Historical & Cultural Astronomy

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Advancing Cultural Astronomy

Studies In Honour of Clive Ruggles

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Efrosyni Boutsikas • Stephen C. McCluskey
John Steele
Editors

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Editors
Efrosyni Boutsikas
Department of Classical
and Archaeological Studies
University of Kent
Canterbury, UK

Stephen C. McCluskey
Department of History
West Virginia University
Morgantown, WV, USA

John Steele
Department of Egyptology and Assyriology
Brown University
Providence, RI, USA

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Cover image: A photograph of the September equinox sunset at Chankillo © Ivan Ghezzi

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Preface

This volume contains a series of studies on cultural astronomy in honour of Clive Ruggles and his groundbreaking work in the field, written by a selection of his close colleagues. We hope that the volume is both a fitting tribute to Clive and a significant contribution to the further development of cultural astronomy as an academic discipline.

On behalf of the editors, the publishers have made a donation to the Alice Ruggles Trust on publication of this book. For more information about the Alice Ruggles Trust and its work, go to alicerugglestrust.org.

Canterbury, UK	Efrosyni Boutsikas
Morgantown, WV, USA	Stephen C. McCluskey
Providence, RI, USA	John Steele

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Contributors

Juan Antonio Belmonte Instituto de Astrofísica de Canarias, Universidad de La Laguna, Tenerife, Spain

Efrosyni Boutsikas Department of Classical and Archaeological Studies, University of Kent, Canterbury, UK

Michel Cotte University of Nantes & ICOMOS, Nantes, France

Ivan Ghezzi Pontifical Catholic University of Peru, Lima, Peru

A. César González-García Institute of Heritage Science, Incipit—CSIC, Santiago de Compostela, Spain

Robert Hannah University of Waikato, Hamilton, New Zealand

Stanislaw Iwaniszewski Escuela Nacional de Antropología e Historia—Instituto Nacional de Antropología e Historia, Ciudad de México, Mexico

Alejandro Martín López Facultad de Filosofía y Letras, Instituto de Ciencias Antropológicas, Sección de Etnología, Universidad de Buenos Aires, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina

Stephen C. McCluskey Department of History, West Virginia University, Morgantown, WV, USA

Barnaby R. M. Norris Sydney Institute for Astronomy, School of Physics, University of Sydney, Camperdown, NSW, Australia

Sydney Astrophotonic Instrumentation Laboratories, University of Sydney, Camperdown, NSW, Australia

AAO-USyd, School of Physics, University of Sydney, Camperdown, NSW, Australia

Ray P. Norris Western Sydney University, Penrith South, NSW, Australia

CSIRO Astronomy & Space Science, Epping, NSW, Australia

Frank Prendergast College of Engineering and Built Environment, Technological University Dublin, Dublin, Ireland

D. Graham J. Shipley School of Archaeology and Ancient History, University of Leicester, Leicester, UK

John Steele Department of Egyptology and Assyriology, Brown University, Providence, RI, USA

Gudrun Wolfschmidt Center for History of Science and Technology, Hamburg Observatory, University of Hamburg, Hamburg, Germany

Clive Ruggles and the Development of Cultural Astronomy

Efrosyni Boutsikas, Stephen C. McCluskey, and John Steele

Clive Ruggles' work has challenged—and ultimately transformed—the way we study the astronomies of other cultures (Fig. 1). Before Ruggles' work, archaeoastronomy was seen by many archaeologists as a not very important ancillary discipline to the field of archaeology (Cotte, this volume) and many of them challenged the validity of archaeoastronomers' claims (Salt, 2015: 213). Clive's earliest work (Cooke, Few, Morgan, & Ruggles, 1977: 131) responded to this scepticism, speaking of the need to convince sceptical "outsiders to believe the claims being made" by archaeoastronomical researchers. His method at that time focused on pre-defining selection criteria, based on the characteristics of the site, and not on any astronomical indication, to determine which alignments were to be measured. These measurements were then converted into astronomical declinations which were used to identify which measured alignments signified possible astronomical alignments. This concern with defining methodologically rigorous procedures is an enduring theme in Ruggles' work, but at this early stage, cultural context played no role in his research, reflecting the common practice of contemporary British archaeoastronomers.

Archaeoastronomy at that time largely consisted of the search for alignments of ancient structures towards positions on the horizon that seemed to be of obvious astronomical significance such as the rising point of the sun at the solstices and equinoxes or the extreme northern and southern rising points of the moon. In its early British version, this practice of "alignment hunting" was usually constructed

E. Boutsikas (✉)
Department of Classical and Archaeological Studies, University of Kent, Canterbury, UK
e-mail: E.Boutsikas@kent.ac.uk

S. C. McCluskey
Department of History, West Virginia University, Morgantown, WV, USA

J. Steele
Department of Egyptology and Assyriology, Brown University, Providence, RI, USA

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Fig. 1 Clive Ruggles (image courtesy of John Steele)

independently of any other archaeological investigation of a site, with little attempt to situate the findings within broader archaeological and contextual studies. Furthermore, many of the assumed "obvious" astronomical alignments can be criticized for simply being those that are of interest to modern astronomers, which may or may not be the same as what interested other societies. It established its validity chiefly through the search for mathematical precision informed by statistical analysis of a large number of sites. Although Ruggles' early papers share the same concern with quantitative rigour, he came increasingly to recognize the need for cultural context.

Ruggles was thus among the first scholars to advocate the embedding of archaeoastronomy, which had until the 1980s been largely the preserve of astronomers dabbling in archaeology, within mainstream archaeology and to develop solid methodologies for the study of sites with possible astronomical meaning. He also sought to bring the study of archaeoastronomy into a wider discourse with ethnoastronomers studying living astronomical traditions and historians of astronomy working with written texts and preserved artefacts.

In his investigation of a group of Scottish recumbent stone circles, Clive continued to insist on establishing statistically significant results, but noted they could be combined with other archaeological data to generate cultural hypotheses. The quantitative data drawn from a well-defined sample still came first, but no longer stood by itself. It was now seen as being combined with archaeological evidence to contribute, in some way, to the framing of "cultural hypotheses" (Cooke et al., 1977: S55). As an indication of his early approach, its short title on the cover of the *Journal for the History of Astronomy* was "Objectivity in Archaeoastronomy". Reflecting that theme, it opened with sections on a "Code of Practice at Megalithic Sites" and "Classification and Selection Criteria". These two concerns of establishing rigorous standards and dealing with cultural context remained, with differing emphases, the guiding themes of Clive's work.

