sunda chain in eastern Indonesia, and also to Sahul (the Greater Australian continent), all of which required challenging marine crossings (O’Connell et al., 2010). Yet archaeological, genetic and human skeletal evidence indicates that all of these water crossings were successfully negotiated (e.g. see Arenas et al., 2020; Gomes et al., 2015; O’Connell et al., 2018; Wurster and Bird, 2014).

As hunter-gatherers the Australo-Melanesians preferred the biotic diversity of coastal habitats, but they quickly adapted to the full range of environments encountered in Sundaland (Boivin et al., 2013). Roberts and Stewart (2018) introduce the term ‘adaptive plasticity’, and elaborate:

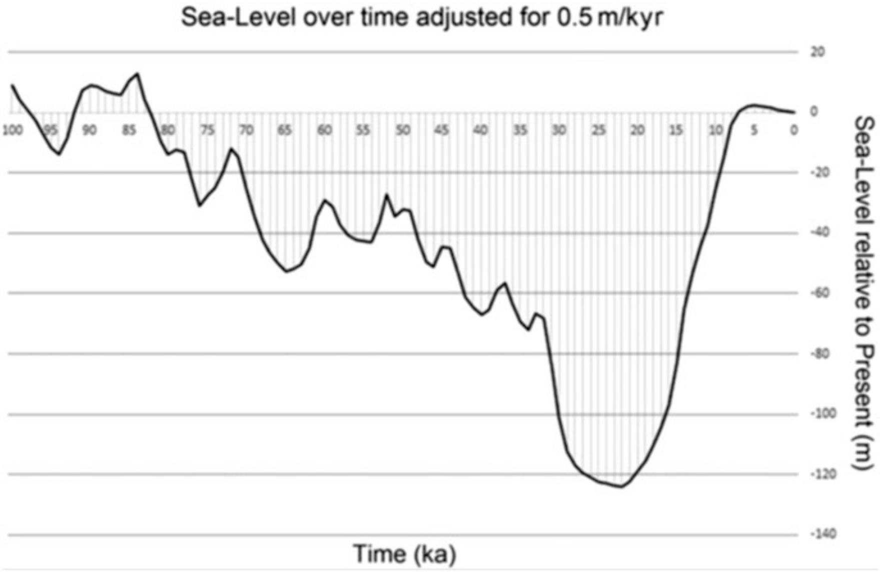

Fig. 24.39 A plot showing the changing sea levels in the Southeast Asian region over the past 100,000 years (after Lambeck and Chappell, 2001, but incorporating an isostatic uplift of 0.5 meters per thousand years, as calculated by Kealy et al. 2017).

> … our species also documents a series of regional specializations in its adaptation to different rainforest environments. For example, at the Niah Caves, Borneo, humans deliberately maintained a mixture of grassland, peat swamp rainforest and evergreen rainforest to exploit primates, migratory suids and a variety of plant products. (*ibid.*)

Barker et al. (2007, 2013, 2020) document the Niah Cave evidence, while Morley (2016) notes that "… growing evidence shows that tropical rainforests, far from being unfavourable for human exploitation as was traditionally thought (see e.g. Bailey et al., 1989), have been successfully exploited for at least the past ~45 ka …" Roberts and Petraglia (2015) review the accumulated evidence for Southeast Asia, and support this conclusion.

It was not just a matter of exploring and adapting to a new environment but the Australo-Melanesians had to adjust to an environment undergoing constant transformation. The sea level fluctuations documented in Fig. 24.39 provided an ever-changing landscape as rising and falling sea levels first drowned coastal habitats and then exposed them, leading to ecological regimes that slowly had to be altered over the course of a century or so. But superimposed on these coastal changes were climatic variations (see Bird et al., 2007; Lewis et al., 2008a; Westaway et al., 2007), which—as with sea levels—were initimately linked to glacial and interglacial phases. Variations in temperature and rainfall (e.g. see Fig. 24.40) also led to expanding and contracting biotic zones (and especially rainforest—see Wurster et al., 2010; Xhauflair et al., 2017) that would be open to human exploitation, only to be closed off when environmental circumstances varied (e.g. see Piper et al., 2011). Humans had to be adaptable to make the best opportunities of this constantly changing environment (Hunt et al., 2012; O'Connor et al., 2011; Samper Carro et al., 2016).

Petraglia et al. (2010: 301) discuss the impact of Late Pleistocene climate change on human populations living in the Indian Subcontinent, and with the exception of reference to desert environments their evaluation is equally applicable to SE Asia:

> Arid phases in South Asia would have led to the expansion of the Thar Desert, but also the production of tropical forest refugia in southwest India and Sri Lanka, as well as the widespread creation of fragmented, mosaic grasslands and woodland habitats in most of the subcontinent. Small groups of foragers could have easily survived and pursued their hunting and gathering lifestyles in this range of habitats.

One aspect of this changing environment that had special significance in Mainland and island SE Asia was megafaunal extinctions, and Louys et al. (2007: 169) have shown how

> … changes in sea level may have allowed easier routes for early colonising mammals, humans among them. It also brought about changes in the structure of the vegetation, disrupted river systems, and isolated islands like Java and Sumatra. This aspect of extinctions is unique to Southeast Asia—it is unlikely that changes in sea level affected the Americas, Europe or Australia in quite the same way.

That said, the role that humans played in these extinctions has still to be determined on a regional basis, or on an island-by-island basis in the Lesser Sunda chain of islands in eastern Indonesia.

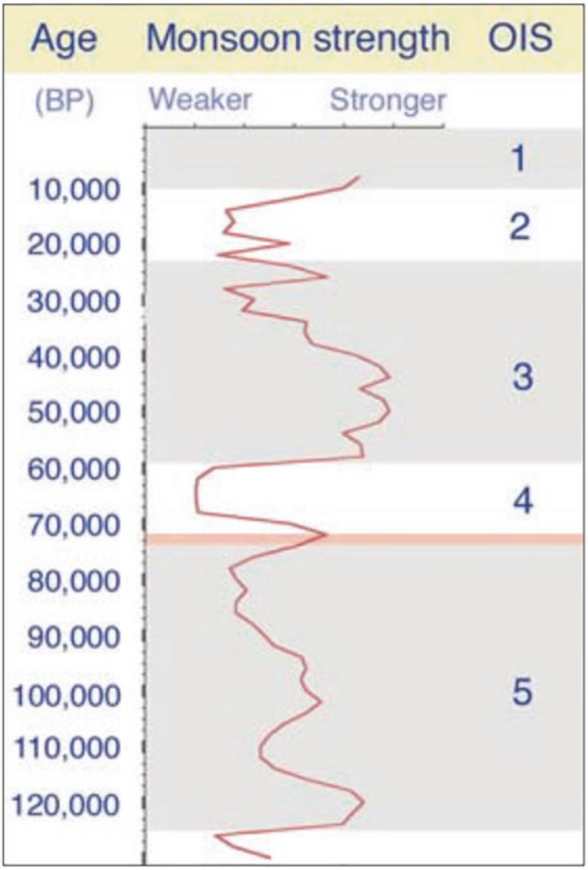

Fig. 24.40 Variations in rainfall over the past 130 kyr as reflected in the strength of the monsoon; 1–5 indicate Oxygen Isotope Stages (adapted from Petraglia et al., 2010: 298, Figure 2).

