The Role of Eclipses and European Observers in the Development of ‘Modern Astronomy’ in Thailand

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Abstract ‘Modern astronomy’ was introduced to Siam (present-day Thailand) (Siam officially changed its name to Thailand in 1939) when the Belgian Jesuit missionary-astronomer Father Antoine Thomas carried out stellar and lunar eclipse observations during 1681 and 1682 in order to determine the latitude and longitude of Ayutthaya. Three years later a contingent of French Jesuit missionary astronomers observed a total lunar eclipse from Lop Buri, which marked the start of an intensive two-and-a-half year period of observational activity at Lop Buri under the sponsorship of King Narai. During this interval, a partial solar eclipse and two further lunar eclipses were observed from a number of different observing sites. Although a substantial astronomical observatory was constructed in Lop Buri and this was used by French Jesuit missionary-astronomers, ‘modern astronomy’ ended suddenly in 1688 when King Narai died and most Western missionary-astronomers were expelled from Siam.

‘Modern astronomy’ only re-emerged in Siam after a hiatus of almost 200 years when another royal supporter of astronomy, King Rama IV, invited French astronomers to observe the total solar eclipse of 18 August 1868 from Siam, and his son, King Rama V, hosted British astronomers during the 6 April 1875 total solar eclipse.

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Thailand's romance with total solar eclipses continued during the 9 May 1929 solar eclipse when King Rama VII visited British and German astronomers based near Siam's southern border, and this was the catalyst required for the birth of home-grown 'modern astronomy'. Soon after, Siam's first astronomy classes began at Chulalongkorn University, and in 1944 this university hosted Siam's first professional astronomer when Rawee Bhavilai, a solar specialist, joined the Physics Department. The latest phase in the professionalisation of astronomy occurred in 2009 when the Government approval the formation of the National Astronomical Research Institute of Thailand (NARIT).

In this paper we trace the critical roles that solar and lunar eclipses played in the emergence and final adoption of 'modern astronomy' in Thailand from 1682 through to the present day.

1 Introduction

This paper deals with the development of modern astronomy in Siam (which is now known as Thailand). By 'modern astronomy' we refer to Western astronomy, as it was practised by trained astronomers in Europe during the seventeenth to twentieth centuries, and the emergence of solar physics and astrophysics in Thailand and other Asian nations in the eighteenth and nineteenth centuries (see Nakamura and Orchiston 2017).

An underlying theme throughout the past 400 years has been the key role that solar and lunar eclipses played in the birth and ultimate adoption of Western astronomy in Asian countries. Initially, eclipse observations were used to determine the longitudes of the observing sites. For example,

> In the 17th and partly also in the 18th century Hipparchos's old method for the determination of longitudes was renovated using the transits of craters on the edge of the shadow ... Though the accuracy of this method could not exceed more than some tenth of a minute of time, its utility was great in those times. For instance the eclipse of 1634 observed in Cairo, Aleppo and the western part of Europe, enabled the astronomers to shorten the Mediterranean Sea by 1000 km in respect to its assumed length before that time ... (Link 1969: 10)

Then, during the second half of the nineteenth century, solar eclipse observations led to major breakthroughs in solar physics, and especially our knowledge of the solar corona (e.g. see Clerke 1893; Meadows 1970; Nath 2013).

In this paper we review lunar and solar eclipses observed from Siam in 1682, 1685, 1686 and 1888, and Siamese observations of the total solar eclipses of 18 August 1868, 6 April 1875 and 9 May 1929. For each eclipse we describe the astronomers involved, their scientific instruments and their observations. We end this paper by briefly noting the development of professional astronomy at a Thai university in the 1930s, and the founding of the National Astronomical Research Institute of Thailand in the early years of the twenty-first century.

2 The Eclipses

2.1 Introduction

The appearance of 'modern astronomy' in Siam was made possible only because of the personal interest of King Narai. One of the most revered of Thailand's historic rulers, King Narai the Great (Fig. 1; see Orchiston et al. 2016) was born in 1633 and died prematurely in July 1688. Narai was the fourth king to rule during the Prasat Dynasty, which was the fourth of the five dynasties of the Ayutthaya Kingdom (see Table 1). He was just 23 years of age when he became the King of Ayutthaya, in 1656, and ruled until his death.

Fig. 1 King Narai. (en.wikipedia.org)

Table 1 Thai kingdoms and dynasties. King Narai ruled during the Prasat Dynasty

Kingdom	Duration (years AD)	Dynasty
Sukhothai	1238–1438	
Ayutthaya	1350–1767	Uthong
		Suphannaphum
		Sukhothai
		Prasat
		Ban Phlu Luang
Thonburi	1767–1782	
Rattanakosin/Thailand	1782–	

Two years before his death, King Narai was described by a visiting Westerner:

> [He is] . . . about 55 years old, handsome, lovely, dark, has good behaviour, and is brave. He is also intelligent, a good ruler . . . [and is] kind-hearted . . . (Chaumont 1686)

Unfortunately there are no other descriptions of King Narai and we cannot be sure that the likeness shown in Fig. 1 is realistic, as not long before the visit that prompted this portrait he 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 Ayuttaya'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 Fig. 2.

King Narai had an enlightened foreign policy. He believed that exposure to Eastern and Western civilizations was a good way of developing Siam, so during his reign he signed treaties with England, France, Holland and Persia, and he expanded trade with India, Indonesia, China and Japan. Soon Ayutthaya, the Siamese capital, gained a ". . . reputation as an 'emporium of the East' . . ." due to its role ". . . as a focus for the transshipment of goods between Europe/India and China/ Japan . . ." (Sternstein 1965: 108).

Fig. 2 A map showing Thailand localities mentioned in the text. (Map: Wayne Orchiston)

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 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. (Orchiston et al. 2016: 28)

One of King Narai's personal interests was astronomy. As a prince, he received a thorough Buddhist education from the monks, but he also was taught astrology and astronomy by lay teachers. Once he was king, Narai's contact with foreigners also contributed to his education, for as Hodges (1999: 36) has pointed out,

> 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 . . .

At this time there was a constant stream of Jesuits and other Europeans passing through Siam *en route* to China or returning to Europe (e.g. see Love 1999; Vande Walle and Golvers 2003), and through them King Narai continued to learn about astronomy, telescopes, other scientific instruments and the newly constructed Paris Observatory. Furthermore, instead of favouring gifts of cloth, spices and jewellery typically presented by visiting dignitaries, King Narai made it known that he also liked to receive telescopes, clocks and military equipment (Hodges 1999).

This was the scientific-cultural milieu in Siam when it gained its first exposure to 'modern' Western astronomy in 1681.

2.2 The Lunar Eclipse of 22 February 1682

In Table 2 we list the start, middle and end times of the total phase of the lunar eclipse in local time,[1] along with the positions of the Moon and Sun, as observed from Ayutthaya. As the table illustrates, this eclipse was visible in the morning just

[1]All of the times listed in Tables 2, 3, 5, 7 and 9 were calculated using Herald's OCCULT v3.6 and the NASA Catalog, which agreed to within 1 min in all instances. 'Local Time' was defined as UT + 7 h. The Jesuits in Siam in the seventeenth century used local apparent solar time for their eclipse timings. This means that for instance the times given in the table for the 1685 lunar eclipse, for comparison with the timings of the Jesuits should be corrected by −18 min to account for the time difference between the 7 h meridian (105° E) and the meridian of Lop Buri (100.65° E). Additionally, they should be corrected by +6 min by the equation of time to get apparent solar time. The start of the totality, 4:37, will then be corrected to 4:25 local apparent solar time and the time of the end of the totality, 6:21, will be corrected to 6:09, both of which are very close to the times actually reported by the Jesuits.

Table 2 Details of the lunar eclipse 22 February 1682

Totality	Local time	Moon		Sun	
		Altitude	Azimuth	Altitude	Azimuth
Start	05 h 25 m	+17°	267°	–19°	96°
Middle	06 h 13 m	+06°	279°	–07°	99°
End	07 h 01 m	–05°	282°	+05°	102°

Table 3 Details of the lunar eclipse of 11 December 1685

Totality	Local time	Moon		Sun	
		Altitude	Azimuth	Altitude	Azimuth
Start	04 h 37 m	+26°	288°	–27°	109°
Middle	05 h 29 m	+15°	290°	–15°	110°
End	06 h 21 m	+03°	293°	–04°	113°

before the beginning of astronomical twilight, and the Moon was low in the western sky. Sunrise occurred at 06 h 39 m local 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.

2.2.1 Father Antoine Thomas: The Observer of the Eclipse

The Jesuits were an order of Roman Catholics with particular interest in astronomy and mathematics (see Udias 2003) and during the sixteenth century the Spaniard Francis Xavier founded Jesuit missions throughout Asia. Thus, when King Narai assumed the throne in 1656 "... there were Jesuits as well as Dominicans [already] established in the Portuguese colony at Ayŭt'ĭa." (Hutchinson 1933: 6).

Despite this early Jesuit presence in Siam during King Naria's reign it was only in 1681 that the missionary-astronomer Father Antoine Thomas took up temporary residence in Ayutthaya, and as far as we have been able to ascertain he was the first to introduce Siam to Western astronomy (Orchiston et al. 2018a).

Antoine Thomas was born in Namur (Belgium) on 25 January 1644, and joined the Jesuit Order in 1660. While training for the priesthood he studied in various towns in Belgium and in France (Lefebvre, 1930), and by the time he was ordained, in 1678, he had developed an interest in mathematics and astronomy. Subsequently he studied mathematics in Portugal and published a short research paper (Thomas 1679) about a lunar eclipse that he observed.

Thomas planned to carry out missionary work in Japan, and while trying to arrange this he had to spend nearly a year in Siam. By good fortune, the 22 February 1682 lunar eclipse occurred during this sojourn.

2.2.2 Father Thomas' Observations of the Eclipse

Soon after he settled in the Portuguese sector of Ayutthaya Father Thomas carried out solar observations in order to determine the latitude of the city. These observations were made from "… the House of the Society of Jesus in the suburbs, to the south of Juthia [i.e. Ayutthaya]." (Thomas 1692; our English translation).

Father Thomas records (1692) that he observed the 22 February 1682 eclipse, but Bhumadhon (2000) suggests that his observations were made in collaboration with Father Gouye. However, Gouye's account (1692: 693) clearly documents that it was only Thomas who made the observations. As we suggested earlier,

> The confusion appears to have arisen because even though Gouye was tasked with publishing the astronomical observations of the Jesuit missionary-astronomers who were based in Siam, he also liked to add his own comments and corrections. However, Gouye's biography (see Thomas Gouye n.d.) clearly indicates that he spent his whole life in France and never visited Siam. (Orchiston et al. 2016: 42)

Unfortunately, we do not know from exactly where Father Thomas observed the eclipse. It would have been from the Jesuit church in the Portuguese district of Ayutthaya or from the veranda or courtyard of the Jesuit residence which was located near the church. The location of the Jesuit church is shown on several old maps of Ayutthaya, and one of these is reproduced here as Fig. 3.