Clive's evolving approach is further indicated by the suggestive title of the volume of thematic papers from the third "Oxford" Conference at St. Andrews, Scotland, which he edited with Nick Saunders, *Astronomies and Cultures*. Ruggles and Saunders titled their chapter "The Study of Cultural Astronomy", foreshadowing the changing focus of the discipline from archaeoastronomy to cultural astronomy (Tirapios, 2019). Despite their growing focus on the need to understand and describe the concepts by which another culture expresses their notions of reality, they still maintained that statistical rigour was required "for estimating the likelihood that observed patterns have real (and quantifiable) cultural significance" (Ruggles & Saunders, 1993: 15).

At the ninth "Oxford" conference, in Lima, Peru, Clive addressed the increasing role of social theory in our discipline, crediting Stanislaw Iwaniszewski (who also contributes to this volume) with "the first attempt to introduce the topic into the Oxford agenda at Oxford II" (Ruggles, 2011: 7). A new "interpretative archaeoastronomy" addressed issues that Clive now considered to be more fundamental (Ruggles, 2011: 3). He explicitly noted the tension between change and continuity in his own shifting emphasis, conceding that while he had "long since abandoned my insistence of 30 years ago upon a statistical objectivity … I stand by the need for scientific rigor" (Ruggles, 2011: 12) (Fig. 2).

Although many aspects of Clive's research have changed, his concern with employing rigorous criteria to convince the sceptical outsider continues almost 40 years later (Fig. 3). In discussing the evaluation of archaeoastronomical heritage

Fig. 2 Clive Ruggles speaking at the Oxford Conference in Lima, Peru in 2011 (image courtesy of Stephen C. McCluskey)

Fig. 3 Clive Ruggles making a comparative measurement of a village church orientation in Leicestershire in 2002 (image courtesy of Stephen C. McCluskey)

sites (Ruggles, 2015b: 97), he described this concern as lying “at the heart of archaeoastronomical methodology and interpretation”. As he saw it, “[E]stablishing the credibility of the archaeoastronomical interpretations is crucial to any assessment of their value”. In a more general presentation, rather than stressing a dichotomy between rival approaches, he proposed that the central issue remains “how best … to interpret purely archaeological data (where only this is available) as opposed to how best to integrate diverse types of data (in other cases) in order to identify the most credible interpretations” (Ruggles, 2015a: 355).

1 The Equinoxes

In 1996, about the time of the spring equinox, Clive participated in an archaeological conference on Science and Stonehenge, organised by the British Academy. His paper, an overview of the astronomy of Stonehenge, began with an introduction to the conceptual framework of prehistoric astronomy (Ruggles, 1997a: 205–212). He outlined for his audience the “recipe book”, commonly consisting of the solstices, the lunar standstills, and in some cases, the equinoxes, which had frequently been used in archaeoastronomical investigations. He questioned whether the lunar standstills and the equinoxes have any meaning outside the framework of “modern western science and its precursors”. He suggested various ways in which prehistoric people may have observed and conceptualized the equinoxes, yet stressed the "fundamental point" that these "bear no relation whatsoever *on the conceptual level* to the modern astronomer's equinox". His recommendation for archaeologists was to avoid using any "recipe book" of significant astronomical targets, but to describe possible astronomical indications in the neutral quantitative terms of astronomical declination.

He soon reworked this critique for the archaeoastronomical community in a methodological essay entitled, "Whose equinox?" For this new audience, Clive elaborated the alternative observational methods by which prehistoric people might have observed and conceptualized the equinoxes, but re-emphasized that none of these would determine our "true" equinox. Significantly, he noted that no systematic studies of groups of monuments of which he was aware showed any evidence of orientations clustering around any of the approximations to the equinox. He concluded that, lacking any plausible models for a culture's cosmological model, it would "probably be helpful if the word 'equinox' were simply eliminated from archaeoastronomers' vocabulary". (Ruggles, 1997b: S49).

Recently, Clive returned to the question of the equinoxes, conceding that in Mesoamerica, where we have a detailed cosmological model and calendrical evidence for counting the passage of days, it is "not surprising that the temporal equinox appears to have been of some significance". Nonetheless, he conceded that while the "equinox" should not remain part of a "recipe book of potential horizon targets", it need not be totally eliminated from our vocabulary. "The equinox … remains useful as a point of reference" for *our* investigations, as long as we do not assume it was "a meaningful point of reference for *them*" (Ruggles, 2017: 134).

As it happens, the question of the equinoxes has become a recurring theme in this volume, as Belmonte and Steele both shaped their chapters around the different concepts of the equinox as evidenced by a wide range of circum-Mediterranean sites (Belmonte) and by Mesopotamian astronomical texts (Steele). Boutsikas studied the orientation of Greek temples in the context of ancient Greek culture for which we know that astronomers defined the equinoxes in terms of the equality of the length of day and night. She concludes that the equinoxes, conceived as the cosmologically significant time when days and nights are of equal length, seem to be "the most likely candidate" for the orientation of Greek Doric temples. Finally, Ghezzi, in his presentation of the Chankillo Solar Observatory and Ceremonial Center, notes several heretofore neglected examples of equinoctial indications at the site. These include observation of equinoctial sunrise in a prominent notch on the distant natural horizon and a replication of this effect on the artificial horizon calendar by equinoctial sunrise in a narrow gap between towers 6 and 7. A third equinoctial effect was found in the light and shadow phenomena produced by sunlight passing through slits in the pillars of the Temple of the Pillars.

If we can generalize from these studies of the equinoxes, it seems that the term continues to be useful for our investigations, both as a guide for comparative investigations of how different cultures conceptualize the equinoxes and for investigations of how the "equinoctial" orientation of a culture's structures may reflect that culture's known cosmological formulation of the equinoxes.

2 Archaeology, Archaeoastronomy, and Cultural Astronomy

Initially known for his work at sites in the British Isles, Clive soon expanded his research to include projects in Africa, mainland Europe, South America, and, most recently, Hawai'i. Among these projects are several that go beyond traditional archaeoastronomy into mainstream landscape archaeology (e.g. mapping Nazca lines in Peru (Ruggles & Saunders, 2012)), ethnography (e.g. investigating traditional time reckoning among the Mursi (Turton & Ruggles, 1978) and Hawai'ian star names (Johnson, Mahelona, & Ruggles, 2015), and combining textual sources with archaeological and ethnographical evidence (e.g. the study of ancient Georgian astronomical heritage (Simonia, Ruggles, & Chagunava, 2008)).