Some of these environmental and associated ecological changes would have impacted on the astronomical systems of the Australo-Melanesians, and our task as ethnoastronomers is to try and identify and quantify these.

24.9.2.2 Australo-Melanesians, the Post-Glacial Sea Level Rise and Evolving Astronomical Systems

The most dramatic changes in sea levels experienced by the Australo-Melanesians occurred during terminal Pleistocene times, between 22 kyr and 6 kyr when the seas continued their rapid and relentless rise towards current levels, drowning habitat after habitat as they flooded the Sunda shelf (Hanebuth et al., 2000; Sathiamurthy and Voris, 2006), destroying Sundaland in the process (Oppenheimer, 1998), and forming the present-day islands of island Southeast Asia (e.g. for the case of Palawan, see Robles et al., 2015). Soares et al. (2008: 1215–1216) suggest that these sea level changes

> … triggered major displacements of human groups living on the Sunda coastline and had an important role in shaping subsequent life in the region, in particular its maritime orientation and development of sailing technology …

> With the opening up of approximately twice as much coastline as there had previously been, the coastal populations of Sundaland (and perhaps also northwestern Wallacea) would have been well placed to expand into this rapidly growing habitat. Conversely, the hinterland-based populations would have faced severe land pressures from both the drowning of their ancestral lands and the encroachment of rainforest over the savannas and monsoon forests to which they had adapted (Bird et al. 2005).

There is accumulating archaeological evidence of the ways in which the occupants of Southeast Asia responded to these environmental changes (e.g. see Lewis et al., 2008b; Mijares, 2008; Pawlik et al., 2014a, 2014b), but not all environmental changes demanded major ecological changes. Sometimes biomes remained the same during the sea level rise—as in the case of mangrove forests (Berdin et al., 2003)—and it was merely a matter of redefining the boundaries of the changing human exploitation territory.

Although it is clear that populations were split and became geographical bound as a result of the post-glacial sea level changes, maritime technology allowed continuing contact between separated populations, thereby facilitating trade (e.g. see Reepmeyer et al., 2011), parallel cultural evolution and the perpetuation of evolving astronomical knowledge systems. Some of the Late Pleistocene genetic evidence assembled by Hill et al. (2007) and Soares et al. (2008) can be interpreted in terms of these sea level changes and the relocation of human populations.

As an aside we should mention that in Australia some coastal Aboriginal groups have a memory of this late-Pleistocene sea level rise preserved in their myths and legends (see Nunn and Reid, 2016), and it will be interesting to see if comparable accounts emerge from any island Southeast Asian negrito groups.

24.9.2.3 The Arrival and Superimposition of Austronesian Astronomical Systems

Without doubt, one of the most important threats to the long-term survival of the established astronomical systems of the Australo-Melanesians occurred about 4000 years ago when a totally new human population swept into island South East Asia. Termed the Austronesians, these people of Asian genetic stock had their origin in the farming communities of south-eastern China (Chi and Hung, 2010; Lu, 2006), but were firmly settled in Taiwan (Ko et al., 2014) before finally making their way southwards into northern Luzon, via the Batanes Islands (Bellwood and Dizon, 2008; Piper et al., 2009). This population movement is not only documented in the archaeological record, but is clearly identified through genetic studies (e.g. see Kayser et al., 2008; Lipson et al., 2014; Mörseburg et al., 2016; Tabbada et al., 2010; Trejaut et al., 2005, 2014).

One of the features of the Austronesian settlement of island Southeast Asian that has preoccupied some scholars is the timing, given that the Austronesians were firmly (and apparently happily) settled in Taiwan for perhaps 1500 years before they began to move southwards and occupy Luzon and other islands in the Philippine archipelago (Bellwood, 2005). It transpires that the time when this migration occurred was marked by extremely low temperatures (see Berkelhammer et al., 2012), coupled with several hundred years of alternating drought and flood conditions as the monsoon was dominated by the Il-Niño-Southern Oscillation (ENSO). This corresponds to what geologists and paleaoclimatologists refer to as the '4.2 Ka Event', and it has been investigated in detail by Kathayat et al. (2018: 1875):

> (Fig. 8) illustrates the ISM [Indian Summer Monsoon] variability between ~3.8 and 4.6 ka … The interval marking the onset of the 4.2 ka event in our record (~4.255 ka) is indicated by a transition from pluvial (inferred by the lower $\delta^{18}O$ values) to variable ISM (dry–wet) conditions, with the latter superimposed by a few short-term (<decade) droughts (Fig. 8). Subsequently, the period between 4.07 and 4:01 ka is marked by persistently lower $\delta^{18}O$ values, implying stronger ISM (Fig. 8). The latter was terminated by a rapid increase in the $\delta^{18}O$ values (~1.0‰, Fig. 5), suggesting an abrupt weakening of the ISM at ~4.01 ka that occurred within a period of ~10 years. Notably, as discussed above, the ML.1 and ML.2 $\delta^{18}O$ profiles show gradual increasing trends over the entire length of the record, which was punctuated by two multi-decadal weak monsoon events centered at ~3.970 (~20 years) and ~3.915 ka (~25 years), respectively (Fig. 8). These aspects of our ISM reconstruction differ from previous proxy records from the ISM domain, which typically portray the 4.2 ka event as a multi-century drought (e.g., Berkelhammer et al., 2012; Dixit et al., 2014). Our new data, however, demonstrate that prominent decadal to multi-decadal variability, together with the intermittent occurrence of multi-decadal periods of low rainfall, was the dominant mode of ISM variability during the period coeval with the 4.2 ka event …

The Fig. 8 referred to above by Kathayat et al. (2018) is reproduced here as Fig. 24.41. Perhaps it was the never-ending succession of floods and long-term droughts experienced in Taiwan from around 3,800 BP, coupled with increasing population pressure on land, which triggered the initial migration of Austronesians to the Philippines.

One of the mysterious features of this migration is that although the Asian mainland newcomers were experienced horticulturalists, there is little evidence that rice or millet-farming or their traditional cultigens (banana, breadfruit, coconut, pineapple, taro and yam), were important once they settled in Luzon (Bulbeck, 2008), and all of the early archaeological evidence indicates that they practiced broad-spectrum hunting and gathering where they made optimal uses of the various biomes within their exploitation territories (see Orchiston et al., 2021b). Only perhaps 1500 years later did rice-cultivation become important (Barker and Richards, 2013; Snow et al., 1986). The astronomical implications of these ecological changes warrant investigation.