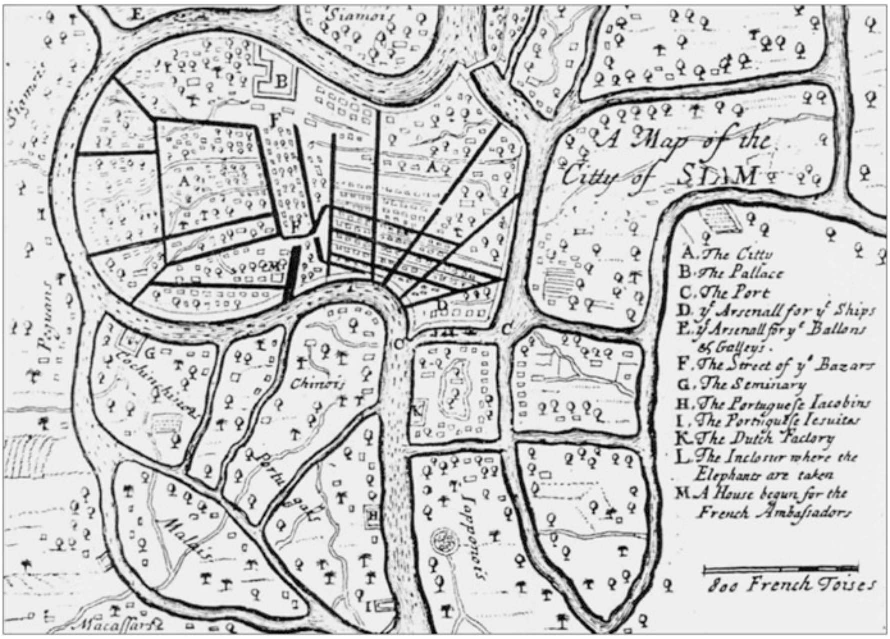

Fig. 3 A map of Ayutthaya in the 1680s showing the location of the Portuguese residential precinct (marked 'Portugals' to the south of the river on the left), and above the Malayan precinct. The Portuguese Jesuit church was on the western bank of the river close to the bottom of the map, and is marked by the 'I'. (After Loubère 1693)

Father Thomas (1692) makes no mention of having access to a telescope, so we can presume that he observed the eclipse with the naked eye, but to record the contact times we know that he used a simple pendulum clock (ibid.).

For further information about Father Antoine Thomas and his observation of the 1682 lunar eclipse see Orchiston et al. (2018a).

2.3 The Lunar Eclipse of 11 December 1685

In Table 3 we list the start, middle and end times of the total phase of this lunar eclipse in local time based upon modern calculations, along with the positions of the Moon and Sun, as observed from Lop Buri. As the table illustrates, the eclipse of 10–11 December 1685 was visible from Siam on the morning of 11 December, with the start of totality occurring before the beginning of astronomical twilight. At this time, the Moon was about 20° north of due west and was low in the sky. Astronomical twilight would have just begun when the eclipse reached the mid-totality phase, and there would have been a minor twilight glow on the horizon about 20° south of east.

2.3.1 The French Jesuit Contingent to Siam: Observers of the Eclipse

This eclipse was observed by a group of French Jesuit missionary-astronomers that had arrived in Siam on 24 September 1685 as part of a French diplomatic mission. This mission resulted from efforts by King Narai and his principal adviser Constantine Phaulkon (1647–1688; Sioris 1988) to build closer diplomatic relations between Siam and France. This initiative was seen as a counter to the growing economic presence of the Dutch in Siam (see Cruysse 2002; Hutchinson 1933), and fortuitously, at the time Louis XIV (1638–1715) was keen to establish a major trading facility in Siam (Love 1994a, b).

Leading the French mission was the diplomat Alexandre Chevalier de Chaumont (1640–1710; see Chaumont 1686), who was accompanied by the notorious transvestite François-Timoléone Choisy (1644–1724; see Choisy 1687), Father Bénigne Vachet (1641–1720) from la Société des Missions Étrangères de Paris (who had lived in Siam since 1671), and the six Jesuits listed in Table 4. These six missionary-astronomers had been

> . . . sent out by Louis XIV., under a royal patent, to carry out scientific work in the Indies and in China, in order, as the patent puts it, "to establish Security in Navigation and to improve Sciences and Arts." (Giblin 1909: 1)

Leading the missionary-astronomers was Father Jean de Fontaney, and with the exception of Guy Tachard,[2] they were bound for China but had to sojourn in Siam

[2]Guy Tachard (1651–1712) would stay behind and play a key political role in the development of scientific astronomy in Siam (see Orchiston et al. 2016, 2018b).

Table 4 Jesuit missionary-astronomers who came to Siam in 1685 with the French delegation

Name	Birth/death dates	Immediate destination after Siam
Jean de Fontaney	1643–1710	China (1688–1702)
Joachim Bouvet	1656–1730	China (1688–1697; 1699–1730)
Louis le Comte	1655–1728	China (1688–1691)
Jean-François Gerbillon	1654–1707	China (1688–1707
Guy Tachard	1648–1712	Remained in Siam
Claude de Visdelou	1656–1737	China (1688–1709); India (1709–1737)

Professor Michael Smithies (2003: 189), arguably the world's foremost authority on Siam of the 1680s, refers to these Jesuits as ". . . mathematicians [and] . . . astrologers . . ." Today there is a clear distinction between astrologers and astronomers, and we believe that Smithies was misled by the English translation of Tachard's tome, which reads: *Relation of the Voyage to Siam Performed by Six Jesuits sent by the French King, to the Indies and China, in the Year 1685, with their Astrological Observations, and their Remarks on Natural Philosophy, Geography, Hydrography, and History* (Tachard 1688). However, this is a serious mistranslation, because the original French volume refers specifically to '*Astronomical Observations*' and never mentions astrology

until the end of 1687. Consequently, they were able to observe the December 1685 lunar eclipse.

It is significant that before they left France,

> Tachard and the other five Jesuit astronomers were admitted to the Académie Royale des Sciences [in Paris], and supplied with astronomical instruments on the understanding that these would be used—among other things— to determine the latitude and longitude of different geographical features and population centres . . . [They also] were supplied with tables of Jovian satellite phenomena, courtesy of Paris Observatory, and various reference books and charts. (Orchiston et al. 2016: 31)

2.3.2 The Location of the Observing Site

The December 1685 lunar eclipse was observed from Lop Buri, not from Ayutthaya. Although Ayutthaya was the capital of Siam, King Narai developed Lop Buri as an attractive alternative capital (see Thavornthanasan, 1986), and he preferred to spend up to 9 months each year there. When members of the French delegation arrived in Lop Buri (or 'Louvo' as it was usually referred to)[3] they were extremely impressed, finding a ". . . town which is, so to speak, in the Kingdom of Siam what Versailles is in France." (Gervaise 1689).

Although he had a commodious palace in the centre of Lop Buri, King Narai also had a 'country retreat' in the form of a ". . . very roomy Palace . . . surrounded by brick walls fairly high." (Giblin 1904: 11), located at the water reservoir called 'Tale Chup-sawn' about 4 km east of Lop Buri (Giblin 1904: 22). This artificial lake was described by Father Tachard:

[3]In the 1680s Lop Buri was variously referred to as Louvo (Tachard 1686), Louveau (Gervaise 1689), Luvo (see Giblin 1904) and La-wo (ibid.) by the French.

> There is a large stretch of water which makes of it a peninsula [where King Narai's 'country retreat' was located], and on this water the King of Siam has built two frigates with six small pieces of cannon, on which this Prince takes pleasure in going about. Beyond this canal [lake] is a forest, 15–20 leagues in extent and full of Elephants, Rhinoceros, Tigers, Deer and Gazelles. (Giblin 1904: 12)

Figure 4 shows the location of the water reservoir and the 'country retreat' relative to King Narai's palace in Lop Buri and Wat San Paulo, the observatory that was later built for the Jesuit missionary-astronomers.[4]

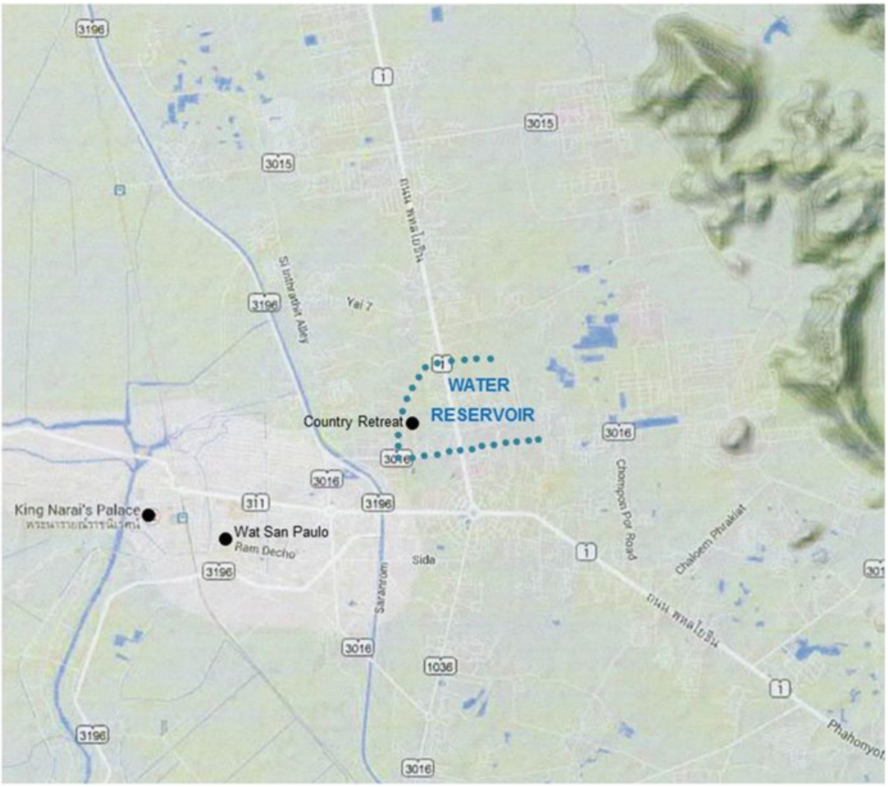

Fig. 4 A map of Lop Buri showing the location of King Narai's water reservoir and his 'country retreat' in relation to his palace and Wat San Paulo. The blue dots mark the position of the 12–13 feet high earth embankment that was erected to stop run-off from the mountains to the east, thereby forming the water reservoir. During his survey, Mr. Irwin noted that terracotta pipes had carried water from the south-western corner of the water reservoir to King Narai's palace. (Map modifications: Wayne Orchiston)

[4]Note that Fig. 4 is an updated version of Fig. 14 that was published in Orchiston et al. 2016: 39. In Fig. 4 the revised boundary of the water reservoir is now based on the cadastral map that was prepared by A.J. Irwin in the 1890s, but was unavailable when the 2016 paper was researched and written.

King Narai used his 'country retreat' palace when he went on hunting and

> . . . pleasure trips to the forests abounding with every variety of trees and to the wild mountain scenery abounding in birds and beasts, and [he] was enchanted with the romantic scenery of the region. (Smith 1880)

There is some confusion in the literature about the location where the French contingent made their observations (e.g. see Soonthornthum 2011), but a careful analysis quickly resolves this issue. When King Narai met the French astronomers in Lop Buri on 22 November 1985 he invited them to join him and observe the eclipse from his 'country retreat'.

2.3.3 Observations of the Eclipse

In preparing for the eclipse, Phaulkon and the Jesuit astronomers visited King Narai's 'country retreat' on 9 December and were impressed:

> A more convenient spot could not be selected. We saw the Heavens on all sides and we had all the space necessary for setting up our instruments. Having settled everything we returned to Louvo. (Tachard, 1686).[5]

On 10 December,

> . . . we had cause to be transported to the Tale-Poussonne our telescopes and a spring clock very trustworthy and regulated by the Sun . . . [so that we could] observe there the Eclipse, according to the orders of the King. (ibid.)

They set up their telescopes and the clock on a terrace beside the water reservoir, and after resting for 3–4 h they went to their observing site. They noted that by this time "It was then nearly three hours after midnight." (ibid.).

By good fortune the night was clear, and

> We prepared for the King a very long telescope of 5 feet [length] in a window of a saloon which opened on the corridor [terrace] in which we were. (ibid.)

It is interesting that although the presents that King Louis XIV gave King Narai included telescopes, the Jesuit astronomers chose to set up one of their own telescopes for King Narai to use. But—as we shall see—they selected the wrong telescope.

Once the eclipse had begun,

> . . . the King was informed and came at once to the window. We were seated on Persian mats, some with telescopes, others with the clock, others ready to write the time of the observation. We saluted His Majesty with a profound bow, after which the observations were begun. (Tachard 1686)

[5] This quotation and subsequent ones listed as 'Tachard (1686)' are actually taken directly from Giblin (1909) and are Giblin's English translations of the astronomical excerpts contained in Tachard's two-volume work *Voyage de Siam des Pères Jésuites Envoyés par le Roi aux Indes & à la Chine* (1686).