Two studies bear particular mention. With Ivan Ghezzi, Clive undertook a detailed study of the site and landscape of Chankillo in northern Peru. They convincingly demonstrated the presence of clear and deliberate solar alignments incorporated into the design of the site (Ghezzi & Ruggles, 2007, 2011). Provocatively, they described the site as a "solar observatory". The term "observatory" has often been used uncritically by archaeoastronomers to describe a large number of different types of structures. It is problematic for several reasons: aside from the danger of anachronism in applying a modern term to an ancient context, the world invokes the idea of "scientific observation", which was surely not the purpose of most ancient interactions with the sky. It also implies that the function of the structure was first and foremost as a place to make astronomical observations. Clive was of course well aware of these issues—a long and productive conversation about them took place between Clive, John Steele, and several others at a workshop at Durham University in 2005—but made a strong case that Chankillo is one of the few ancient sites where this term can justifiably be used. Ghezzi returns to Chankillo in his contribution to this volume.

In his recent work with Patrick Kirch on an ancient temple system on Maui, Hawai'i (Kirch & Ruggles, 2019), Ruggles has brought the study of archaeoastronomy to its fullest conclusion: as a tool of analysis rather than an end in itself. Instead of trying to primarily reconstruct the astronomical knowledge of the ancient Hawai'i, here Ruggles uses archaeoastronomical evidence from ancient structures in order to address cultural questions about the people who built and lived with them. Archaeoastronomy is no longer an end in itself but has become part of a broader archaeology.

3 Astronomical Heritage

As former president of both Commission 41 on Historical Astronomy and Commission four on World Heritage and Astronomy of the International Astronomical Union, Clive has been at the forefront of efforts to preserve astronomical heritage in all forms. He has taken on the role of connecting the astronomical and archaeological communities with the World Heritage Organization in efforts to obtain World Heritage Status for sites of astronomical significance. Thanks in large part to these efforts, a number of sites have now been awarded World Heritage Status on the basis of the significance of their astronomical heritage ranging from Risco Caldo and the sacred mountains of Gran Canaria to Jodrell Bank Observatory in the United Kingdom.

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Part I
Methodology

Clive Ruggles' classic paper "Whose Equinox?" drew attention to the problem of modern preconceptions of what is a significant astronomical event or phenomenon within the study of cultural astronomy (Ruggles, 1997). Crucially, it highlighted that just because an astronomical event is apparently obvious and significant in our astronomy, it need not be so in other astronomies and worldviews. The papers in this section explore this topic further, arguing that whether or not a phenomenon is significant and how it is defined is culturally dependent, and indeed that different ideas about a phenomenon may even exist within a culture.

Responding directly to Ruggles' challenge to the ambiguous concept of the equinox, Belmonte presents a wide ranging and precise investigation of the variety of "equinoctial" concepts indicated by structures oriented to the "East" in a wide range of cultures in the Mediterranean region and beyond. Rather than reject the term outright, as Ruggles (1997: S49) had proposed, Belmonte prefers "to keep it with different levels of meaning and understanding."

Steele also addresses the issue of the meaning of "equinox" in a different culture. He examines Mesopotamian astronomical texts asking "were the solstices and/or equinoxes defined calendrically, i.e., by their position in the year, temporally, i.e., by the length of daylight, or spatially, either with reference to the place on the horizon when the sun rises or sets or to the intersection of the ecliptic and the celestial equator, or by a combination of these possibilities?" He concludes that in Mesopotamia the solstices and equinoxes were primarily conceived in terms of "the length of day and night: the solstices were the days on which the day was the longest or shortest and the equinoxes were those days when day and night were of the same length. A secondary definition of the solstices was as the days on which the sun rose at its most northerly or southerly point on the horizon; there does not seem to have been a similar definition of the equinoxes referring to the sun rising due east or setting due west."

McCluskey's paper responds to Ruggles' (2015) call for "more sophisticated methods" to assess the credibility of archaeoastronomical sites that "reflect the current state of theory and practice in the discipline." He examines what can constitute a horizon marker—a point on the horizon used to indicate a direction towards an astronomical phenomenon—arguing that what we may at first think of as significant features on the horizon are not necessarily the same as what other cultures consider significant. Discussing the extensive ethnographic evidence for Hopi horizon based observations of the sun, McCluskey proposes archaeological correlates for evaluating the significance of purported archaeoastronomical sites.

In his paper López argues that even the most basic approaches to the sky can be radically different in different societies. Whereas western academic astronomy, based on a worldview that assumes the separation between nature / culture / supernature, understands the events of the celestial space as "astronomical phenomena," using ethnographic evidence Lopez shows that *Moqoit* experience and theories about the cosmos are based on the social relations between diverse intentional beings, which are fundamentally modeled by asymmetries in power (*quesaxanaxa*). He contrasts signs (carrying messages concerning important issues) with phenomena (and their scientific explanations). He points out that in order to address academically how "different cultures construct knowledge about the sky and other areas of existence…, we are impelled to deconstruct the assumptions on which our experience of the world is grounded, in order to understand those cultures according to their own logics."

In the final paper of this section, Shipley shows how the same issue raised by Ruggles of ensuring we do not impose modern western astronomical ideas on other cultures must also be considered when considering ancient texts. Even concepts such as the cardinal directions may have different meanings—and be expressed in different ways in different contexts—in ancient or non-western societies. Shipley's problem as a translator of Greek texts of making the directional terms of a different culture meaningful to a modern, English speaking, audience is analogous to the cultural astronomer's task of making a culture's astronomical concepts intelligible to a modern audience. His concern with unpacking Greek directional terms around the compass is not unlike Ruggles' concern with unpacking the various meanings of the term "equinox" in archaeoastronomical studies.

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What Equinox?