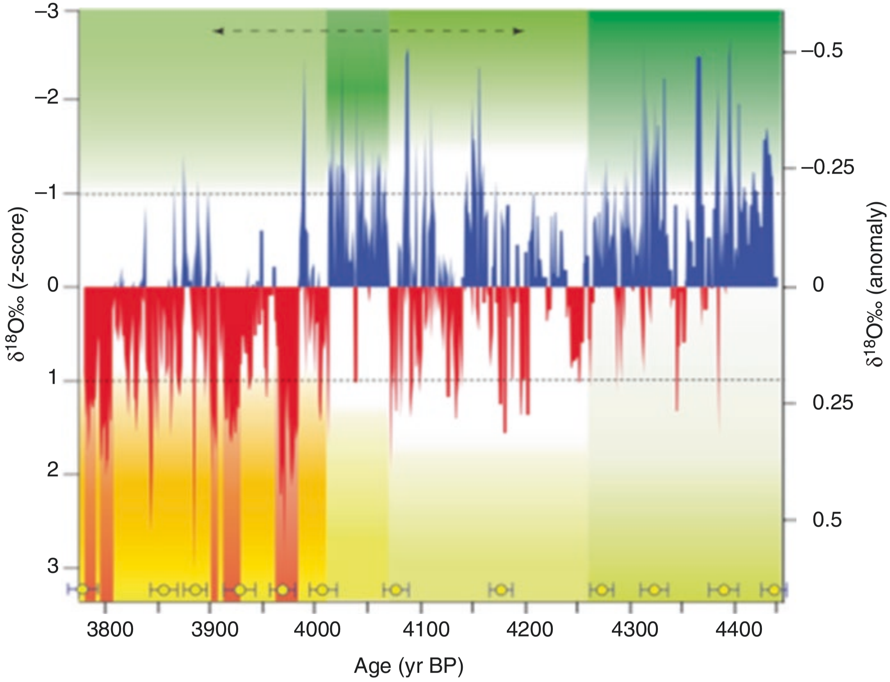

Fig. 24.41 The inferred pattern of Indian summer monsoon variability during the 4.2 ka Event. The horizontal dashed double arrows show the commonly-accepted duration of the 4.2 ka Event. Periods with yellow shading experienced drier conditions while those in green had wetter conditions. The red bars show periods of multi-decadal drought, and the blue bars intervals of intensive rainfall (after Kathayat et al., 2018: 1876).

The present-day distribution of negrito ethnic groups in the Philippines (Fig. 24.42) would indicate that the Austronesians must have frequently encountered negritos when they first occupied Luzon, and genetic data point to extensive initial gene-sharing between these two populations (e.g. see Scholes et al., 2011), followed in some cases by isolation (Heyer et al., 2013). However, gene-sharing was a long-term process among the Mamanwa of Mindanao, as illustrated in Fig. 24.43. Although we have no details of the dynamics of these interactions we note that initially the Austronesians mimicked the ecological practices of the local negrito groups, while the negritos eventually ended up adopting the language of the newcomers (see Reid, 1987, 1994).

The Austronesians did not just occupy the Philippines area but they also settled in the eastern half of Indonesia (Gomes et al., 2015; Mona et al., 2009; Spriggs, 2011), and then some groups exploited the advanced maritime technology that was a feature of their culture to venture eastwards (Tumonggor et al., 2013), establishing settlements on and off the coasts of New Guinea (see Skelly et al., 2014), then in Near Oceania (Friedlaender et al., 2007; Spriggs, 2000), before eventually spreading across the Pacific as the Polynesians (Bellwood, 2017; Kayser et al., 2008). Notwithstanding the passage of time, one interesting research project will be to determine whether any remnants of the ancestral Austronesian astronomical system of island Southeast Asia have survived in Polynesian astronomy. An equally insightful study will be to see which elements of Austronesian astronomy were adopted by the negrito populations of the Philippines, and *vice versa*.

24.9.2.4 The Arrival and Superimposition of Austro-Asiatic Astronomical Systems

Archaeological (Bellwood, 2017), skeletal, and genetic evidence (Hill et al., 2007; Karafet et al., 2010; Lipson et al., 2018; Matsumura et al., 2011, 2018, 2019; McColl et al., 2018) document the arrival of a second major influx of Asian settlers in island Southeast Asia, beginning about 3000 years ago. These immigrants, known as Austro-Asiatics, originated from South China and Vietnam, and are thought to have entered island Southeast Asia following a land route that ran from Vietnam to Java, via Thailand and the Malay Peninsula and Sumatra. From Sumatra they spread northwards into Borneo, and from Java they migrated northwards into Sulawesi (Simanjuntak, 2017) and eastwards into the Lesser Sunda Islands. However, "… in most areas of Southeast Asia where they settled (except in some parts of the Malay Peninsula) the Austro-Asiatic groups decided to abandon their original mainland Southeast Asian language and adopt the Austronesian languages that already were widely spoken and accepted throughout Island Southeast Asia." (Orchiston et al., 2021b: 65).

These latest newcomers to island Southeast Asia were the ancestors of the majority of the current occupants of island Southeast Asia. They were

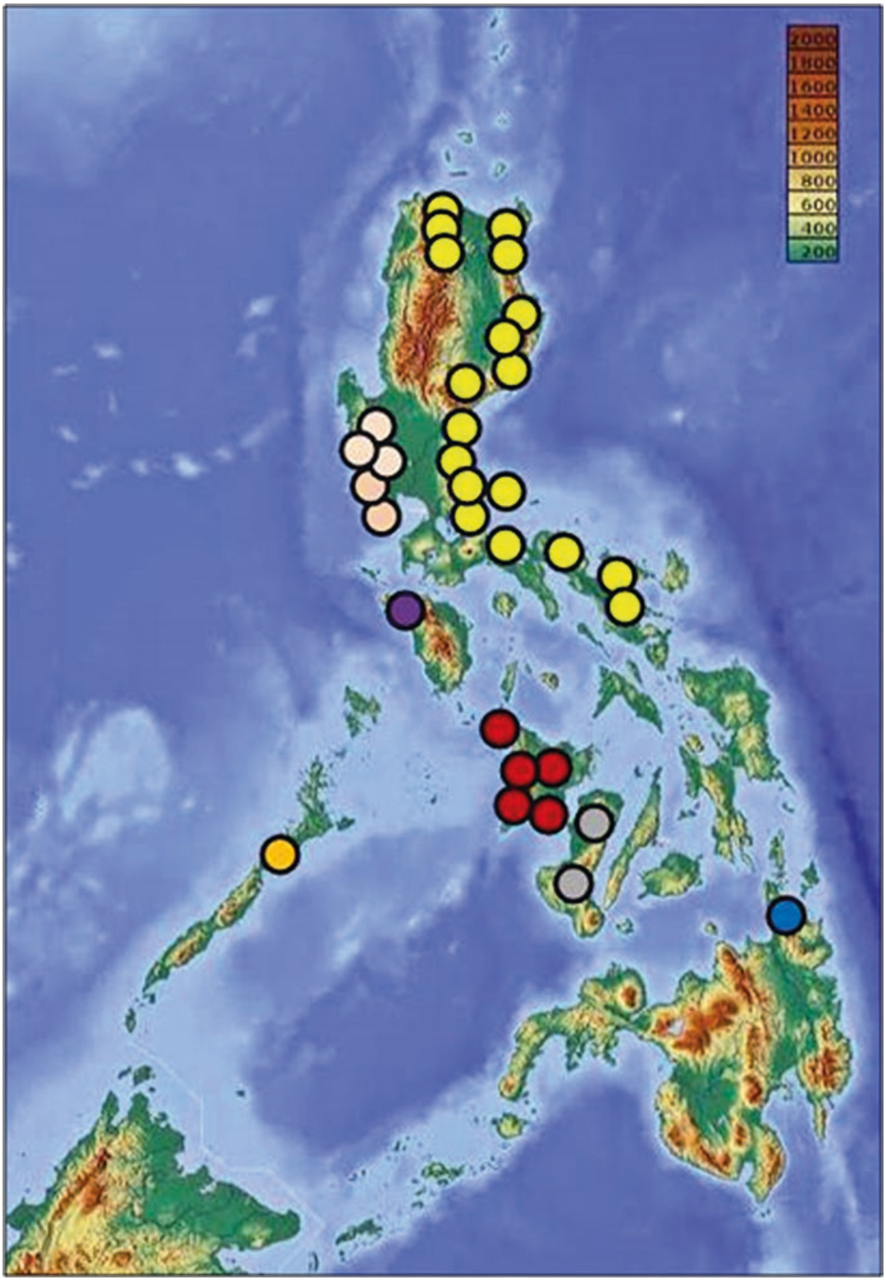

Fig. 24.42 The geographical distribution of the main Philippine negrito groups (Aeta = pink; Agta = yellow; Ata = grey; Ati = red; Batak = orange; Iraya = purple; Mamanwa = blue; map: Wayne Orchiston).