Subsequently, King Narai

> . . . wished to look through a telescope 12 feet long, which Father de Fontaney was using, and we immediately carried it to him. He allowed us to rise and stand up in his presence, and he was quite willing to look through the Telescope after we had done so, for it was necessary to put it in position to show it to him.
>
> Those who know the respectful attitude which Siamese Kings expect from those who may be in their presence have spoken to us of this favour as of something very unique. (ibid.)

Figure 5 is a drawing that was published later, and purportedly shows the Jesuit astronomers and King Narai observing the eclipse.[6] Elsewhere (Orchiston et al. 2016) we have shown that this drawing contains considerable artistic licence and should not be regarded as a realistic representation of the eclipse observations.

Be that as it may, King Narai apparently enjoyed observing the eclipse, and he

> . . . expressed a special satisfaction seeing all the spots [craters, etc.] of the Moon in the Telescope, and in seeing that the plan [map] which had been drawn of it at the Paris

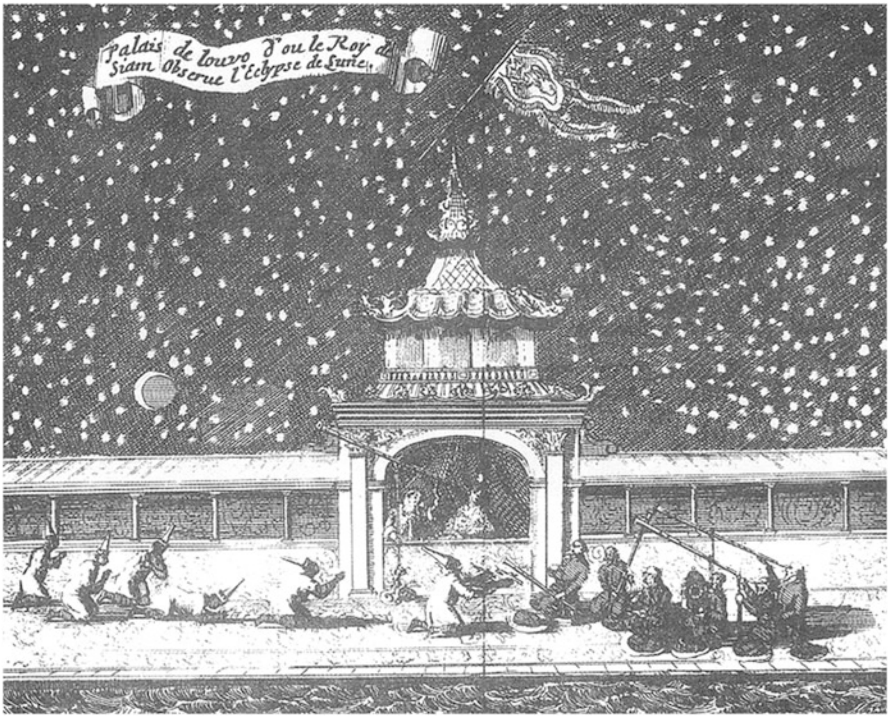

Fig. 5 A drawing showing King Narai and the Jesuit astronomers observing the 11 December 1685 total lunar eclipse from the King's country retreat which was on an island in the water reservoir that was located to the northeast of his palace in Lop Buri. (en.wikipedia.com)

[6]The prostrated individuals in this drawing are King Narai's court astrologers.

> Observatory agreed with it so well. He put several questions to us during the Eclipse. For example: Why the Moon appeared upside down in the Telescope? Why one could still see the part of the Moon which was eclipsed? What time was it at Paris? What could be the utility of such observations made at the same time at two places at such a distance apart? &c. (Tachard 1686)

The map of the Moon to which Tachard refers was prepared in 1678 and on 18 February 1679 was presented to the Academy of Sciences in Paris by Jean Dominique Cassini, the Director of Paris Observatory (Launay 2003).

After the eclipse, the French computed the longitude of Lop Buri as 121° 02′ E of the island of El Hierro. Meanwhile, the latitude of Lop Buri later was reported to be 14° 48′ 17″ N (Tachard 1689). The currently accepted value is 14° 48′ 00″ N, while Lop Buri is now known to be 118° 42′ E of the island of El Hierro.

For further information about the 1685 eclipse and the dynamic socio-political environment in which it was observed see Orchiston et al. (2016), while Gislén et al. (2018) provide a detailed examination of the contact timings for different lunar craters and other features.

2.4 The Lunar Eclipse of 30 November 1686

In Table 5 we list the start, middle and end times of the umbral phase of the partial lunar eclipse in local time, along with the positions of the Moon and Sun to the nearest degree, as observed from Lop Buri. As the table illustrates, this eclipse began in the morning not long before the beginning of astronomical twilight (the Sun was still 25° below the horizon), and the Moon was in the western sky. By mid-eclipse, when 51% of the Moon's diameter was in the Earth's shadow, civil twilight was about to begin; around this time, the sky would have been blue all over and normal daylight activities could have commenced, even though some of the brightest stars would still have been visible. As the twilight continued to increase in brightness, the Moon continued to move even lower in the western sky, setting at sunrise, which occurred at 06 h 27 m local time (before the eclipse had ended). In the period just before sunrise, the Moon would have been far less prominent due to its low altitude and the quite bright twilight.

Table 5 Details of the lunar eclipse of 30 November 1686

		Moon		Sun	
Umbral phase	Local time	Altitude	Azimuth	Altitude	Azimuth
Start	04 h 40 m	+24°	288°	−25°	107°
Middle	06 h 00 m	+06°	291°	−07°	111°
End	07 h 20 m	−11°	297°	+11°	116°

Table 6 Observers of the total lunar eclipse of 30 November 1686 and their instruments

Observing site	Observers	Instruments
Ayutthaya	Father Jean-François Gerbillon	Three telescopes with focal length of 2.5, 6 and 12 feet, respectively. A small pendulum clock.
	Mr. de Lamar (Royal Engineer of Siam)	
	Father Louis le Comte	
	Mr. Verét (Director of the French East India Company in Ayutthaya)	
	Father Claude de Visdelou	
Lop Buri	Father Joachim Bouvet	Two telescopes, one with a focal length of 5 feet. A small pendulum clock.
	Father Jean de Fontaney	
	Father John Baptist Malbonard	
	"Other priests"	

After Bhumadhon (2000: 47–49)

2.4.1 Observations of the Eclipse

It is interesting that not all of the Jesuit astronomers mentioned in Table 4 observed this eclipse, and that they were joined by others. Furthermore, the observations were carried from Ayutthaya *and* Lop Buri. Relevant information is summarised below in Table 6. Of the original contingent of six Jesuit missionary-astronomers only Guy Tachard missed this eclipse, but his absence is excusable for he was in France at the time (see Sect. 2.5.2, below).

According to the information assembled by Bhumadhon (2000), in Ayutthaya the eclipse was observed from the terrace and backyard of an unidentified house (presumably located in the Portuguese sector of the city), while in Lop Buri, Fathers Bouvet, de Fontaney and Malbonard assembled at the house of Louis Laneau (1637–1696), the Patriarch of Metellopolis and Head of the French Foreign Missions in Siam, along with other local priests. Father Malbonard was identified as the leader of the monks at Ayutthaya (Bhumadhon 2000). It is reported that King Narai planned to join Fathers Bouvet and Fontaney and observe the eclipse, but at the appointed time he was too busy to do so (ibid.).

A notable outcome of these eclipse observations was the discovery that Lop Buri was just 12 km east of Ayutthaya (ibid.).

The foregoing is merely an interim report on this eclipse. Records of the observations are housed at Paris Observatory, and have still to be studied in detail.

2.5 The Lunar Eclipse of 16 April 1688

In Table 7 we list the start, middle and end times of the umbral phase of the partial lunar eclipse in local time, along with the positions of the Moon and Sun to the

Table 7 Details of the lunar eclipse of 16 April 1688

		Moon		Sun	
Umbral phase	Local time	Altitude	Azimuth	Altitude	Azimuth
Start	00 h 11 m	+65°	177°	−65°	356°
Middle	01 h 37 m	+58°	220°	−58°	040°
End	03 h 04 m	+42°	241°	−42°	061°

nearest degree, as observed from Lop Buri. As the table illustrates, this eclipse was visible on the evening of 15–16 April in the few hours following midnight in a completely dark sky, ending long before the beginning of astronomical twilight. The event began with the Moon very high in the southern sky. By mid-eclipse, when 59% of the Moon's diameter was in the Earth's shadow, the Moon was still almost as high but in the south west, and at the end of the event it was somewhat farther west, but still almost half way between the horizon and the zenith.

2.5.1 Observers of the Eclipse

This lunar eclipse was observed by a new contingent of French Jesuit missionary-astronomers, whose presence in Siam can be traced back to the unbridled success of the total lunar eclipse of December 1685 and the observations carried out at King Narai's 'water reservoir' palace.

On 15 December 1685, just a few days after the eclipse, Chevalier de Chaumont set sail for France, accompanied by Father Tachard and a Siamese delegation led by Kosa Pan. King Narai was so impressed by the Jesuit observations of the recent eclipse that he sent King Louis XIV a letter inviting him to send a second contingent of Jesuit missionary-astronomers to Siam (see Orchiston et al. 2018b).

Father Tachard (1689) explains how this came about:

> . . . Phaulcon conversed with the King about obtaining 12 Jesuit Mathematicians, with the idea of building an observatory similar to those at Paris and at Peking. He explained to His Majesty the glory and utility which would accrue to him and the advantage which his subjects would draw from these from which they would learn the most beautiful Arts and finest Sciences of Europe. The King consented to this project, and it was decided that Tachard should return to France for the Jesuits. (Tachard 1689)

We can see that in next to no time Father Tachard ". . . had become an astronomical advisor to King Narai and Constantine Phaulkon and a scientific ambassador for King Narai . . ." (Orchiston et al. 2018b; cf. Giblin 1904), but Smithies (1994) and Cruysse (1992) both take a rather jaundiced view of Father Tachard's political acumen (see Orchiston et al. 2016: 31–32).

When he sailed for France in December 1685, Father Tachard carried not only the letter from King Narai to King Louis XIV but also a letter from Constantine Phaulkon to Father François de la Chaise (1624–1709), King Louis' personal confessor in Paris. In part, this letter reveals King Narai's plans to rapidly develop Western astronomy in Siam:

> The King my master having already ordered the Father Superior to select a site at Louvo [Lop Buri], and another at Ayutia, *to build* Churches, *Observatories* and Houses, which may seem to him proper, I undertake at the same time to give orders that all these will be ready to receive the Fathers on their arrival. *If the six Mathematicians (the Fathers and my Brothers), have been able to accomplish so much in two months what will not fifty or more do in the space of twenty years*. (Tachard 1689; our italics)

If nothing else, the above letter assumed that King Louis XIV would accede to King Narai's request for more Jesuit astronomers, and this is precisely what came to pass. Indeed, King Louis XIV was pleased with what the six French astronomers had been able to achieve in the short time they had been in Siam so he obliged by sending not 12, but 16, new Jesuit missionary-astronomers (Tachard 1689), and they are listed in Table 8.[7] They, Father Tachard and the new 'Envoy Extraordinary from Louis XIV to the King of Siam', Simon de la Loubère (1642–1729) arrived in Siam at the end of September 1687 and went straight to Ayutthaya.

But when the contingent of new missionary-astronomers visited Lop Buri they were not only welcomed by the original Jesuit contingent but also discovered Wat San Paulo,[8] one of the new observatories promised by Phaulkon (and mentioned in his letter to Father François de la Chaise). A contemporary drawing of this impressive astronomical facility is reproduced here in Fig. 6.[9]

The plan that the first contingent of French Jesuit missionary-astronomers, except Father Tachard, would go to China eventuated towards the end of 1687, and Wat San Paulo was left in the care of Father Tachard and the newly arrived astronomers. But all this changed in January 1688 when Father Tachard sailed once more for Europe, destined for Paris and the Vatican as King Narai's personal representative (Smithies and Bressan 2001). Father Tachard left Father le Royer in charge of the Observatory (Smithies 2003).