Juan Antonio Belmonte

1 Introduction: Whose Equinox?

> … *it would probably be helpful if the word 'equinox' were simply eliminated from archaeo-astronomers' vocabulary* … (Clive Ruggles 1997)

It is an honour and a pleasure to be part of this volume. I first met Clive Ruggles in September 1996 during the SEAC Conference in Salamanca, although I already had several references about his extraordinary work and skills through common friends and had read several of his papers. For a rookie archaeoastronomer as I was then, this was like a fan meeting his favourite rock-star. I could not imagine this would be the beginning of a long lasting collaborative effort and, far more important, camaraderie and friendship. Since then, we have always been in close contact. I would like to emphasize two aspects. The first one was the chance to work at his orders during the edition of the Handbook of Archaeoastronomy and Ethnoastronomy (Ruggles, 2015). The second one has been the efforts to promote the IAU and UNESCO 'Astronomy and World Heritage' initiative (Ruggles, 2017; Ruggles & Cotte, 2010), culminating in the process to declare the interior of the island of Gran Canaria as a World Heritage Cultural Landscape (Belmonte et al., 2018); a process where Clive had put all his skills and knowledge, despite his harmful personal situation. This is a fact that greatly honoured him. Finally, we—a huge multidisciplinary team—were successful in July 2019.

Back to 1996, we had just published our first part of the paper on 'equinoctial markers' in Gran Canaria (Esteban, Belmonte, Schlueter, & González, 1996) and were shocked by a preprint where the whole meaning, and even existence, of the equinox within a cultural astronomy study was questioned. The situation was so problematic that Clive thought it would be adequate and indeed useful to ask himself: 'Whose

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J. A. Belmonte (✉)
Instituto de Astrofísica de Canarias, Universidad de La Laguna, Tenerife, Spain
e-mail: jba@iac.es

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equinox?' (Ruggles, 1997). In this work, he established the difference between the true astronomical equinox ($\delta = 0°$), when the sun crosses the celestial equator, the day midway between the two solstices, sunrise at due-East, or the mid-horizon sunrise point between solstice sunrises, among other possible definitions. All of them were near the same point on the horizon where sunrise occurs but could represent quite different concepts in the worldview of the builders under scrutiny.

The concept of equinox (from the Latin 'equal night', meaning the day when the length of the day and night are equivalent) has a precise meaning within the framework of classical spherical astronomy—derived from Greek sources—that underline our Western religious and scientific tradition. From the scientific point of view, the equinox is the instant when the sun, moving along the ecliptic, crosses the celestial equator and has a declination of 0°. The day of the equinox (either spring or autumn) is considered as the day when this fact happens. Alternatively, the preceding sunrise and subsequent sunset (or vice versa when it occurs at night) could be termed the equinoctial sunrise and sunset, respectively.

A culture's understanding of the equinox can be teased out from how they used that concept. For instance, a decade after Clive's question, González-García and Belmonte (2006) asked themselves 'Which equinox?' when the date and concept of the equinox in ancient Rome at the time of the Julian reform had to be taken into account. The Romans apparently favoured the day midway between the solstices instead of the astronomical equinox itself. This could have obvious consequences when interpreting the archaeoastronomical data of the Roman era as we will later demonstrate. As the reader can imagine, from the perspective of a totally different worldview, finding a concept similar to Western equinox would be far from simple, and as Clive argued, and will be proved later on, 'it could make no sense at all' (Ruggles, 1997).

In the following section, a diachronic, geographic approach to different cultural environments somehow related to our Western world, from the hill of Göbekli Tepe to the Christian churches of the Iberian Peninsula, will be performed, seeking for what could have been the exact meaning of equinox and how a people approached it. This will be completed with a few sketches of alien cultures where this concept has also been claimed. Finally, in the conclusion we will concentrate on how reliable the concept of equinox is and if it still deserves to be preserved in cultural astronomy studies, including archaeoastronomy and ethnoastronomy.

2 Discussion: Which Equinox?

Until recent times, the megalithic monuments in Europe were the archaeological remains earning all the credit for any potential astronomical knowledge of the earliest ancestors of humankind. However, a discovery in southeast Anatolia has changed these ideas. There, on a barren isolated hill called Göbekli Tepe, a team of German and Turkish archaeologists (see Schmidt, 2006 for the discovery) have been excavating a cluster of suggestive cyclopean monuments erected with large, megalithic pillars in the form of a T, within a series of dry-stone enclosures. They were built by a completely unknown pre-ceramic, hunter-gatherer society, beginning more than 11,000 years ago. Individual sanctuaries of this series were built presumably one after—and even upon—the other. Each one of them would have remained in use for centuries, perhaps millennia, but was deliberately buried by the progenies of their own constructors for unknown reasons. This is a very peculiar fact that has certainly contributed to their excellent state of preservation despite of their great antiquity. These monuments are mostly ellipsoidal in form and had megalithic accesses mostly open to the S-SE that might define a preferred orientation (Fig. 1). A series of mutually contradictory ideas have been put on the table (see Belmonte, González-García, Rodríguez-Antón, & Shaltout, 2016).

However, what is undeniable is that between the series of monumental structures, there is one on the top of the hill, which has nearly rectangular walls almost perfectly aligned according to the cardinal directions (Fig. 1). This circumstance alone would force us to think that we are faced with a society that had looked at the sky and used it as a guide to find appropriate ways of orientation in space and, almost certainly, also in time. In this context, additional exercises could be performed, analysing the profuse T-pillar decoration where totemic representations of animals are present. These might remind atavistic constellations, such as Leo, Taurus or Scorpius, that can be recognize in the skies of other evolved cultures in the region several centuries later. Besides, one of the pillars of the cardinally orientated hall, which was framing an altar on the eastern side of the structure, has a representation of a lion; and Leo was rising with the vernal equinoctial sun precisely at east in the epoch of construction of this particular shrine (Fig. 1). Are we facing the genesis of the ‘equinox’ concept? Was this concept born in the plains of Mesopotamia? This is indeed a most interesting point to be discussed but far from the scopes of this essay (see, however, Steele, this volume).

2.1 ‘Megalithic’ Equinoxes

In the line of argument of the previous paragraphs, Clive has consistently argued that: ‘it is far from self-evident, then, that any fundamental concept similar to our equinox had any meaning, let alone any importance, to people in prehistory’ (Ruggles, 1997). This is an especially sensitive argument when megalithic monuments are considered. It would be farfetched to focus here on the many different occasions that the equinox has been claimed to explain the orientation of certain megalithic monuments in agreement to what has been termed the ‘megalithic equinox’ (Ruggles, 1999: 54), seldom interpreted as the day midway between the solstices. Hence, we will concentrate in three major examples: the large tumulus of Knowth in Ireland, the dolmen of Viera in Antequera (Spain), and the temples of Mnajdra in Malta. The tumulus is Knowth is a nice example of data overinterpretation. The two main corridor tombs located inside the tumulus are roughly orientated east and west, respectively, and have accordingly been interpreted as equinoctially