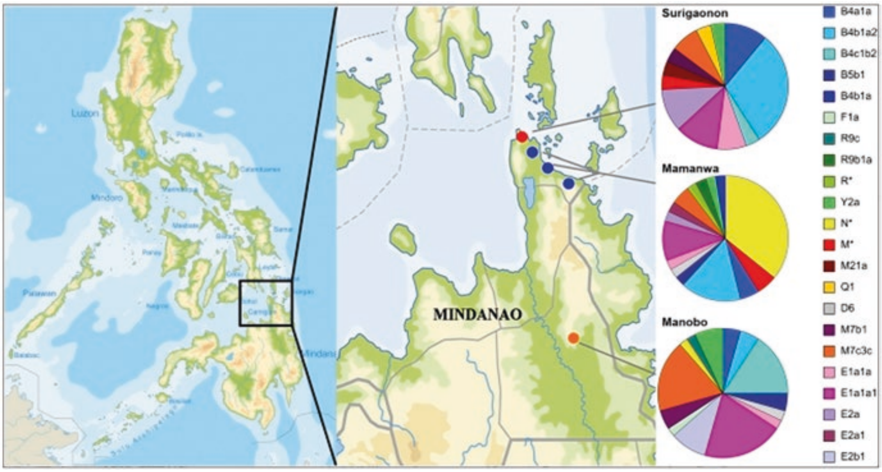

Fig. 24.43 A diagram showing the main haplogroups of the Mamanwa negritos of northern Mindanao and the extent of gene-sharing by the neighbouring Manobo Austronesian ethnic group (after Gunnarsdóttir et al., 2011: Figure 3).

horticulturalists, experienced in rice-cultivation, and *Pranotomongso* of Java (Dardjoeni and Hidayat, 1987; see Fig. 24.44) and a comparable rice-growing calendar found in northwestern Malaysia (Jaafar and Khairuddin, 2021b) reflect local modifications to the ancestral Austro-Asiatic astronomical systems, and evolved in island Southeast Asia in response to specific cultural and environmental demands (Orchiston and Orchiston, 2018). For example, we see the modification of these astronomical systems displayed in the origins of the months shown in Fig. 24.44: most of these are of Indonesian derivation, but two, Dhestal and Sadaha, are from India. For further details of the *Pranotomongso* calendar see Suryadarma (2019).

In addition to developing their own distinctive components of their astronomical knowledge bases, throughout island Southeast Asia the Austro-Asiatic groups had to decide which elements—if any—of the astronomical systems of the existing populations they should adopt. This was a particular challenge in what is now Indonesia where they encountered vibrant Austronesian *and* negrito (i.e. Australo-Melanesian) astronomical systems, as reflected in the ancestry bars in Fig. 24.45 that show combinations of green, blue and orange, or green, blue and yellow. On the other hand, our challenge as ethnoastronomers is not just to unravel these cultural changes, but also to determine the extent to which the Austronesian and negrito astronomical systems in this southern region of island Southeast Asia adopted, or were inspired by, elements of the newly-introduced astronomical systems of the Austro-Asiatics.

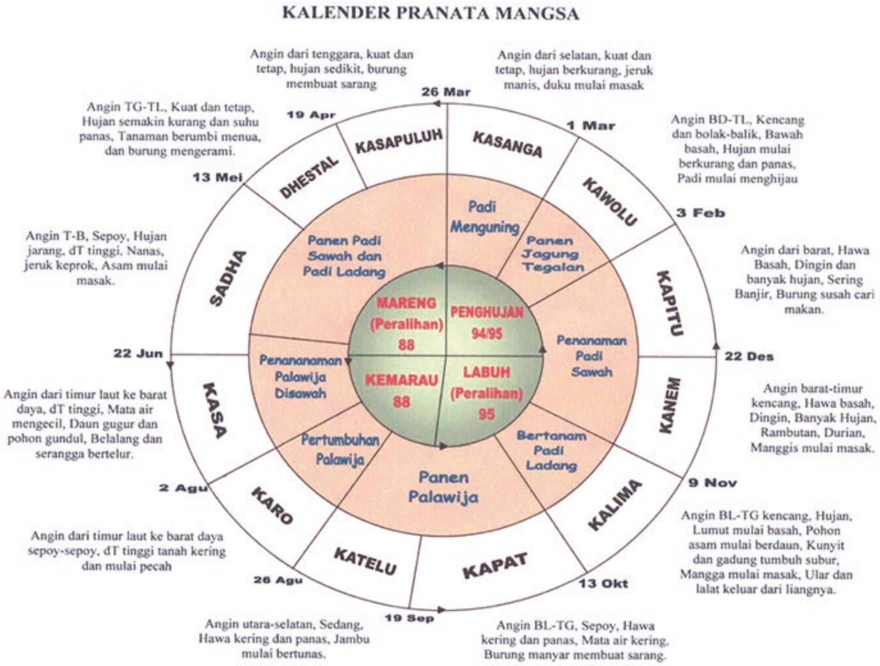

Fig. 24.44 The *Pranotomongso* (rice-growing) calendar of Java, Indonesia. The four central green sectors show each of the 'seasons' (anti-clockwise from the top: transition, dry, transition, and wet, and the duration, in days of each season). The eight pink sectors outline the sequence of planting, cultivating and harvesting the rice (anti-clockwise from the top: harvest lowland and upland rice; plant new seedlings in the rice fields; the plants grow; harvest the rice; plant new seedlings in the rice fields; tend the crops; harvest the corn; yellow rice). The twelve white sectors show the months of the year in the *Pranotomongso* calendar. The outer information describes the wind, temperature, rainfall and other characteristics of these periods of the year relative to rice cultivation, as summarized in Table 24.1 (after Kearifan lokal kalender tanam …, 2018).

24.9.2.5 The Spread of the Hindu and Islam Religions throughout Island SE Asia and Changing Astronomical Systems

Hindu religion spread throughout much of mainland and island Southeast Asia from about 1200 BP (see Fig. 24.46), and had a profound impact on Southeast Asian astronomical systems (as outlined in Section 24.6 above). It was associated with both the transmission of ideas *and* people, but the 'people' in this case only involved small groups—religious leaders and their supporters—not large-scale mass migrations spread over hundreds of years, as is thought to have occurred when the Austronesian and Austro-Asiatic populations settled island Southeast Asia.