2.5.2 Observations of the Eclipse

King Narai observed the 16 April 1688 lunar eclipse from his palace in Lop Buri together with "... his Brahmin astrologer, and he even sent to the [Jesuit] Fathers a mandarin to ask them some questions." (Le Blanc 1692). Meanwhile, the Jesuits carried out their observations independently from Wat San Paulo (ibid.). As it turned

[7]Although Tachard (1689) states that sixteen Jesuit astronomers went to Siam in 1687, Udias (2003) could track down only fourteen when he researched this topic, and these are individuals listed in Table 6. Smithies (2003: 192) also refers to these astronomers as 'astrologers'.

[8]There is confusion over the correct spelling of Wat San Paulo, with both this (correct) version and 'Wat San Paolo' featuring at different times on different interpretive panels at the site itself! Even Soonthornthum (2011: 181) mistakenly uses Wat San Paolo.

[9]In fact, by this time only one observatory had been built (cf. Hodges, 1999). Moreover, part of the massive building shown in Fig. 6 was still under construction when Constantine Phaulkon and King Narai died in June and July 1688 respectively (Smithies 2003). Because of their passing, the planned Ayutthaya observatory was never built.

Table 8 Jesuit missionary-astronomers who embarked for Siam in 1687 with the second French mission

Name	Birth/death dates	Ultimate fate
Claude de Bèze	1657–1695	Returned to France
Jean Venant Bouchet	1655–1732	Went to Pondicherry, India, and carried out astronomy
Charles de la Breuille	1653–1693	Remained in Siam with Portuguese Jesuits in Ayutthaya; died in a shipwreck in 1693
Jean Colusson	????–1722	????
Patrice Comilh	1658–1721	Returned to France
Charles Dolu	1655–1740	Went to Pondicherry, India
Jacques Duchatz	1652–1693	Died in a shipwreck in 1693
Pierre d'Espagnac	1650–1689	Died en route from Bangkok to India in 1688
Marcel Le Blanc	1653–1693	Died in a shipwreck in 1693
Jean Richaud	1633–1693	Went to Pondicherry, India; carried out astronomy in India; died in a shipwreck in 1693
Louis Rochette	1646–1687	Died en route from France to Siam in 1687
Abraham le Royer	1646–1715	????
Pierre de Saint-Martin	???? –1689	Died en route from Bangkok to India in 1688
Francois Thionville	1650–1691	????

After Udias (2003: 54)

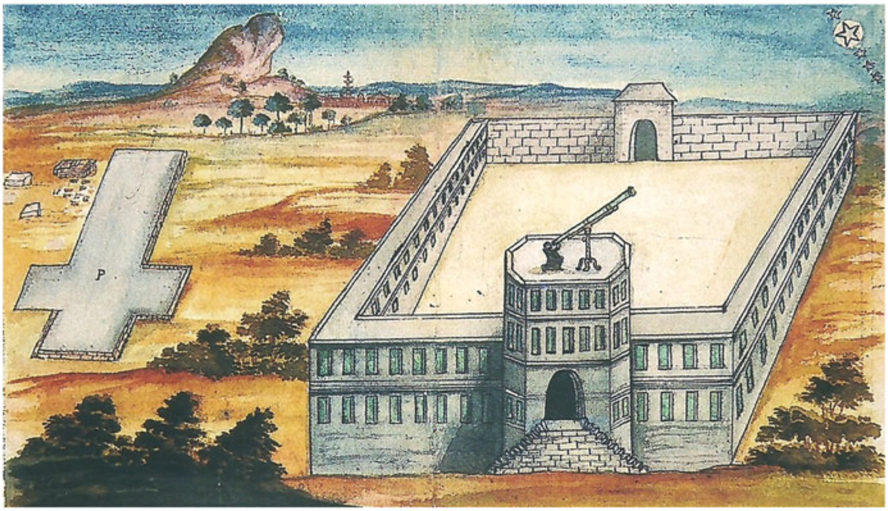

Fig. 6 A contemporary painting of Wat San Paulo, with its distinctive 4-storey observatory. (Wikimedia Commons)

out, this was destined to be the first and the last eclipse observed from Wat San Paulo by the Jesuit missionary-astronomers.

The records of this eclipse are preserved in Paris, and have yet to be studied in detail.

2.6 The Partial Solar Eclipse of 30 April 1688

The final seventeenth century eclipse observed from Siam by the second contingent of French missionary-astronomers was the 30 April 1688 solar eclipse. This occurred just 2 weeks after the 15–16 April lunar eclipse.

As Fig. 7 and Table 9 reveal, this was a partial solar eclipse as viewed from Siam, with the Sun in the eastern morning sky. At mid-eclipse, 73% of the Sun's diameter was covered by the Moon. The eclipse was total along a path beginning in India, passing to the north of Thailand, and ending in present-day Canada.

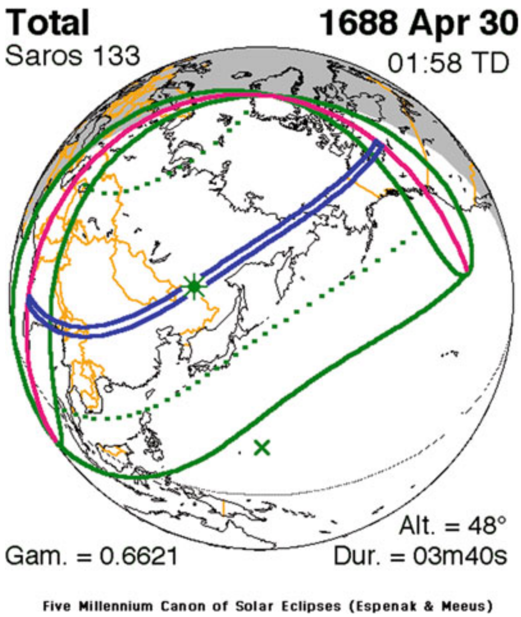

Fig. 7 A map showing the path of totality in blue of the solar eclipse of 30 April 1688. (After Espenak and Meeus 2006)

Table 9 Details of the 30 April 1688 partial solar eclipse

		Sun	
Phase	Local time	Altitude	Azimuth
Start	06 h 40 m	+10°	077°
Middle	07 h 35 m	+23°	080°
End	08 h 35 m	+37°	082°

2.6.1 Observations of the Eclipse

King Narai was ill at the time, but in a manuscript dating to 1688 Major de Beauchamp wrote that

> Mr Constance [Phaulkon] took advantage of this occasion to speak to him [King Narai] about an eclipse of the sun which was to occur in a few days; he asked if his health was strong enough to allow him to witness it, and [if so] the Jesuit Fathers would give him this pleasure. He replied he was, and he should bring them when the eclipse was to occur. *Mr Constance brought the Jesuit Fathers to the palace*; they set up their telescopes before the king who spent at most less than half an hour with them because the weather was not as good as one would have hoped. (cited by Smithies 2003:197; our italics)

Figure 8 is a contemporary painting of this event. This shows the Jesuit astronomers on the roof of one of the palace buildings, using eyepiece projection to view an image of the Sun on a piece of paper or card. Prostrated and surrounding the Jesuit astronomers are King Narai's Court astrologers, while the King is seen at the window on the right, being briefed, probably, by Father le Royer. Constantine Phaulkon is most likely the seated non-Jesuit, directly behind the telescope. Note that Fig. 8 includes a degree of artistic licence, for it shows only one astronomical telescope, not the 'telescopes' reported by Major de Beauchamp.

Fig. 8 A painting showing the observation of the partial solar eclipse of 30 April 1688 by French Jesuit missionary-astronomers from King Narai's palace in Lop Buri, in the company of the King and his prostrated Court astrologers. (en.wikipedia.org)

Further details of the Siamese observations of this eclipse are presented by Gislén et al. (2019).

To our knowledge, the solar eclipse April of 1688 was the last astronomical event that King Narai witnessed. His passion for Western astronomy, reliance on Constance Phaulkon, tolerance of Roman Catholicism and eagerness to foster closer ties between France and Siam created increasing disquiet among some members of the Royal Family, in the Siamese Court and amongst Buddhist monks. This culminated. in the staging of a *coup d'etat* by Phra Phetracha, King Narai's foster brother, and the King and his supporters were arrested. On 5 June 1688 Phaulkon, King Narai's son and other supporters were executed, and an ailing King Narai died soon after, on 11 July (Cruysse 2002; Smithies 2002). It has been suggested that it was poisoning that led to his lingering, and ultimately terminal, illness.

For 'Western astronomy' in Siam the result was disastrous:

> 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. 2018b)

After this, almost 200 years would pass before Western astronomy would return to Siam.

2.7 *The Total Solar Eclipse of 18 August 1868*

This is a famous eclipse in the annals of astronomy, and we would describe it as a 'watershed event'. Astronomical knowledge expanded enormously during the second half of the nineteenth century (Clerke 1903), when photography and spectroscopy were applied to astronomy (see Hearnshaw 2009; Hughes 2013). The solar corona finally was accepted as a tenuous outer atmosphere of the Sun rather than a mysterious terrestrial or lunar feature, and the basic chemical composition of the chromosphere, prominences and the corona were firmly established.

In fact it was the spectroscopic observations during the 18 August 1868 total solar eclipse that led to major breakthroughs (see Cottam and Orchiston 2015; Nath 2013). The path of totality is shown in Fig. 9, and the eclipse was observed from Aden, India (see Launay 2012; Nath 2014; Orchiston et al. 2017), Siam (Orchiston and Orchiston 2017), and the Dutch East Indies (present-day Indonesia; see Mumpuni et al. 2017), but

> … the most important observations—the ones that led to the aforementioned 'major breakthroughs'—came predominantly from India. (Kochhar and Orchiston 2017: 737–738)

What of the observations made from Siam?

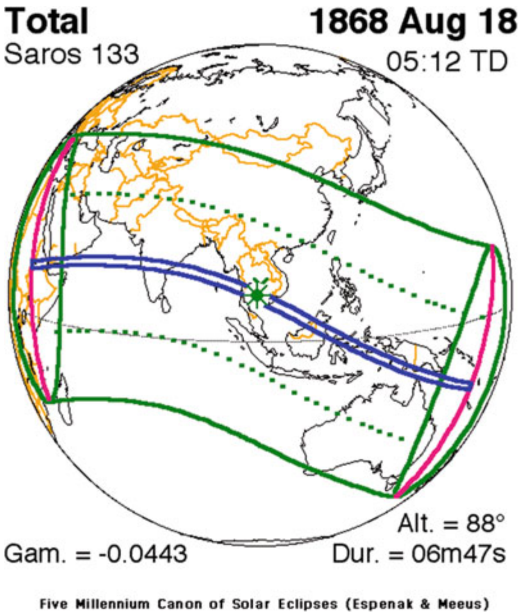

Fig. 9 A map showing the path of totality in blue of the solar eclipse of 18 August 1868. (After Espenak and Meeus 2006)

2.7.1 The French Expedition to Siam: Observers of the Eclipse

The 'Father of Thai Science', King Rama IV (1804–1868; Saibejra 2006) had a keen interest in astronomy (Aubin 2010), just like King Narai, and apart from organising his own observing expedition and attracting local political dignitaries such as Singapore's Sir Harry Ord (see Orchiston and Orchiston 2019), he also invited a team of French professional astronomers to visit Siam and observe the eclipse from Wah-koa on the west coast of the Gulf of Thailand (see Fig. 10).

Leading the French expedition was the Director of Marseilles Observatory Édouard Jean-Marie Stephan (1837–1923; Fig. 11a; Tobin 2014), who was assisted by two Paris Observatory astronomers, Georges-Antoine-Pons Rayet (1839–1906; Fig. 11b; Baum 2014) and François-Félix Tisserand (1845–1896; Fig. 11c; Débarbat 2014).

2.7.2 French Observations of the Eclipse

The French set up their observing camp on ancient sand dunes adjacent to the beach at Wah-Koa (Fig. 12), their principal instruments being 40-cm and 20-cm reflectors with silver-on-glass primary mirrors, a 15-cm refractor, a meridian telescope and an astronomical clock.