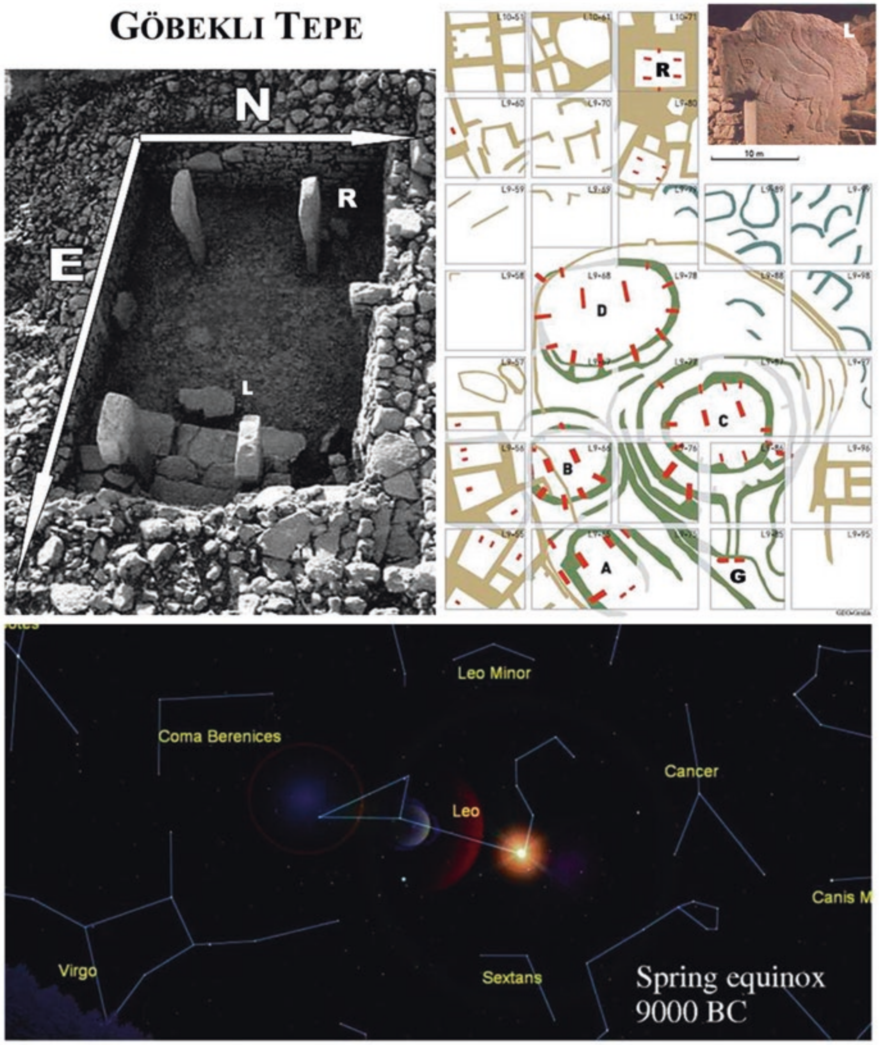

Fig. 1 Composite diagram of Göbekli Tepe. The walls of the rectangular structure (R) built c. 8500 BC in the upper sector of the site are perhaps the first manmade building ever orientated close to the cardinal directions discovered so far. One of the pillars (L) was decorated with an image of a lion. Either by chance or design, the equinoctial sun was easterly rising in conjunction with Leo constellation in that epoch. Adapted from Belmonte et al. (2016)

aligned (Eogan, 1986: 178–179). However, the rough alignment of the corridors and other aspects to be considered has forced a completely different interpretation of the data, discarding any kind of ‘equinox’ as responsible for the tomb orientations (Ruggles, 1999: 129).

However, there is another interesting case worth discussing. The dolmen of Viera, a megalithic tomb of the mid-third millennium BC integrating the fascinating group of prehistoric tombs in the Antequera Archaeological Park, recently declared as a World Heritage site by UNESCO (Ruiz González et al., 2015), was fist explored by Michael Hoskin in his extensive archaeoastronomical research in the Iberian Peninsula (Hoskin, 2001, and references therein). The initial datum was not very promising (Belmonte & Hoskin, 2002: 77–80) but later observations and, among all, detailed photographic documentation of the dolmen alignment, preparing for the UNESCO candidacy proved otherwise. All in all, Viera was considered, and heartily proposed, as a monument orientated to equinox sunrise. Once more the dichotomy!

Figure 2 beautifully illustrates the problem. The photograph presented there was taken at full-moon the night of the equinox when the declination of our satellite was c. 0°, and hence mimic the exact behaviour of the sun at $\delta \sim 0°$. The alignment seemed perfect. However, the devil is in the details and having a close inspection at the image, a small but still perceptible effect can be ascertained, proving that the photograph was taken slightly off axis (this precision would be impossible at sunrise when strong light and shadow contrasts would preclude such clear perception). If the correct chamber and corridor axis is considered, the moon would have been seen a whole disk diameter to the left of the axis. Actually, the horizon window observable from the chamber would have permitted not only the equinoctial sun light entering the chamber, but also at the day midway between the solstices, and a couple of days before the spring and after the autumn equinoxes.

Fig. 2 'Equinoctial' moonrise on March 21st 2019 on the axis of the dolmen of Viera (Antequera, Spain): The full-moon had a value of the declination of virtually 0°, thus mimicking the behaviour of the sun at the equinox. Photograph by courtesy of Fernando del Pino

Hence, the equinoctial alignment is not as 'precise' and we would desire and perhaps different approaches ought to be considered. Could the moon be the relevant celestial object? Anyway, the lighting phenomenon is very suggestive and will certainly keep attracting people to the site every equinox.

Our last singular case is that of the southern megalithic temple of the three present at Mnajdra in Malta. The peculiar orientation of this temple, the only one of the many prehistoric temples in Malta clearly facing sunrise, has often been termed as equinoctial. Michel Hoskin (2001: 30–31) dismissed this possibility as unreliable but it has remained in the literature and the most serious work on the topic has come back with this possibility (Lomsdalen, 2014: 132). Figure 3 shows a model of the three temples at Mnajdra located at the Malta Archaeological Museum in La Valetta, where the light and shadow effect observable at Mnajdra south can be reproduced. Observing this model (and also on direct observations on site), it is easy to notice that the temple gate was designed to allow the light of the sun entering and illuminating different sacred spots inside the shrine from winter solstice to summer solstice and vice versa. Does this mean that the 'equinoctial' alignment of the temple is just a chance and was forced by the need to lightening the interior every sunrise throughout the year? The answer is not simple. The most recent data (Lomsdalen, 2014; Fig. 5.16) shows that the temple was aligned to $\delta = 0.7°$. This is far from 0° and hence to the true astronomical equinox, but close enough to the value of the sun declination at the day midway between the solstices (c. 0¾°).