The second major religion to spread throughout Southeast Asia was Islam, beginning about 800 years ago (see Fig. 24.47), but it was mainly associated with the

Table 24.1 Characteristics of the months of the year in the *Pranotomongso* calendar (after Kearifan lokal kalender tanam …, 2018).

Time Period	Month	Characteristics
22 June–1 August	First	Winds are from the northeast to the southwest. Temperatures are high. Springs dry up. Leaves fall and trees are bare. Grasshoppers and insects are seen.
2 August–25 August	Second	Winds are from the northeast to the southwest and are strong and continuous. Temperatures are high. The soil is dry and starting to break up.
26 August–18 September	Third	Winds are from the north to the south and are moderate. It is dry and hot. Guavas begin to ripen.
19 September–12 October	Fourth	Winds are from the northwest to the southeast and are continuous. It is dry and hot, and springs are dry. Weaver birds make their nests.
13 October–8 November	Fifth	Winds are always from the northwest to the southeast. It is raining and moss is growing. Turmeric and gadung thrive, and mangoes start to ripen. Snakes and flies appear.
9 November–21 December	Sixth	Winds are from the east to the west and are strong. It is wet and cold, with heavy rain. Rambutan and mangosteen start to ripen.
22 December–2 February	Seventh	Winds are from the west. It is wet and cold, with heavy rain. There is often flooding. Birds have difficulty finding food.
3 February–28/29 February	Eighth	Winds are always from the southwest to the northeast and are variable. It is wet and hot, but the rain starts to lessen. The rice starts to turn green.
1 March–25 March	Ninth	Winds are from the south, and are strong and regular. There is less rain. Oranges begin to ripen.
26 March–18 April	Tenth	Winds are from the southeast and are strong and steady. There is little rain. Birds make their nests.
19 April–12 May	Eleventh	Winds are from the southeast to the northeast and are strong and steady. There is even less rain and temperatures become hotter. Crops ripen. Birds lay their eggs.
13 May–21 June	Twelfth	Winds are from the east to the west and are continuous. Rain is rare, and temperatures are high. Pineapples, tangerines and tamarind begin to ripen.

transmission of ideas and belief systems, not wholesale migrations of people. While Hindu influences permeated many aspects of everyday life, Islam was reserved mainly for religious observances (see Section 24.7, above). In this context, sometimes in rural areas the traditional astronomical systems introduced originally by the Austro-Asiatics were allowed to continue without alteration, but at other times they were modified in order to accommodate Islamic concepts, or were abandoned entirely. Thus, when she did ethnoastronomical fieldwork on the island of Madura (off the north-east coast of Java) in 2015–2016, Siti Fatima found, particularly in the towns, that "… some people now prefer to respond to eclipses in a traditional Islamic way through *shalat* (prayers), even if they are aware of the traditional Madurese responses expected during eclipses." (Fatima et al., 2021: 583).

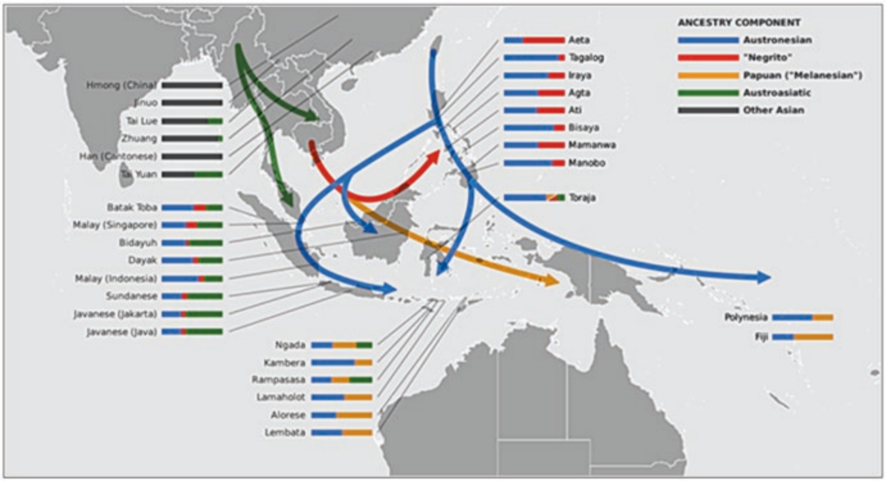

Fig. 24.45 Genetic evidence from island Southeast Asia that clearly identifies the presence of the Australo-Melanesian (orange and red), Austronesian (blue) and Austro-Asiatic (green) ancestral populations. Their genetic imprints are now preserved in the present-day populations of island Southeast Asia (after Lipson et al., 2014: Fig. 2).

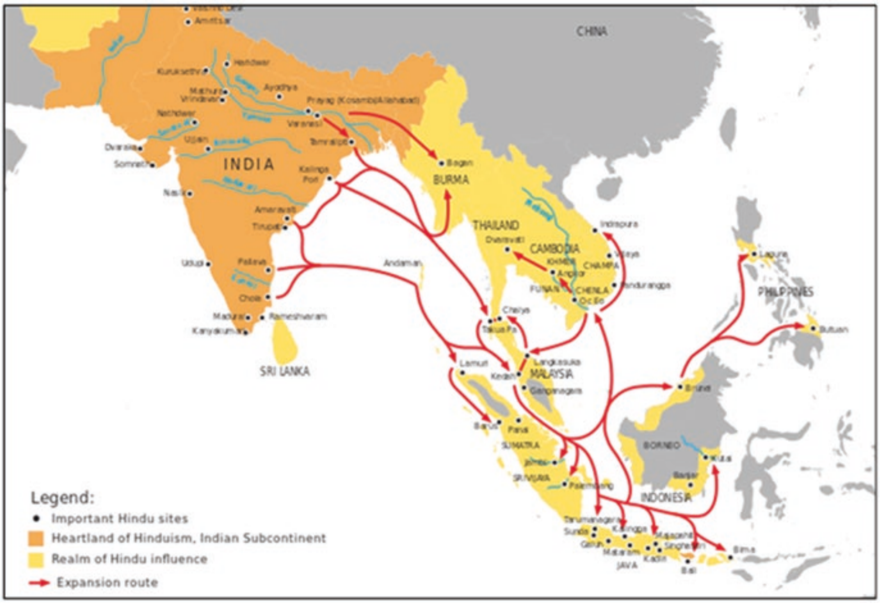

Fig. 24.46 A map showing the spread of the Hindu religion (sometimes in tandem with Buddhism) from the Indian Subcontinent throughout mainland and island Southeast Asia in the last 1,200 years (https://commons.wikimedia.org/wiki/File:Hinduism_Expansion_in_Asia.svg).