When the French expedition reached Wah-koa, Stephan

> . . . was heartened to find that Mr Hatt [a local hydrograpic engineer assisting the expedition] had been far from idle: before leaving Saigon he had arranged for prefabricated observatories

Fig. 10 A map showing Wah-Koa (the red bull's eye) and the path of totality of the 1868 eclipse across Siam. (Map modification: Wayne Orchiston)

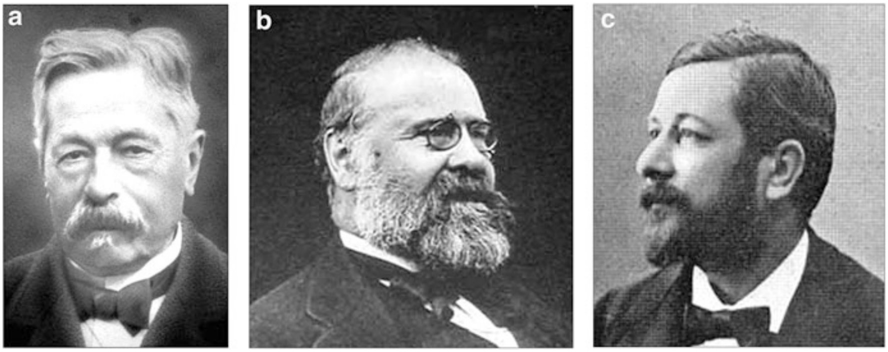

Fig. 11 (**a**) (left): Édouard Stephan. (en.wikipedia.org); (**b**) (centre): Georges Rayet. (adapted from *Astrophysical Journal*, 1907: facing page 53); (**c**) (right): Felix Tisserand. (After *Bulletin de la Société Astronomique de France* 1913)

to be built for the meridian telescope and the Cauche refractor, and these were now on site. Meanwhile, he also had arranged for the local people to build a very large bamboo house parallel to the beach. This was fully 80m in length, and was open towards the sea and flanked by two long galleries which were subdivided into numerous compartments.

A flat area to the south-west of the large bamboo building was reserved for the astronomical instruments, and their installation now became the main priority of the eclipse party. Mr Hatt

Fig. 12 A photograph by Rayet of the French eclipse camp, 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)

> had successfully erected a large granite column inside the 'meridian house', and the meridian telescope was attached to this, and the astronomical clock was installed on its own column in this same building. (Orchiston and Orchiston 2017: 305)

With totality lasting an exceptionally long 6 minutes and 57 seconds,[10] this eclipse promised exciting research opportunities, but the French team must have been disheartened on the morning of 18 August when the sky was completely covered by clouds and it was raining just a few miles north-east of their observing site. But 10 min before totality most of the clouds disappeared, and the astronomers were able to observe the eclipse.

The French had no photographic equipment at Wah-koa, so they relied on visual and spectroscopic observations, with particular interest in the form of the corona and the locations and nature of prominences. Stephan (1869: 25) concentrated on the prominences (he called them 'protuberances'), ". . . which appeared to me in the big telescope in marvellous clarity . . ." Three of Stephan's drawings showing prominences and the corona are reproduced here in Fig. 13.

Meanwhile, Rayet subjected the chromosphere and the most prominent prominence to spectroscopic scrutiny and recorded a number of emission lines. He tried to correlate these with known lines in the solar spectrum, but mistook one prominent line for the well-known D line of sodium. In fact, this marked a new element, first

[10]This was only 35 s shorter than the longest possible duration of totality of a total solar eclipse, which is 7 min 32 s.

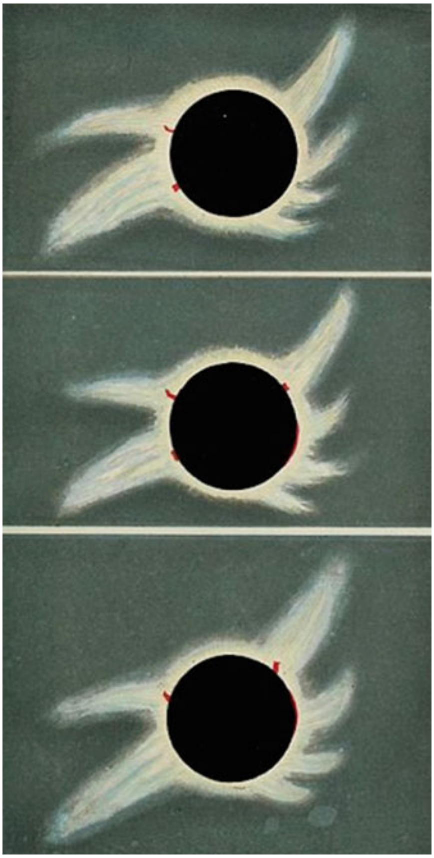

Fig. 13 Three drawings of the 18 August 1868 total solar eclipse by Édouard Stephan. (en.wikipedia.org)

mentioned by Madras Observatory Director Norman Robert Pogson (1829–1891; Snedegar 2014), which would later be named helium (after 'helios', the Greek God of the Sun). So Rayet

> . . . was not party to the discovery . . . Without doubt, this 'missed opportunity' arose from Rayet's familiarity with stellar rather than solar spectra. Had he made the connection, his name would now be much better known as the co-discoverer of helium rather than of Wolf-Rayet stars. (Orchiston and Orchiston 2017: 315)

Nonetheless, the French observations of this eclipse were a success, and

> . . . useful new data on the nature of the prominences were accumulated, even if the overall scientific outcomes paled into insignificance when measured against those published by Jules Janssen on the basis of his observations of this same eclipse made from India. (ibid.)

For further information about the French expedition to Siam in 1868 and their observations of the 18 August total solar eclipse see Orchiston and Orchiston (2017).

Meanwhile, observations of the eclipse by members of King Rama IV's expedition and Sir Harry Ord's party made little contribution to science and so are not discussed here. However, this eclipse was used very astutely by King Rama IV as a political weapon against the British and the French, both of whom had colonial aspirations involving Siam (see Aubin 2010; Orchiston and Orchiston 2019).

2.8 The Total Solar Eclipse of 6 April 1875

As Fig. 14 illustrates, the path of totality of the 6 April 1875 total solar eclipse passed through the Gulf of Thailand (not far north of where the 1868 eclipse was observed from). As well as offering a chance to build on the spectroscopic success of the 1868 eclipse and continue to explore the form of the corona, the 1875 event also invited astronomers to investigate the mysterious green coronal line, K 1471, that American astronomers had discovered during the 7 August 1869 total solar eclipse and named 'coronium' (see Maunder 1899).

2.8.1 The British Expedition to Siam: Observers of the Eclipse

King Rama IV had contracted malaria when he was at Wah-Koa observing the 1868 solar eclipse and he died soon afterwards, so in 1875 it was his son, King Rama V (1853–1910; also known as Chulalongkorn) who invited foreign astronomers to Siam to observe the eclipse, "Inspired by the memory of his father *and his [own] great interest in and knowledge of astronomy* . . ." (Hutawarakorn-Kramer and

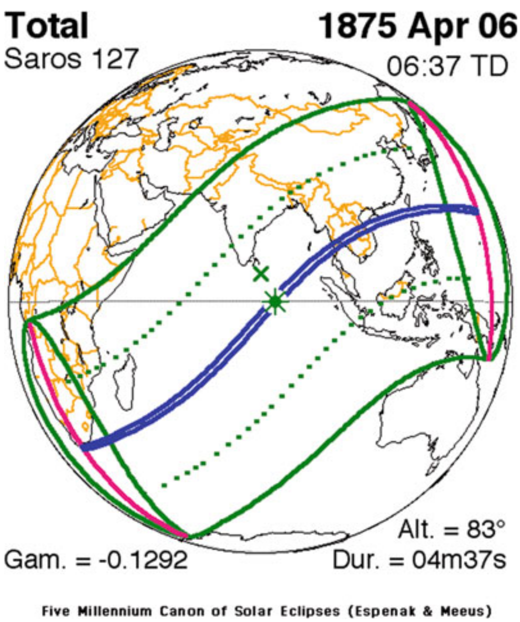

Fig. 14 A map showing the path of totality of the solar eclipse of 6 April 1875. (After Espenak and Meeus 2006)

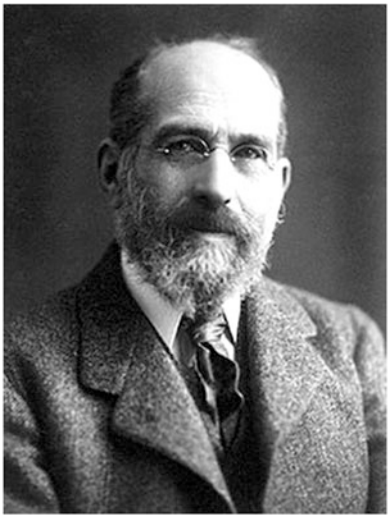

Fig. 15 Arthur Schuster. (en.wikipedia.org)

Kramer 2017: 319; our italics). But on this occasion he invited the British and the French, and both accepted. While the famous French astronomer Pierre Jules César Janssen (1824–1907; Launay 2012) accepted King Rama V's invitation, it was the British expedition that would make most impact (see Lockyer and Schuster 1878), and is discussed here.

The Royal Society decided to send an expedition to Siam, and leading it was the youthful Manchester University astronomer, Arthur Schuster (1852–1934; Fig. 15; Knill 2014) who was only 23 years of age at the time. As Hutawarakorn-Kramer and Kramer 2017: 320) point out, Schuster ". . . considered the task to lead the expedition a great challenge, the outcome of which would determine his future career."

2.8.2 British Observations of the Eclipse

After a 45-day sea voyage from England, the British party reached Siam just 8 days before the eclipse occurred. But when they arrived at their observing camp on sand dunes near the Chao Lai Peninsula (see Fig. 16) they found that the Siamese had already erected houses for them (e.g. see Fig. 17) and an observatory building. Each house contained a dining room, bedrooms, bathroom facilities and storage space for provisions, while

> The observatory consisted of two parts, separated by about 35 m. The smaller part was intended for a siderostat to obtain a spectrum of the prominences and the lower corona . . . The larger part of the observatory was bounded by a dark room on each side, with preparation of the photographic plates on one side and development of them on the other (Lockyer and Schuster 1878). The main part contained an equatorial telescope with a prismatic camera which was of shorter focal length than the camera attached to the siderostat . . . Another equatorial telescope, which was lent to the expedition, had a spectroscopic camera attached in order to also obtain spectra of the prominences and the corona. In

Fig. 16 A map showing the Chao Lai Peninsula eclipse site (the red bull's eye) and the path of totality of the 1875 eclipse across Siam. (Map modification: Wayne Orchiston)

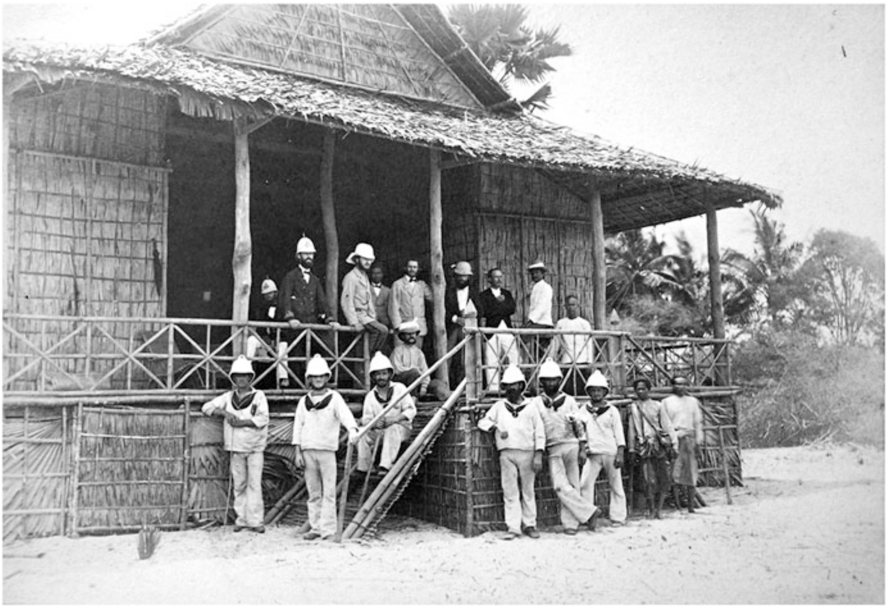

Fig. 17 One of the houses erected for the British expedition. (Courtesy: Royal Astronomical Society)

Fig. 18 The siderostat used during the expedition, with its protective cover removed. The associated telescope and spectroscopic camera were located in the adjacent hut. (Courtesy: Royal Astronomical Society)

> addition, a number of small cameras were available, the pictures from which were to be supplemented by sketches made during the eclipse. (Hutawarakorn-Kramer and Kramer 2017: 321)

As this quotation suggests, the main research focus of the expedition was to be the chemical composition of prominences and the corona, and the aforementioned siderostat is shown in Fig. 18.