Clive had argued that: 're-examination of both the conceptual basis and the actual evidence casts considerable doubt on the idea that any monuments were

Fig. 3 Model of the three megalithic temples of Mnajdra (Malta). Mnajdra I, first to the left, is the youngest of the set, showing the main axis of it oriented towards sunrise at the 'equinoxes' (actually to $\delta \sim 0¾°$). Photograph by Margarita Sanz de Lara, courtesy of the National Archaeological Museum of Malta

deliberately aligned upon sunrise or sunset on dates that happen to approximate to the true equinox, because they were conceived as halfway … between the solstices' (Ruggles, 1997). Apparently, Mnajdra South would contradict this statement, unless the orientation of the axis was a mere byproduct of the general design of the temple, as previously discussed (Fig. 3). Consequently, the day midway between the solstices perhaps had more relevance than the one we might expect, or desire.

2.2 *Mediterranean Equinoxes*

The first buildings which are arguably orientated close to the astronomical equinox, whenever the eastern horizon in nearly flat, are the funerary temples and related structures (e.g., the Sphinx) of the pyramid complexes of Egypt during the Old and Middle Kingdoms (Fig. 4). Various researchers, including the author of this essay (Belmonte, Shaltout, & Fekri, 2009) have thus claimed for equinoctial alignments in ancient Egypt. However, interestingly, this pattern of orientation could simply be interpreted as the byproduct of an actual interest in due-North and the realm of the imperishable stars, rather than sunrise itself. Only later, this transformed, notably with the solar temples of the 5th Dynasty—and perhaps earlier during the reign of Snefru –, into a true solar relationship, whether or not the ancient Egyptians had a knowledge of the astronomical equinox.

Figure 5 illustrates this possibility. The figure presents the declination histograms of a sample of 330 temples of ancient Egypt divided into a global one (panel a) a three series of independent data on temples of the Old and Middle Kingdoms (when pyramid complexes were built), the New Kingdom and the Late Period up to the 26th Dynasty, and finally of Egyptian temples built during and after the Persian conquest up to the Roman period. The statistically significant peak at the equinox, present in the whole sample which made us define a family of equinoctial

Fig. 4 Equinox at Giza in March 2005. Sunrise in front of the Sphinx (**a**) and sunset behind it at the corner of Khaefre Pyramid (**b**) are clear focal points. Photographs: Juan Antonio Belmonte

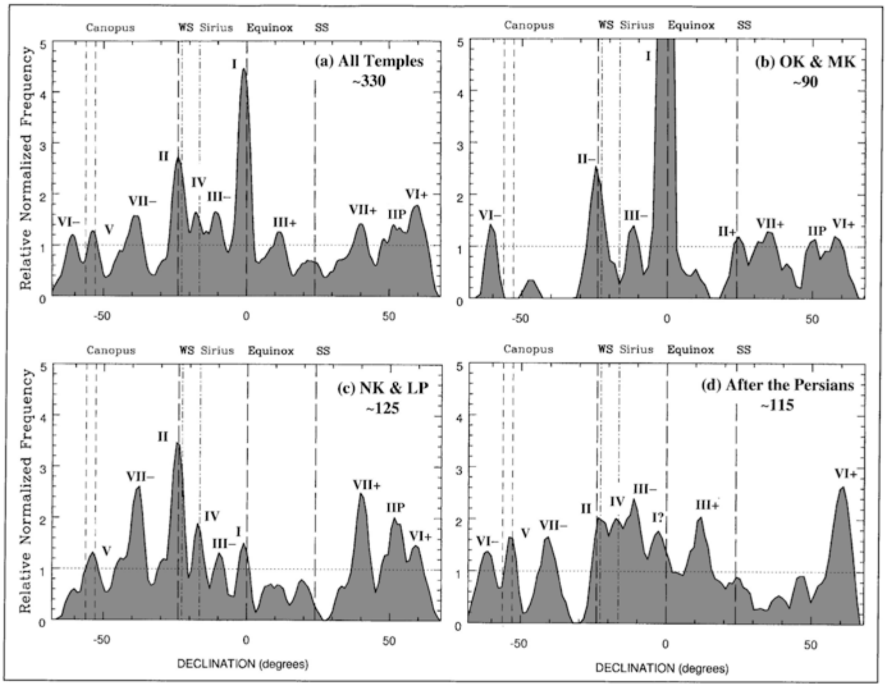

Fig. 5 Declination histograms of the temples of ancient Egypt vs. historical period: (**a**) Complete histogram of a sample of 330 temples showing the seven families of orientation, including family I peak close to 0° declination. (**b**) Temples from the pre-Dynastic period to the end of the Middle Kingdom. (**c**) Temples of the New Kingdom and the Late Period until the Persian conquest. (**c**) Late temples with a dominance of buildings of the Graeco-Roman period. The three series of data plotted in panels (**b**), (**c**) and (**d**) are independent of each other. In panel (**b**), the peak of family I climbs to more than 12 but has been cut to keep the same scale in the different plots. Adapted from Belmonte et al. (2009)

orientations (I) is, however, misleading. This comes from the huge peak related to the orientation of the temples adjoining the pyramids from the 4th to the 12th Dynasties, as clearly demonstrated in Fig. 5, panel b. I am now nearly convinced that this peak, and what it represents, is the results of simple geometry applied to the pyramid complexes, where the pyramid was the first building to be aligned to the north and the realm of immortality. Later on, the shrines associated with the complex, the so-called funerary and valley temples, would be built with an axis perpendicular to the northern one, indeed facing sunrise (solar eschatology was concomitant to the stellar one since the 4th Dynasty), but perhaps facing sunrise at the equinoxes just by chance.

The idea would be reinforced by the fact that, in later epochs, as in the glorious New Kingdom, the ‘equinoctial’ family is hardly significant or, even worse, during the architecturally splendorous Ptolemaic Period, not easily identifiable (Fig. 5, panel d). This was an epoch when the concept of astronomical equinox was already well-known but it seems to be absent from contemporaneous, traditional Egyptian architecture.