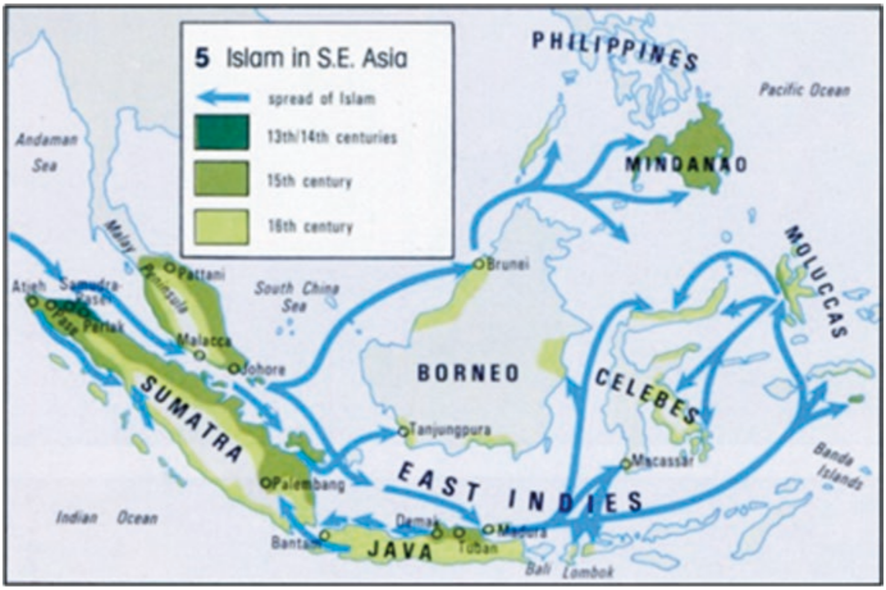

Fig. 24.47 A map snowing the spread of Islam into island Southeast Asia during the thirteenth to sixteenth centuries (xenohistorian.wordpress.com).

Table 24.2 Colonialism in Southeast Asia (adapted from Ty, n.d.).

Colonising Nation	Territory Occupied	Time Interval
Portugal	Throughout island SE Asia initially, until expelled by the Dutch in the seventeenth century, leaving only Timor as a Portuguese colony.	1511–1641/1975
Spain	The Philippines archipelago.	1565–1898
Netherlands	The Dutch East Indies (most of present-day Indonesia).	1605–1799; 1825–1940s
Great Britain	Burma (now Myanmar) until independence in 1948; Singapore; Malaya (now Malaysia) until independence in 1957.	1824–1957
France	Cochin China (now Laos, Cambodia and Vietnam) until independence in 1954.	1859–1954
United States of America	The Philippines archipelago, until independence in 1946.	1898–1946
Japan	Much of mainland and island Southeast Asia	WWII

24.9.2.6 The Spread of Western Colonialism throughout SE Asia

The Spanish had colonial ambitions in the Philippines archipelago and the Dutch in what is now Indonesia from the sixteenth century, in competition mainly with the British and the Portuguese, while the French tended to focus on mainland Southeast Asia (see Fig. 24.48). The United States of America came later (see Table 24.2). All of these colonising nations were inspired by commercial opportunities, international status and prestige, and also in the case of the Philippines the desire by Catholic priests to win religious converts (see Hall, 1981).

Apart from their involvement in eclipse expeditions to mainland and island Southeast Asia, as summarized above in Section 24.8, astronomical interests of the colonial nations were restricted mainly to the establishment of local time services,

Fig. 24.48 This colourful map shows the territories of the different colonial powers in Southeast Asia. Code: red, purple and blue were British (Burma = Myanmar; Malaya, Sarawak and British North Borneo = Malaysia, and Singapore); green (top-left) was French (Indochina = Cambodia, Laos and Vietnam); orange was Dutch (Dutch East Indies = Indonesia); yellow was Spanish up to 1989 and American thereafter (the Philippines—the only colony shown here that subsequently did not change its name); and dark green (bottom, right of centre) was Portuguese (Timor) (https://www.ehm.my/about/history-of-malaysia).

and the gathering and dissemination of meteorological data. Accurate knowledge of time was critical for commerce and communications, and in the nineteenth and early twentieth centuries was best portrayed by the presence of time balls and other devices used to indicate time at various ports and other locations throughout Southeast Asia. The geographical distribution of these is shown in Fig. 24.49, and is discussed in the chapter by Kinns (2021) elsewhere in this book.

The focus on meteorology also was understandable given the agricultural and horticultural concerns of the colonial nations, and the very real threats posed by droughts and cyclones (for the Philippines see García Herrera et al., 2007). Thus, for the most part the astronomical observatories that were set up were small-scale affairs (Williamson 2020)—sometimes nothing more than a transit telescope facility with an astronomical clock, connected to a time ball. That said, looks can be deceptive because even the very impressive-looking Central Indochina Observatory in Haiphong (northern Vietnam) shown in Fig. 24.50 (Lagrula, 1935; Pham and Le, 2021) only housed an extremely modest 12-cm (4.7-inch) refracting telescope. Meanwhile, Manila Observatory in the Philippines (Fig. 24.51) could boast a 48.3-cm (19-inch) refractor (Seitzer, 2020)—by far the largest in Southeast Asia at the

Fig. 24.49 The white stars show the locations of the time balls of mainland and island Southeast Asia (after Kinns, 2021). From north to south, they were at Haiphong, Rangoon, Manila, Hanoi, Singapore, Makassar, Jakarta and Surabaya (map: Wayne Orchiston).

Fig. 24.50 The Central Indochina Observatory, in Haiphong, which was established by the French in 1902 (photograph courtesy: Klaus Hülse Collection).

Fig. 24.51 A view of Manila Observatory. The 19-inch refractor with a lens by Merz (Germany) and mounting by Saegmuller (USA) was housed in the dome on the extreme left (courtesy: Manila Observatory Archives).

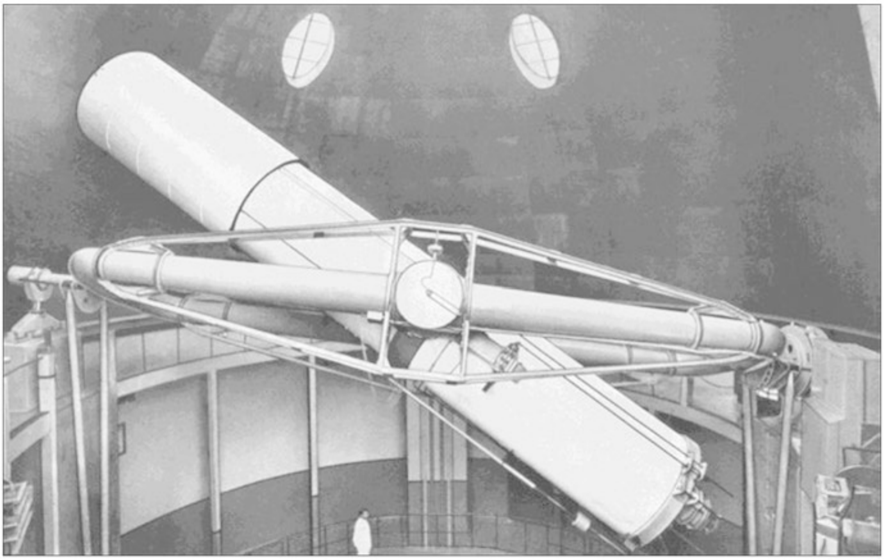

Fig. 24.52 The 60-cm Zeiss double refractor (after Voûte, 1933: Plate V).

time—but Manila's tropical weather meant that its research potential was limited. So the professional astronomical observatories of Southeast Asia were totally unlike those maintained during the nineteenth and early twentieth centuries in other Asian and Oceanic British colonies such as India and Australia, which also were actively engaged in astronomical (and later astrophysical) research (e.g. see Haynes et al., 1996; Kochhar and Orchiston, 2017; Orchiston, 2017: Chapter 3).