Fortunately, clear skies greeted the astronomers on 6 April 1875, and totality commenced at 1130 h, but unfortunately,

> No useful results were obtained with the spectroscopic camera mounted on the equatorial telescope. Lockyer and Schuster (1878) later attributed this failure to the fact that the telescope used was not designed for this purpose. (Hutawarakorn-Kramer and Kramer 2017: 322)

However, spectroscopic studies made with the siderostat were a success, and Lockyer and Schuster (1878) summarized the key results, which included:

1. The upper corona was found to emit a 'homogeneous' photographic spectrum which was attributed to the "... hydrogen line near (Fraunhofer line) G."
2. The lower corona was found to emit a strong continuous spectrum extending into the UV up to a wavelength of 353 nm (i.e. "beyond N"), reaching to a height of about 3′ from the Sun.

3. Photographs showed that the extent of the corona rapidly increased with increasing exposure time, suggesting that the corona had no definite outline.

No mention was made of the ‘coronium’ line. Much later, Schuster (1932) noted that it was their observations of the 1875 eclipse that documented the existence of calcium in prominences and the chromosphere for the first time.

For further details of the British expedition see Hutawarakorn-Kramer and Kramer (2017) and Euarchukiati (2019).

Meanwhile, as with the 1868 eclipse, observations of the 1875 eclipse by members of the Royal expedition made no significant contributions to solar physics, so they are not discussed here.

2.9 The Total Solar Eclipse of 9 May 1929

The path of totality of this eclipse crossed Thailand, Malaysia, Indochina, Vietnam and the Philippines (Fig. 19), and attracted eclipse parties from England, France,

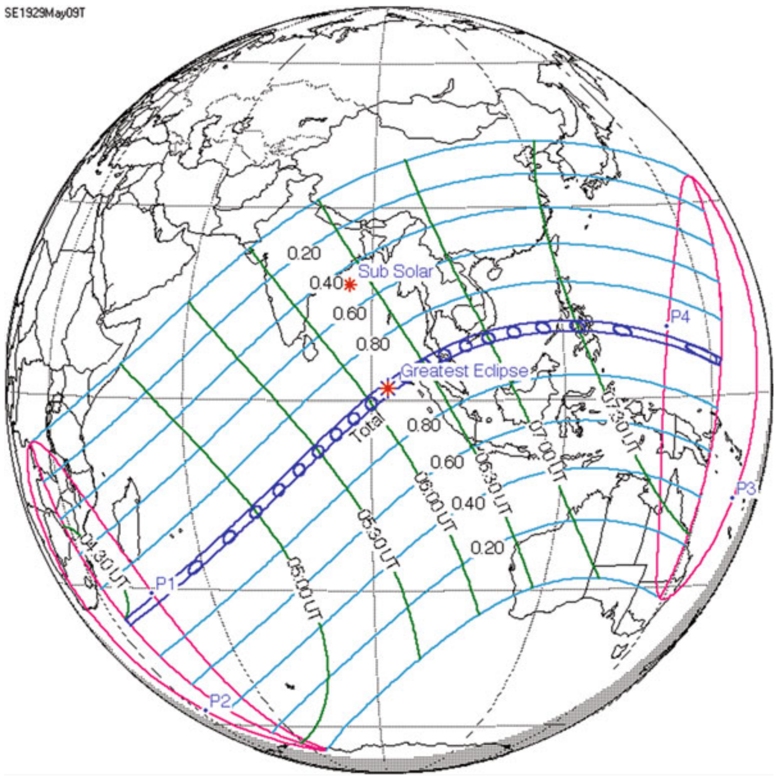

Fig. 19 A map showing the path of totality of the solar eclipse of 9 May 1929. (Courtesy: Eclipse Predictions by Fred Espenak, NASA’s GSFC http://eclipse.gsfc.nasa.gov/)

Table 10 Overseas expeditions and the 9 May 1929 total solar eclipse

Country	Expedition	Observing site
Siam	British	Pattani
	German	Pattani
Federated Malaya States	American	Alor Star
	British	Alor Star
	Japanese	
Dutch East Indies (Sumatra)	Dutch	Idi
	German	Takengong
	Japanese	
Indochina	French	Poulo Condore Island
Philippines	American (4)	
	German	Cebu Island

Germany, Holland, Japan and the USA (see Table 10). With totality lasting about 5 min, this eclipse offered not only an opportunity to investigate the chemical composition of the corona but also to again confirm Einstein's General Theory of Relativity.

In this paper we will discuss only the expeditions that went to Siam. There were two—from Britain and Germany—both there at the invitation of King Rama VII. The King was convinced that the 1929 eclipse observations would benefit science and at the same time "...create good relations between Siam and European countries." (Soonthornthum et al. 2019). So an Eclipse Committee was formed, and suitable facilities were prepared for the two eclipse expeditions.

2.9.1 The British Expedition to Siam: Observers of the Eclipse

Plans for the British expedition were initiated by the Astronomer Royal, Sir Frank Dyson (1868–1939) in 1926, and it was decided that Professor Frederick John Marrian Stratton (1881–1960; Fig. 20; Batten 2014) from Cambridge University and Philibert Jacques Melotte (1880–1961; Teare 2014) from the Royal Observatory, Greenwich, would go to Pattani in the very south of Siam, near the border with Malaya, while John Jackson from Greenwich and Dr. J.A. Carroll from the Solar Physics Observatory at Cambridge would proceed to nearby Alor Star in Malaya (see Fig. 21). Dr. Thomas Royds (1884–1955), Director of the Kodaikanal Observatory in India, also was invited to joined Stratton's party.

2.9.2 British Observations of the Eclipse

The scientific instruments taken to Pattani included two spectrographs, a 13-in f/10.4 astrograph, a coronagraph and a polariscope. The plan was to use these to explore the nature of the corona and photograph stars in the vicinity of the eclipsed Sun (for the

Fig. 20 Professor Stratton in Japan in 1936. (https://commons.wikimedia.org/wiki/File:F.J.M._Stratton_astrophysicist.png)

Fig. 21 A map showing the British Pattani (red bull's eye) and Alor Star (blue bull's eye) eclipse sites and the path of totality of the 1929 eclipse across Siam and Malaya. (Map modification: Wayne Orchiston)

'Einstein experiment'). Unfortunately, heavy clouds prevent any observations on the day of the eclipse—so from a scientific viewpoint, all the preparations and expense had been for naught.

2.9.3 The German Expedition to Siam: Observers of the Eclipse

Leading the German expedition was Professor Hans Oswald Rosenberg (1879–1940; Theis 2014) from the University of Kiel, assisted by Dr. D. Stobbe and W. Pape. Their observing camp was at Khok Pho, Pattani district, 34 km south-west of the British eclipse camp.

2.9.4 German Observations of the Eclipse

Stratton (1928: 200–201) reports that

> 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.

Accordingly, the Germans took four spectrographic cameras to Khok Pho, along with an astrograph.

The sky over Pattani was less than encouraging on 9 May. However, because the German and British observing camps were at different locations, the Germans were able to take a few photographs during totality, although these did not provide details of the solar corona (e.g. see Fig. 22).

2.9.5 King Rama VII and the 1929 Eclipse

It could be argued that Kings Rama IV and V were Siamese 'Sun Kings', in that they both had a personal interest in astronomy, organised their own eclipse expeditions, and observed both eclipses. However, King Rama VII's interest in eclipses was more political than scientific, so even had the skies been co-operative on 9 May 1929 he had no plan to carry out the same range of observations as his illustrious astronomical predecessors. Certainly he hoped to view the eclipse, but instead all he could do was visit the British and German astronomers on the day before the eclipse (e.g. see Fig. 23), and later commiserate with them.

Fig. 22 The Sun at totality taken with the astrograph at the German site at Khok Pho. (Courtesy: King Prajadhipok Museum)

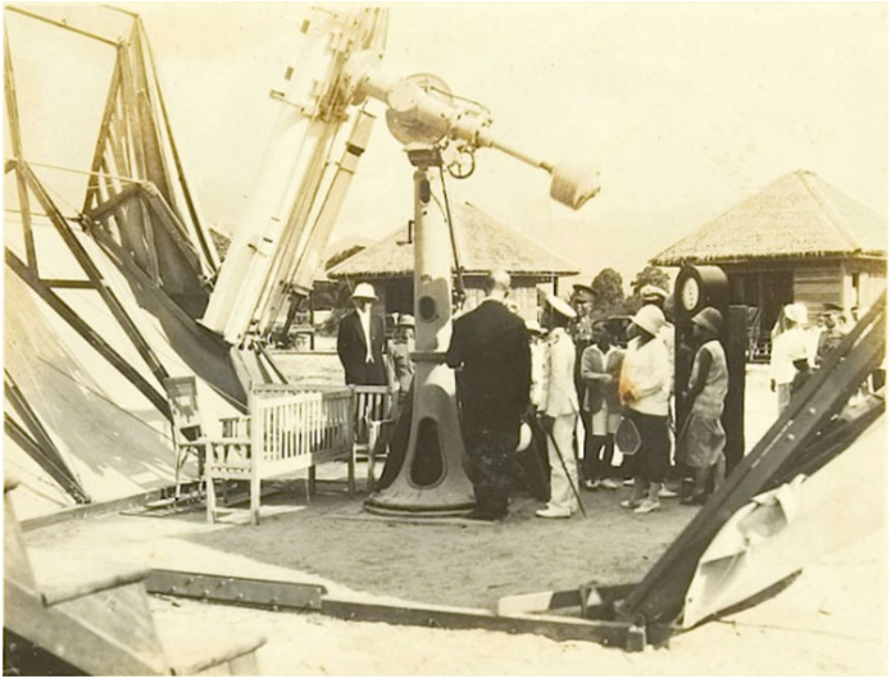

Fig. 23 King Rama VII and the Queen visiting the German eclipse camp on 8 May 1929 and inspecting the astrograph. (Courtesy: King Prajadhipok Museum)

3 The Emergence of Astronomy at Chulalongkorn University

The 1929 eclipse was the catalyst that led to the emergence academic astronomy in Siam, and

> . . . in 1930 astronomical research was established at Chulalongkorn University in Bangkok, the first university in Thailand (and named after King Rama V). (Soonthornthum 2017: 280–281)

Soonthornthum et al. (2019) also report that Colonel Phra Salvidhan Nides (Fig. 24), a prominent member of the Siamese committee that organised the construction of the British and German eclipse camps in 1929 and welcomed the European astronomers, taught astronomy courses at Chulalongkorn University for science and engineering students.

The University's interest in solar astronomy continued when Rawi Bhavilai (1925–2017; Fig. 25) joined the Physics Department in 1944. Bhavilai[11] would remain at Chulalongkorn University until his retirement in 1986, by which time he

[11]Other spellings of his name are Rawee Bhavilai and Rawī Phāwilai.