Hence, if the true equinox had no relevance in the orientation of monuments of the megalithic phenomenon, neither in those of other western mother cultures, as ancient Egypt was, where should we look for it, if anywhere. The mathematical concept of equinox was fully developed in the Hellenistic world. Instruments like the sundial of Ai Khanoum, from the third Century BC, clearly reflects it (Hannah, 2009: 121), and perhaps even earlier in the first uses of a gnomon attributed to Anaximander in the sixth Century BC (Hannah, 2009: 69). However, as Hannah (2009: 71) argues, the knowledge of the equinox is not reflected at all in Hesiod's *Works and Days* two centuries earlier.

Consequently, it is not surprising to notice that early Greek temples in the Balkan Peninsula and the Aegean islands lack any sort of equinoctial pattern (Bousikas, 2007–2008). This is, for example, the case for the temple of Apollo at Bassae which is orientated north-south instead of east-west as would be expected for a solar deity, among many others studied in Boutsikas' PhD work, under Clive's supervision. This was a sort of unexpected outcome at the land where classical astronomy had been presumably born and developed and the term equinox invented.

However, the situation is different when we moved to the western shores of the Mediterranean Sea. Figure 6 shows two interesting cases of equinoctial orientations, combined with conspicuous topographic landmarks. On the one hand, the temple of Apollo (Temple C) at Selinunte (Sicily) faces a distant peak where the sun sets at the equinoxes ($\delta \sim -0¼°$). Built in the mid-sixth Century BC, it would be one of the first Greek temples with such an orientation (Belmonte & Hoskin, 2002: 204). Why? We do not have the answer but Selinunte was built in an area of Sicily under strong Punic influence and when the city was conquered by the Carthaginians in 409 BC the area was devoted to the cult of the supreme divine couple of Carthage integrated by Ba'al Hammon and Tanit, so Punic influence cannot be discarded. In this sense, other temples of the city, such as the impressive Temple E, also faced the distant topographic landmark but they were clearly not equinoctial (Belmonte & Hoskin, 2002: 205).

Interestingly, on the other hand, this same Punic influence can be ascertained across the sea, in Mactar (Tunisia). In data taken in Africa Proconsularis (Belmonte, Tejera, Perera Betancor, & Marrero, 2007), where Punic, Roman and local (Numidian) traditions intermingled, there is one relevant peak centred at c. 0°. This could be associated with a substantial number of temples devoted to the sun, or deities of solar character, spread throughout the region. This is beautifully illustrated in Fig. 6b, where the equinoctial rising sun can be seen along the axis of the Apollo temple in Mactar. This temple was built upon an early temple dedicated to Ba'al Hammon, the supreme deity of Carthage which was somehow assimilated by the Numidian kings to the Sun. Although the temple orientation is certainly equinoctial, the presence of a notch in the distant horizon, where the sun would have risen a couple of days after the spring equinox (or before the autumn one), and hence at the day midway between the solstices, opens an interesting question.

Fig. 6 Land and skyscape interaction: (**a**) Alignment of Temple C at Selinunte (Sicily) built between 580 and 530 BC, presumably dedicated to Apollo, it was the oldest of the city: sunrise at the 'equinox' was produced over a distant, remarkable topographic landmark ($\delta \sim -0½°$). (**b**) The equinoctial rising sun of March 21st 2002 follows the axis of symmetry of the Sun (Apollo in Roman times) temple in Mactar (Tunisia). The phenomenon is observable close to a notch in a distant mountain which could have been used as a close-equinoctial marker. Photographs by Juan A. Belmonte

Few studies, if any, have been performed in the shores of Levant that can offer a clue of an 'equinoctial' custom perhaps imported from the Middle East (see Steele, this volume). Hittite data shows a preference for near due-east orientations (González García & Belmonte, 2011) and, as we will see later on, Nabataeans played with the concept of equinox (sun entering the 'sign of Aries') and aligned their sacred structures accordingly. However, it is still in the West where some more clues could be ascertained. An example of that are Iberian sanctuaries.

For more than two decades, César Esteban (2016) has been analysing the importance of the equinox in the Iron Age Iberian culture of Mediterranean Spain. He has discovered that more than one third of the explored shrines had equinoctial 'markers'. Some of them are very precise, such as El Amarejo (Fig. 7). However, the vast majority show a remarkable preference for the day midway between the solstices (which he terms the 'temporal midpoint between solstices' and abbreviates as TMPS) when the sun declination is between +0.3° and +1°. Iberian culture developed between the sixth and first centuries BC and most of these 'equinoctial' sanctuaries are dated in that epoch. Esteban (2016) supports a possible Punic-Greek (from western Greeks) inspiration for the use of equinoctial markers in the Iberian ritual, an influence which is also reflected in many other aspects of the culture, such

Fig. 7 Sunrise at the Iberian sanctuary of El Amarejo (September 21st 2004 when the Sun had a declination of 0°9′ (i.e., c. true equinox): The sun climbs the cliff of Montaña Chinar. This would be the most accurate 'equinoctial' marker for Iberian sanctuaries. Adapted from Esteban (2016). Courtesy of César Esteban

as writing. He is possibly right, although the preference for the time midway instead of the astronomical equinox leaves doors open for other possibilities.

A discussion on the equinox in the pre-Hispanic culture of the Canary Islands may follow the same line of argument. Research in Grand Canary has shown that the equinox was an important milestone in the time-keeping system of the ancient Canarians as was reflected in the conquest chronicles and the archaeological record (Esteban, Belmonte, Schlueter, & González, 1996, 1997). Considering the Amazigh ancestry of these populations this may have important connections to the origin of these populations (Belmonte, Perera Betancor, & González-García, 2019). A Roman influence (see below) has been advocated due to the early Roman presence in Proconsular Africa after the defeat of Carthage in 146 BC, although an earlier Punic influence cannot at all be discarded.