Another notable feature of Southeast Asia's professional astronomers was that they had little if any desire to impart astronomical knowledge to the indigenous populations, or address the perceived short-comings of local astronomical knowledge systems—unlike in India where Indian Assistants such as Madras Observatory's Ragoonatha Charry were very active in trying to raise the level of astronomical literacy among local ethnic groups (see Shylaja, 2012; Venkateswaran, 2019).

Nor did a vibrant amateur astronomy tradition—as observed in the British colonies of India (Kochhar and Orchiston, 2017), Australia (Orchiston, 2017 Chapter 4) and New Zealand (Orchiston, 2016)—ever emerge in mainland or island Southeast Asia during the nineteenth and early twentieth centuries, although in the Dutch East Indies there was a collaboration between the professional astronomer, J.G.E.G. Voûte (1879–1963) and the wealthy Dutch tea plantation owner and astronomy enthusiast, K.A.R. Bosscha (1865–1928) that led to the founding of Bosscha Observatory in 1923 (see Hidayat et al., 2017: 335–338; Voûte, 1933: 38). This was located at Lembang, in western Java, and the primary instrument was a 60-cm (24-inch) twin refractor by Zeiss (see Fig. 24.52).

Thus far our focus has been on professional European- and American-style astronomy and the associated astronomers, but we should not forget that many Jesuit missionaries were trained in mathematics and astronomy, and were experienced astronomical observers. As we noted in Section 24.8 Jesuit missionary/

astronomers introduced Western astronomy to Siam (present-day Thailand) during the seventeenth century, but their stay was short-lived (Orchiston et al., 2021a, 2021d). Early Jesuit astronomical observations also were made from what is now Vietnam (see Bonifácio and Malaquais, 2018), and evidence of such observations from the Philippines and Indonesia is now the subject of on-going studies, aided in the case of the Philippines by Blair and Robertson's (1903–1909) invaluable 55-volume work, *The Philippine Islands, 1493–1898*. This is based on archival records in Europe, and documents the history of the Jesuits in the archipelago (for the astronomical content see Dela Crux, 2020). Finally, nor should we forget that the aforementioned Manila Observatory was set up by the Jesuits in 1865 as part of their world-wide network of observatories (see Udias, 2003), only to be destroyed during World War II.

24.9.3 Two Conspicuous Southeast Examples of Multiplex Astronomy (YÔ and WO)

'Multiplex astronomy' was common throughout mainland and island Southeast Asia, where successive ethnic groups followed by religions superimposed their own astronomical imprints on the original astronomical systems first introduced by the Australo-Melanesians. In completing Section 24.9 we will present just two case studies that perfectly demonstrate 'multiplex astronomy'. Both are from mainland Southeast Asia.

24.9.3.1 The Cham Calendar of Vietnam

There was a Champa Kingdom in central and south Vietnam from the late second century CE through to 1832 (see Fig. 24.53), where they had an Indianized calendar that used the Śaka Era. There also are inscriptions using the Śaka Era that date from the sixth century, so we know that the Indianized calendar was used from quite an early date in Southeast Asia (see Sugimoto, 1956).

The Cham people in present-day Vietnam are said to be the descendants of the Champa Kingdom, and they have a rather interesting calendrical system (Nakamura, 1999, 2009; Yoshimoto, 2000, 2003, 2011) that has been intensively studied in recent years by Professor Trương Văn Món (see Sakaya, 2016). The Cham 'calendar' actually comprises two different calendars:

(1) The *'Ahier'* Calendar: This is an Indianized luni-solar calendar, but the 12-year Chinese cycle with animal names is also used.
(2) The *'Awal'* Calendar: This is an Islamic lunar calendar, which was introduced in the tenth century.

These two types of calendar are used by the Cham people in Vietnam. This is an interesting example of multiplex astronomy.

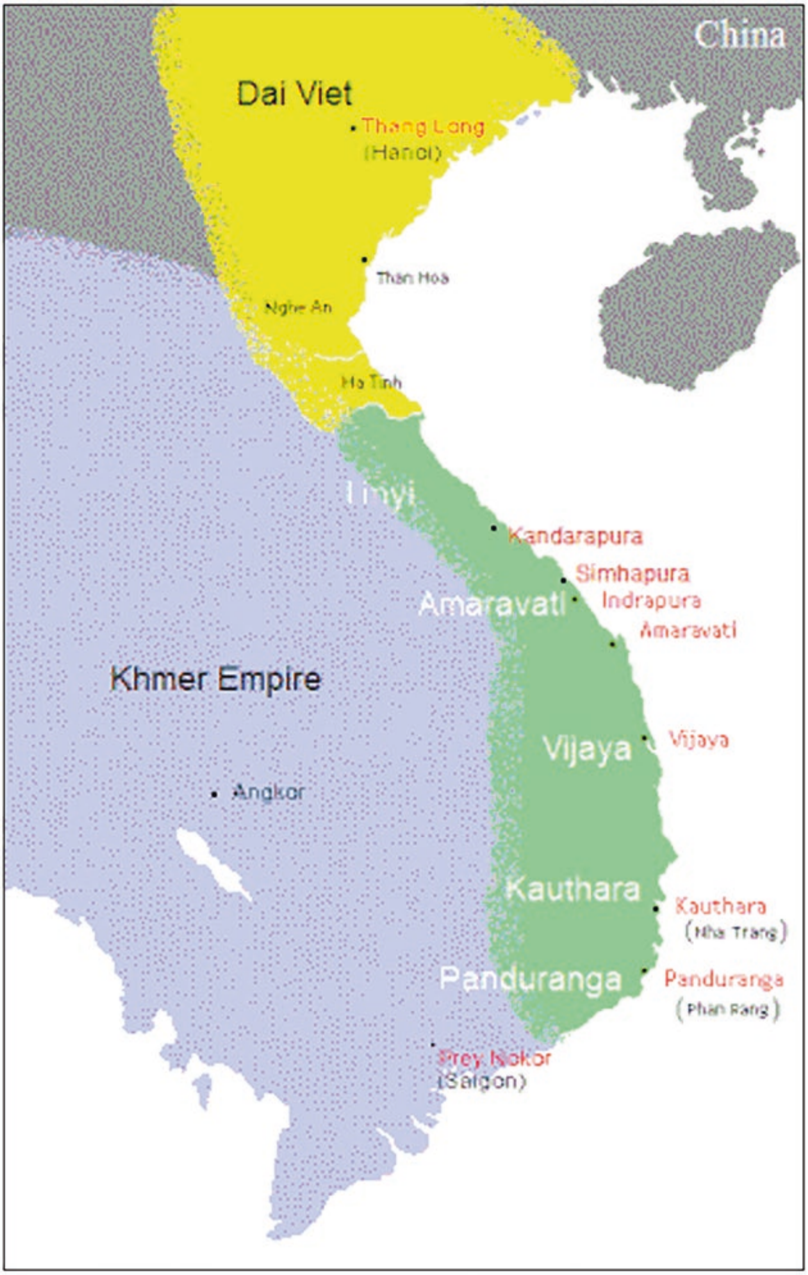

Fig. 24.53 A map showing the extent of the Champa Kingdom (green) between CE 1000 and 1100, and the main population or religious centres (in red) (https://en.wikipedia.org/wiki/Champa#/media/File:VietnamChampa1.gif).