Fig. 24 Colonel Phra Salvidhan Nides, Siam's first university lecturer in astronomy. (Courtesy: Office of the National Research Council of Thailand)

Fig. 25 Professor Rawi Bhavilai, Siam's first solar physicist. (After Knowledge without bounds, 2008)

was a full Professor (Prominent astronomer . . . 2017). During his tenure he secured a Colombo Plan Scholarship and studied for an M.Sc. degree at the University of Adelaide (Knowledge without bounds 2008), graduating in 1952. Subsequently, he continued this love affair with Australian academia by studying for a Ph.D. in astronomy at the Australian National University in Canberra, while based at nearby Mount Stromlo Observatory. In 1965 he was awarded the doctorate for a thesis titled "The Structure and Dynamics of the Solar Chromosphere" (Rawi Bhavilai 2017).

Professor Bhavilai established a solar research group at Chulalongkorn University and not long before the publication of his book *The Fine Structure of the Solar Corona* (Bhavilai 1971) a 15-cm f/10 Zeiss solar chromospheric telescope was installed at the University. This instrument is described in the book.

This book was one of twenty-one books that Professor Bhavilai wrote or edited, but most were in the fields of literature and Buddhism. So although he is well known as an astronomer,

> His life's work . . . has seen him explore areas as diverse as philosophy, physics, Buddhism and poetry. (Knowledge without bounds 2008)

Professor Rawi Bhavilai was Thailand's first solar physicist, but by 1989 the Physics Department had expanded into astrophysics, and

> In October 1989 a 0.45-m reflecting telescope was donated to Chulalongkorn University by the Government of Japan under a cultural grant aid program for the promotion of astronomical education and research in Thailand. (Soonthornthum 2017: 281).

But Chulalongkorn University was not the first Thai university to embrace astrophysics, for this was pioneered in 1977 at Chiang Mai University in northern Thailand, when astronomy became part of the Faculty of Science curriculum (Soonthornthum 2017). Initially, research projects concentrated on stellar astronomy, and particularly photoelectric photometry. This led, ultimately, to the final phase in the development of professional astronomy and emergence of astrophysics in Thailand, with the establishment in 2009 of the National Astronomical Research Institute of Thailand (NARIT) in Chiang Mai; the founding Director, Boonrucksar Soonthornthum, had been an Associate Professor of Astronomy at the University.

4 The Founding and Development of NARIT

As Soonthornthum (2017: 284) has pointed out,

> The development of astronomical research in Thailand took a crucial leap forward when on 20 July 2004 the Government approved the "Establishment of the National Astronomical Research Institute of Thailand (NARIT)" under the Ministry of Science and Technology. On 1 January 2009 NARIT was approved by the Government and officially established with the status of a public organization responsible for policy-making and strategic planning in the development of astronomy in Thailand.

The growth of NARIT since 2009 has been phenomenal, with vibrant schools and public outreach programs,[12] and a Research and Development Division that carries out wide-ranging astrophysical research.

Some of the observations conducted in the course of this research have been made with the Thai National Telescope (TNT), a new 2.4-m Ritchey-Chrétien telescope (Fig. 26) that is located near the summit of Doi Inthanon, Thailand's highest mountain, not far from Chiang Mai (Fig. 27). Her Royal Highness Princess Maha Chakri Sirindhorn officially opened the TNT in January 2013 (just 4 years after NARIT was founded).

[12]For details of NARIT's education and outreach accomplishments see Soonthornthum (2017).

Fig. 26 Two views of the automated 2.4-m Ritchey-Chrétien Thai National Telescope. Left: undergoing testing prior to its installation at the TNO; right: installed and operational at the TNO. (Courtesy: NARIT)

Fig. 27 The Thai National Observatory (TNO) is located near the summit of Doi Inthanon, a 2-hour drive west-southwest of Chiang Mai. (travel.mthai.com)

Fig. 28 The 0.7-m PlaneWave LDK700 reflector being installed at the Sierra Remote Observatories, USA, in December 2015. Third from the left is Dr. Saran Pochyachinda, the current Director of NARIT. (Courtesy: NARIT)

In order to conduct research collaborations and 24-hour monitoring of target stars, NARIT has also established an international network of 60-cm to 1-m telescopes sited in Australia, Chile, China and the USA (see Fig. 28).

The latest (and current) phase in the development of NARIT's astrophysical instrumentation involves radio astronomy. At the time of writing this paper (2018) a stand-alone 40-m diameter radio telescope is under construction near Chiang Mai (see Fig. 29). The plan is

> . . . that eventually there will be three identical dishes in Thailand, in the north, east and south (to maximize base-lines), and that these will form a Thai VLBI Network, but also work closely with the existing VLBI networks in East Asia (China, Taiwan, South Korea and Japan) and in Australia-New Zealand. (Orchiston and Swarup 2018)

NARIT's astrophysical research is now conducted by a growing pool of tenured astronomers, post-doctoral fellows, research assistants and graduate students. Meanwhile, the Thai Government is promoting this strategy by providing funding so that students can study overseas and obtain Ph.D.s in astronomy. Most of these graduates return to Thailand and to posts at NARIT or at one of the many universities that now teach astronomy.

In order to promote astrophysical research and research collaborations at these universities, in July 2007 NARIT signed memorandums of understanding with 24 different universities in Thailand, while at an international level NARIT has

Fig. 29 NARIT's new 40-m radio telescope will be modeled on this dish at Yebes in Spain. (Courtesy: NARIT)

similar arrangements with various universities, observatories and research institutes in more than 15 countries (Soonthornthum 2017).

Meanwhile, NARIT has been very active promoting research among Southeast Asian nations, and following a meeting in 2007 formed SEAAN, the South East Asian Astronomical Network. The goals of this network are

> . . . to establish strong research collaborations, identify key science appropriate to the region, share instruments and develop and utilize human resources among South-East Asian countries. The network now has annual meetings in different cities throughout the region, and acts as a regional platform to bring the advancement in astronomy to each member country. Research collaborations have been organized or are planned in optical and radio astronomy, in the development of instrumentation, and in history of astronomy, not just within the SEAAN region, but also with institutes in Australia, China, India, Japan, Korea and Taiwan. (Soonthornthum 2017: 289)

One of the primary reasons for the amazing developments that have occurred lately in Thai astronomy is the strong support of King Bhumipol Adulyadej (Rama IX; 1927–2016; Fig. 30) and his second daughter, Princess Maha Chakri Sirindhorn (Fig. 31), both of whom have been passionate about astronomy. This follows a long-standing Royal tradition that began with King Narai, and had circumstances been different it is possible that the late King would have become a professional astronomer. Meanwhile Princess Sirindhorn is an avid 'eclipse-chaser', and also makes observations and carries out astrophotography with various NARIT telescopes (including the 2.4-m Thai National Telescope).

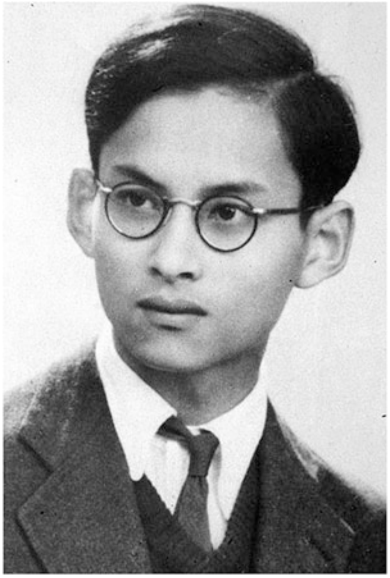

Fig. 30 King Bhumipol Adulyadej (Rama IX) as a young man. (Wikimedia. commons)

Fig. 31 Princess Maha Chakri Sirindhorn (right) examines a scale model of the new NARIT headquarters, now known as the Princess Sirindhorn AstroPark, part of which is still under construction in an outer north-eastern suburb of Chiang Mai. Third from the right is Professor Boonrucksar Soonthornthum who at the time was the Director of NARIT. The current Director, Dr. Saran Pochyachinda, is second from the right. (Courtesy: NARIT)

5 Concluding Remarks

It is well known that throughout history eclipses have filled mankind with dread or wonder. But they have also been party to the development of 'modern astronomy' in many nations and the foundations upon which astrophysics was built. This was no more so than in Siam, where over a period of almost two and a half centuries solar and lunar eclipses were seminal in the emergence of 'modern astronomy' and ultimately in the birth of solar physics and astrophysics.

Moreover, the second half of the nineteenth century was a critical time in the history of astronomy, when spectroscopic, photographic and polariscopic observations of a succession of total solar eclipses led to major breakthroughs in solar physics (Clerke 1893). Siam was able to make an important contribution in this regard, thanks to British and French observations of the 1868 and 1875 eclipses.

An underlying theme throughout this paper has been the significance of royal patronage in fostering European observations of eclipses, and especially total solar eclipses, made from Siam. This patronage was pivotal to the birth of 'modern astronomy' in Siam in the seventeenth century, and continued during the nineteenth and twentieth centuries, finally culminating in the formation of NARIT. France's 'Sun King' aside (see Débarbat 2015), it could be argued that there are few other countries in the world where royal patronage has played so key a role in the long-term development of astronomy, and especially in the emergence of astrophysics.

King Rama IV and King Rama V also used the 1868 and 1875 eclipses as educational vehicles to demonstrate the differences that existed between Western 'scientific astronomy' and Siamese 'traditional astrology', and it is notable that the Thai Royal Family continued this tradition during the twentieth century. Thus, King Bhumipol Adulyadej observed the total solar eclipse of 20 June 1955 and he and Princess Sirindhorn watched the 24 October 1995 eclipse. Both were visible from Thailand, and in 1955 "Radio Thailand station broadcasted a program about the solar eclipse nationwide for the first time in Thai history." (Nitiyanant 2015). By 1995,

> Many Thai people were interested [in astronomy and the eclipse and they] . . . travelled to provinces that the eclipse path passed through and many Thai television channels broadcast live views of the eclipse nationwide . . . (ibid.)

Finally, in this paper we have seen how eclipses, and particularly total solar eclipses, can have important political ramifications. Thus, some of Siam's kings used eclipses, in league with foreign policy, to not only foster international relations but also reinforce Siam's independence, as discussed, for example, by Aubin (2010) and Orchiston and Orchiston (2019) in the case of the 1868 eclipse.

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References

Astrophysical Journal, 25, facing 53 (1907).

Aubin, D., 2010. Eclipse politics in France and Thailand, 1868. In Aubin, D., Bigg, C., and Sibim, H.O. (eds.). *The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture*. Durham (North Carolina), Duke University Press. Pp. 86–117.

Batten, A.H., 2014. Stratton, Frederick, John Marrian. In Hockey et al., 2081–2083.

Baum, R., 2014. Rayet, Georges-Antoine-Pons. In Hockey et al., 1803–1804.

Bhavilai, R., 1971. *The Fine Structure of the Solar Corona*. Ft. Belvoir (Virginia), Defence Technical Information Center.

Bhumadhon, P., 2000. *Astronomical Archives from France Concerning the Kingdom of Siam during the Reign of King Narai*. Bangkok, Thai Astronomical Society (in Thai).

Bulletin de la Société Astronomique de France (1913).

Chaumont, Chevalier de, 1686. *Relation de l'Ambassade de Monsieur le Chevalier de Chaumont à la Cour du Roy de Siam, avec ce qui s'est Passé de plus Remarquable durant son Voyage*. Paris, Arnoult Seneuse et Daniel Horthemels.

Choisy, Abbé de, 1687. *Journal du Voyage de Siam fait en M.DC.LXXXV et M.DC.LXXXVI*. Paris, Sebastien Mabre-Cramoisy.

Clerke, A., 1893. *A Popular History of Astronomy during the Nineteenth Century*. London, Adam and Charles Black.

Clerke, A., 1903. *Problems in Astrophysics*. London, Adam and Charles Black.

Cottam, S., and Orchiston, W., 2015. *Eclipses, Transits and Comets of the Nineteenth Century: How America's Perception of the Sky Changed.* Cham (Switzerland), Springer.

Cruysse, D. van der, 1992. Aspects of Siamese-French relations during the seventeenth century. *Journal of the Siam Society*, 80, 63–69.

Cruysse, D. van der, 2002. *Siam and the West, 1500–1700*. Chiang Mai, Silkworm Books.

Débarbat, S., 2014. Tisserand, François-Félix. In Hockey et al., 2160.