24.9.3.2 The Traditional Thai Calendar

One year in the traditional Thai calendar is a sidereal year, that is, 365.25875 days. This is similar to a year of the Indian Ārdharātrica school, and is evidently of Indian origin. However, the Chinese 12-year cycle of animals is also used in the traditional Thai calendar. And, also, the use of serial numbers to denote lunar months may be of Chinese origin.

For intercalation, a kind of simplified method using the 19-year and possibly the 57-year (57 = 19 × 3) cycle is used. For the 19 years, 7 intercalary months are added. The 19-year cycle of intercalation is mentioned in the 'Souriat' of the Ayutthaya Dynasty (de la Loubère, 1693(II): 190) and was quite popular in ancient China, but was not popular in ancient India.

If the 57-year cycle is strictly used, 57 years are 705 months (705 = (19 × 12 + 7) × 3) and are 20,819 days (20819 = 6 × 57 × (29 + 30) + 7 × 3 × 30 + 11). Then, one year becomes 365.2456 days, and one lunar month becomes 29.530496 days. Here, one year is close to a tropical year.

This 57-year cycle is not found in Indian calendars or in official Chinese calendars. However, there was a modified *Taichu* (太初) calendar, which was not officially used, in the Eastern Han Dynasty (CE 25–220) of China, which has the same Southeast Asian 57-year intercalation. So, the first author of this chapter has hypothesised (Ôhashi, 2002, 2006a, 2011) that the Southeast Asian intercalation originated from the Chinese modified *Taichu* calendar (see Fig. 24.54 for the relationship between the length of a year and the length of a month. The line is horizontal when the 19-year cycle (or its multiple) of intercalation is used.

Eade (1995: 56) mentions that the 57-year cycle consists of 20,819 days, but it seems that the actual use of this cycle in Southeast Asia is uncertain. The cycle that is usually used in Southeast Asia is the 703-month cycle, which consists of 20,760 days (instead of 20,819 days of the 705-month cycle). Zhang and Chen (1981: 250–251) suggested the actual use of the 57-year cycle in the 'Xitan' calendar system of the Dai people in Yunnan Province, China. This topic needs to be researched further.

A similar calendar to the Thai calendar is in use in Myanmar, Laos and Cambodia, but in the actual calendars, some modifications have been made in different areas (including in Thailand) and in different ways. Gislén (2018) explains the difference between the Thai and Burmese calendars, and he suggests the possibility (Gislén, 2019) that the original Burmese calendar was influenced by the *Romaka-siddhānta* (one of the five astronomical systems described in the *Pañca-siddhāntikā*, an Indian Sanskrit text by Varāhamihira from the sixth century), and only later was the Hindu sidereal year adopted. This suggestion needs further investigation.

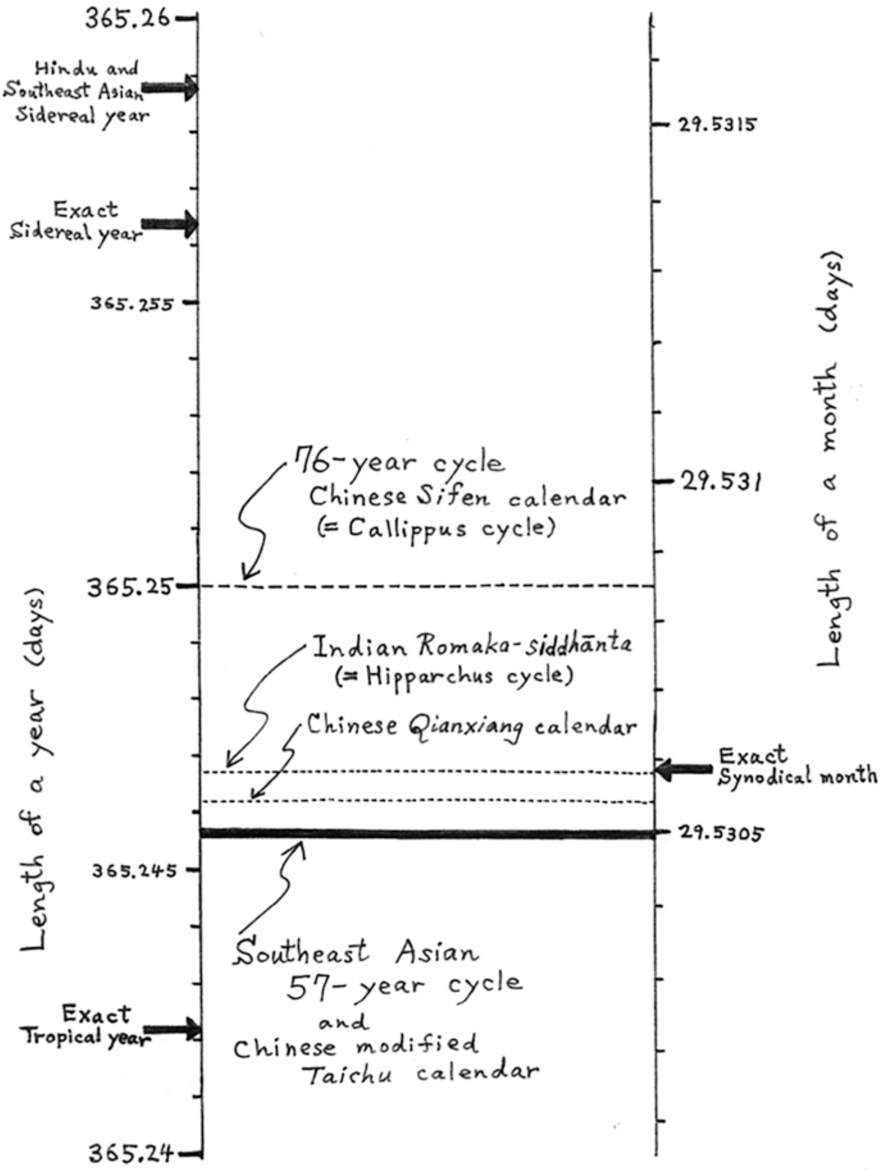

Fig. 24.54 The length of a year and a lunar-month when the 19-year cycle (or multiples of it) is used (diagram: Yukio Ôhashi).

24.10 Concluding Remarks (YÔ and WO)

Several different astronomical traditions are found in Southeast Asia that are regionally unique. For example, traditional Thai astronomy and some other Mainland Southeast Asian astronomical systems were created by combining local astronomical knowledge, Chinese influence and Indian influence, and they offer exciting research opportunities. Meanwhile, an even greater challenge lies in trying to identify the components of the various existing astronomical systems found throughout island Southeast Asia, given the complicated occupation history of this region and the key role that environmental change probably played. In this light, Southeast Asian astronomical history represents a unique field laboratory with a seemingly endless succession of challenging research projects for astronomical historians, ethnoastronomers, and especially graduate students.

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