Débarbat, S., 2015. A homage to Richard Stephenson: French observations of the Sun at the time of the 'Sun King'. In Orchiston, W., Green, D.A., and Strom, R. (eds.). *New Insights from Recent Studies in Historical Astronomy: Following in the Footsteps of F. Richard Stephenson. A Meeting to Honor F. Richard Stephenson on his 70th Birthday.* Cham, Springer. Pp. 53–60.

Espenak, F., and Meeus, J., 2006. *Five Millennium Canon of Solar Eclipses: −1999 to + 3000*. Greenbelt, NASA (Technical Publication TP-2006-214141).

Euarchukiati, V., 2019. The 1875 British solar eclipse expedition to Siam led by Sir Arthur Schuster. In Orchiston and Vahia.

Gervaise, N., 1689. *Histoire Naturelle et Politique de Royaume de Siam*. Paris, E. Ducastin.

Giblin, R.W., 1904. Lopburi past and present. *Journal of the Siam Society*, 5(3), 8–28.

Giblin, R.W., 1909. Early astronomical and magnetic observations in Siam. *Journal of the Siam Society*, 6(2), 1–15.

Gislén, L., Launay, F., Orchiston, W., Orchiston, D.L., Débarbat, S., Husson, M., George, M., and Soonthornthum, B., 2018. Cassini's 1679 map of the Moon and French Jesuit observations of the lunar eclipse of 11 December 1685. *Journal of Astronomical History and Heritage*, 21, in press.

Gislén, L., Orchiston, W., Orchiston, D.L., George, M., Soonthornthum, B., Débarbat, S., Husson, M., and Launay, F., 2019. Exploring the first scientific observations of a solar eclipse carried out in Siam. In Orchiston and Vahia.

Gouye, T., 1692. *Recueil des Observations Physiques et Mathématiques pour Servir à la Perfection de l'Astronomie et de la Géographie*, *Envoyées de Siam par les Jésuites Missionnaires*. Paris, Imprimerie Royale.

Hearnshaw, J., 2009. *The Analysis of Starlight: One Hundred and Fifty Years of Astronomical Spectroscopy*. Cambridge, Cambridge University Press.

Hockey, T., et al., (eds.), 2014. *Biographical Encyclopedia of Astronomers. Second Edition*. New York, Springer.

Hodges, I., 1999. Time in transition: King Narai and the Luang Prasoet Chronicle of Ayutthaya. *Journal of the Siam Society*, 87, 33–44.

Hughes, S., 2013. *Catchers of the Light: The Forgotten Lives of the Men and Women Who First Photographed the Heavens. Their True Tales of Adventure, Adversity & Triumph. Two Volumes*. Paphos, ArtDeCiel Publishing.

Hutawarakorn-Kramer, B., and Kramer, M., 2017. King Rama V and British observations of the 6 April 1875 total solar eclipse from the Chao Lai Peninsula, Siam. In Nakamura and Orchiston, 319–325.

Hutchinson, E.W., 1933. The French Foreign Mission in Siam during the XVIIth century. *Journal of the Siam Society*, 26, 1–71.

Knowledge without bounds. *Lumen* [The University of Adelaide Magazine], Winter issue 2008.

Knill, O., 2014. Schuster, Arthur. In Hockey et al., 1957–1959.

Kochhar, R., and Orchiston, W., 2017. The development of modern astronomy and emergence of astrophysics in India. In Nakamura and Orchiston, 705–770.

Launay, F., 2003. La tête de femme de la carte de la Lune de Cassini. *L'Astronomie*, 117, 10–19.

Launay, F., 2012. *The Astronomer Jules Janssen: Globetrotter of Celestial Physics*. New York, Springer.

Le Blanc, M., 1692. *Histoire de la Revolution du Roiuame de Siam Arrivée en l'Anée 1688. Deux Tomes*. Paris, Horace Molin.

Lefebvre, B., 1930. *Antoine Thomas de Namur: Missionnaire et Astronome (1644–1709)*. Bruxelles, Établissements Émile Bruylant.

Link, F., 1969. *Eclipse Phenomena in Astronomy*. New York, Springer.

Lockyer, J.N., and Schuster, A., 1878. Report on the total solar eclipse of April 6, 1875. *Philosophical Transactions of the Royal Society of London*, 169, 139–154.

Loubère, S., de la, 1693. *A New Historical Relation of the Kingdom of Siam*. London, T. Horne.

Love, R.S., 1994a. The making of an Oriental despot: Louis XIV and the Siamese embassy of 1686. *Journal of the Siam Society*, 82, 57–78.

Love, R.S., 1994b. Simon de la Loubere: French views of Siam in the 1680s. *Journal of the Siam Society*, 82, 155–164.

Love, R.S., 1999. Monarchs, merchants, and missionaries in early modern Asia: the missions Étrangères in Siam, 1662–1684. *The International History Review*, 21, 1–27.

Maunder, E.W. (ed.), 1899. *The Indian Eclipse 1898. Report of the Expeditions Organized by the British Astronomical Association to Observe the Total Solar Eclipse of 1898, January 22*. London, Hazell, Watson and Viney.

Mumpuni, E.S., Orchiston, W., and Steinicke, W., 2017. J.A.C. Oudemans' observations of the 18 August 1868 and 12 December 1871 total solar eclipses from the Dutch East Indies. In Nakamura and Orchiston, 357–373.

Nakamura, T., and Orchiston, W. (eds.), 2017. *The Emergence of Astrophysics in Asia: Opening a New Window on the Universe*. Springer International Publishing.

Nath, B.B., 2013. *The Story of Helium and the Birth of Astrophysics*. New York, Springer.

Nitiyanant, P., 2015. Solar Eclipses in Siam (Thailand). Chiang Mai, National Astronomical Research Institute of Thailand (www.narit.or.th/en/index.php/public-outreach/articles-for-public/357-solar-eclipses-in-siam-thailand).

Orchiston, W., and Orchiston, D.L., 2017. King Rama IV and French observations of the 18 August 1868 total solar eclipse from Wah-koa, Siam. In Nakamura and Orchiston, 291–317.

Orchiston, W., and Orchiston, D.L., 2019. King Rama IV, Sir Harry Ord and the total solar eclipse of 18 August 1868: power, politics and astronomy. In Orchiston and Vahia.

Orchiston, W., and Swarup, G., 2018. The emergence of radio astronomy in Asia: opening a new window on the Universe. In Vahia, M., Orchiston, W., and Sule, A. (eds.). *Growth and Development of Astronomy and Astrophysics in India and the Asia-Pacific Region. Proceedings of the 9th International Conference on Oriental Astronomy*. Mumbai, Tata Institute of Fundamental Research. Pp. 179–204.

Orchiston, W., and Vahia, M. (eds.), 2019. *Exploring the History of Southeast Asian Astronomy: A Review of Present Projects, and Future Prospects and Possibilities*. Cham (Switzerland), Springer International Publishing.

Orchiston, W., Lee, E.-H., and Ahn, Y.-S., 2017. British observations of the 18 August 1868 total solar eclipse from Guntoor, India. In Nakamura and Orchiston, 771–793.

Orchiston, W., Orchiston, D.L., George, M., and Soonthornthum, B., 2016. Exploring the first scientific observations of lunar eclipses made in Siam. *Journal of Astronomical History and Heritage*, 19, 25–45.

Orchiston, W., Orchiston, D.L., George, M., Soonthornthum, B., and Komonjinda, S., 2018b. Seventeenth century Jesuit astronomical activities in Siam. In Shi, Y.-L. (ed.). *Astronomical Heritages in Asia-Pacific Areas: Proceedings of the Eighth International Conference on Oriental Astronomy*. Hefei, University of Science and Technology of China.

Orchiston, W., Orchiston, D.L., George, M., Gislén, L., Débarbat, S., Husson, M., Launay, F., and Soon-Thornthum, B., 2018a. Father Antoine Thomas and the birth of 'modern astronomy' in Thailand. *Journal of Astronomical History and Heritage*, 21, in press.

Prominent astronomer Prof Rawi Dies. *Bangkok Post*, 17 March 2017.

Rawi Bhavilai. Australian National University web site: https://rsaa.anu.edu.au/people/alumni/rawi-bhavilai (2017).

Schuster, A., 1932. *Biographical Fragments*. London, Macmillan.

Sioris, G.A., 1988. *Phaulkon – The Greek First Counsellor of the Court of Siam: An Appraisal*. Bangkok, Siam Society.

Smith, S.J., 1880. *History of Siam in the Reign of Phra Narai 1657–1682*. Bangkok, S.J. Smith's Office.

Smithies, M., 1994. Saint Tachard: a rejoinder to Vongsuravatana. *Journal of the Siam Society*, 82, 175–178.

Smithies, M., 2002. *Three Military Accounts of the 1688 "Revolution" in Siam*. Bangkok, Orchid Press.

Smithies, M., 2003. Eclipses in Siam, 1685 and 1688, and their representation. *Journal of the Siam Society*, 91, 189–204.

Smithies, M., and Bressan, L., 2001. *Siam and the Vatican in the Seventeenth Century*. Bangkok, River Books.

Snedegar, K., 2014. Pogson, Norman Robert. In Hockey et al., 1739–1741.

Soonthornthum, B., 2011. The emergence of astronomy in Thailand. In Nakamura, T., Orchiston, W., Sôma, M., and Strom, R. (eds.). *Mapping the Oriental Sky. Proceedings of the Seventh International Conference on Oriental Astronomy*. Tokyo, National Astronomical Observatory of Japan. Pp. 179–186.

Soonthornthum, B., 2017. The development of astronomy and emergence of astrophysics in Thailand. In Nakamura and Orchiston, 271–290.

Soonthornthum, B., Euarchukiati, V., and Orchiston, W., 2019. The total solar eclipse of 9 May 1929: the British and German expeditions to Siam. In Orchiston and Vahia.

Sternstein, L., 1965. 'Krung Kao': the old capital of Ayutthaya. *Journal of the Siam Society*, 53, 82–121.

Stratton, F.J.M., 1928. The solar eclipse of May 9, 1929. *Journal des Observateurs*, 11, 199–201.

Tachard, G., 1686. *Voyage de Siam des Pères Jésuites Envoyés par le Roi aux Indes & à la Chine*. Paris, Seneuze et Horthemels.

Tachard, G., 1688. *Relation of the Voyage to Siam Performed by Six Jesuits sent by the French King*, *to the Indies and China*, *in the Year 1685*, *with their Astrological Observations*, *and their Remarks on Natural Philosophy*, *Geography*, *Hydrography*, *and History*. London, J. Robinson and A. Churchil.

Tachard, G., 1689. *Second Voyage du Père Tachard et des Jésuites Envoyez par le Roy au Royaume de Siam: Contenant Diverses Remarques d'Histoire*, *de Physique*, *de Geographie*, *& d'Astronomie.* Paris, Horthemels.

Teare, S.W., 2014. Melotte, Philibert Jacques. In Hockey et al., 1454–1455.

Thavornthanasan, T., 1986. The role of Lopburi during the reign of King Narai (1656–1688). In Renard, R.D. (ed.). *Anuson Walter Vella*. Honolulu, University of Hawaii. Pp. 134–155.

Theis, C., 2014. Rosenberg, Hans. In Hockey et al., 1861–1862.

Thomas, A., 1679. Observations de l'éclipse de lune du 29 Octobre 1678 à Coimbre. *Journal des Sçavans*, 56.

Thomas, A., 1692. Observations faites aux Indes et à la Chine. In Gouye, 120–196.

Thomas Gouye, n.d. http://fr.wikipedia.org.wiki/ Thomas_Gouye

Tobin, W., 2014. Stephan, Jean-Marie-Edouard. In Hockey et al., 2053–2054.

Udias, A., 2003. *Searching the Earth and the Sky. The History of Jesuit Observatories*. Dordrecht, Kluwer.

Vande Walle, W.F., and Golvers, N. (eds.), 2003. *The History of the Relations between the Low Countries and China in the Qing Era (1644–1911).* Leuven, Ferdinand Verbiest Institute (Leuven Chinese Studies 14).