The term 'equinox' is clearly used in the chronicles, but it is ignored what this concept meant for the pre-Hispanic society. The work for preparation of the UNESCO candidacy of 'Risco Caído and the sacred Mountains of Gran Canaria Cultural Landscape' as a World Heritage site (Belmonte et al., 2018) did not clarify the situation despite Clive's role as a scientific advisor of the team was fundamental on the discussion. Of the sites within the property, the sanctuary at Roque Bentayga may suggest an astronomical equinox relationship (Fig. 8, see also Esteban et al., 1996), although the day midway between the solstices—other important time-marks of their calendar—cannot be discarded as proven by other sites in the island (Esteban et al., 1997). However, the astronomical phenomenology present at Cave 6 in Risco Caído indicates that the first and last days when sunlight enters the cave though a very peculiar oculus are—with the margin of a day—March 19 and September 25 in

Fig. 8 The *almogarén* (sanctuary) of Roque Bentayga (**a**), a pivotal element for UNESCO's 'Risco Caido and the sacred Mountains of Gran Canaria' Cultural Landscape. At the equinoxes, sunlight crosses an artificial notch and device (**b**), illuminating the large central circular cup-mark of the sanctuary (**c**). At autumn equinox 2018, a member of our team made a libation for the success of the candidacy (**c**). Prof. Ruggles and the author were present at the event. Photographs by Juan A. Belmonte (**b**) and by courtesy of the Gran Canaria Council (**a** and **c**)

the Gregorian calendar, respectively. During autumn and winter months, it is the full-moon which periodically illuminates the interior of Cave 6 (Cuenca Sanabria et al., 2018). This clearly divides the year between two dark and bright halves. All in all, present data does not offer further clues of the actual conception of the term equinox for this ancient society and if they brought it with them in the process of colonization—perhaps under Roman or Punic influence—or if they developed it locally according to environmental needs. The solar hierophany at Mactar (Fig. 6) would support the first possibility.

It is worth noticing that, although the astronomical definition of equinox was certainly known in Rome, it was not applied for the reform of the Republican calendar introduced by Julius Caesar in 46 BC. This was performed to adjust the year and festivities to the seasons, and Caesar certainly carried out his reform with the problem of the equinox in mind. Probably, for the Romans of the end of the Republic, there were varying definitions for equinox, but March 25th was accepted as the canonical date for the vernal equinox by both Caesar and Augustus. Under this consideration, the sense of equinox used probably was the day that marked the middle of the time interval between the winter and summer solstices, i.e., the day midway between the solstices and not the true equinox (González-García & Belmonte, 2006).

In order to check whether those ancient criteria were really present in other spheres of Roman life, and also to reinforce the idea of a likely relationship between Roman city planning and the sky, an analysis of the orientation patterns of Roman cities in general has been performed (Rodríguez-Antón, 2017). This highlights the integration of important dates of the Roman or pre-Roman calendars into urbanism. That is, if beliefs or even political ideology were embodied within city plans. Eastern—aka ‘equinoctial’—orientations are not unusual within the Roman world. However, they became standard in the Era of Augustus when they were related (together with those to the winter solstice) to the hagiography of the Princeps (see Espinosa-Espinosa & González-García, 2017).

This is nicely illustrated in Fig. 9, where a comparative between the declination histogram of Augustan vs. non-Augustan cities in the Western Roman Empire is presented (González García, Antón, Quintela, Espinosa, & Belmonte, 2019; Rodríguez-Antón, 2017). There are two clearly significant peaks in the Augustan data of 64 cities mainly from Hispania, Gallia, Africa and Italia: one centred at the winter solstice and another centred close to equinoctial declinations. It is worth emphasizing that Augustus’ imperial propaganda put a strong emphasis both in the *Dies Natalis Augusti* at September 23rd in the Julian calendar, which could be considered as a sort of ‘equinox’, and subsequently on the entering of the sun at the sign of Capricorn at the moment of the winter solstice when he was supposed to be

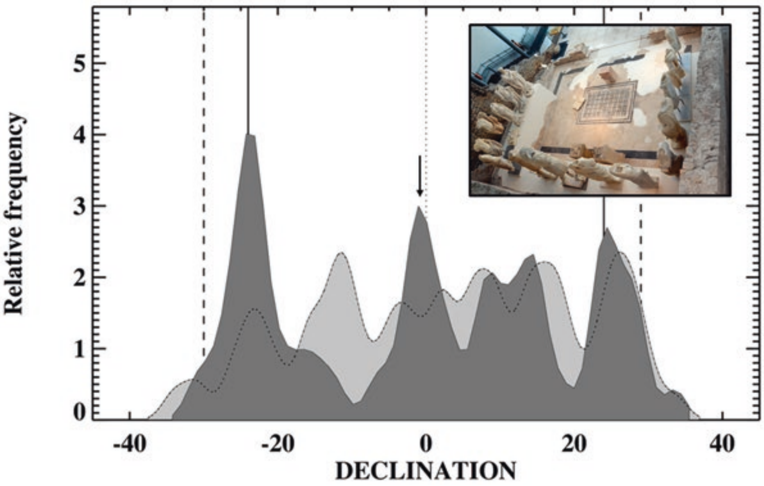

Fig. 9 Declination histogram of Augustan (dark grey) vs. non-Augustan cities located in the Western Roman Empire. Notice the privative ‘Augustan’ peak (arrow marked) at ‘equinoctial’ declinations probably related to the anniversary of Augustus in September 23rd. Inset: Sanctuary of Augustus at Narona. Orientated to a $\delta \sim 0¼°$, this is arguably one of the nicest Augustea ever erected in the provinces. Histogram adapted from Rodríguez-Antón (2017) and a photograph by Juan A. Belmonte

conceived (Barton, 1995; González García et al., 2019). Hence temples and cities throughout the empire were orientated accordingly.

Most interesting is the case of the Augusteum at Narona (Fig. 9) since its orientation ($\delta \sim 0½°$) would confirm the possibility that this suggestive monument was built in commemoration of Augustus' 75th birthday, and accordingly aligned (Belmonte, Rodríguez-Antón, & González-García, 2020).

When Christianity ruled over the Roman Empire, the new religion assimilated several concepts of Roman culture. Christmas was assimilated to the birth of the Unconquered Sun in the night from December 24th to 25th and hence, Jesus conception was assumed to be 9 months earlier at the Roman spring equinox at March 25th. This was assimilated as the Feast of the Annunciation. In this sense, church alignments in the Iberian Peninsula followed certain specific rules throughout the early Middle Age. In particular, a vast majority of churches tended to be orientated with the apse facing sunrise on the vernal equinox, taking this as March 25th. This prescription seems to have been followed for almost a 1000 years and can be observed in the shift of the main maximum in the orientation histograms through the different time periods. Such a shift is due to the drift of the Julian calendar in relation to the seasons (González García & Belmonte, 2015). For example, for Mozarabic churches (Fig. 10), the architectural style used in the Christian territories of the Peninsula just before the arrival of Romanesque, the maximum of the declination histogram was at c. 4°, corresponding to March 30th, Gregorian proleptic (or March 25th, 1050 AD, Julian).

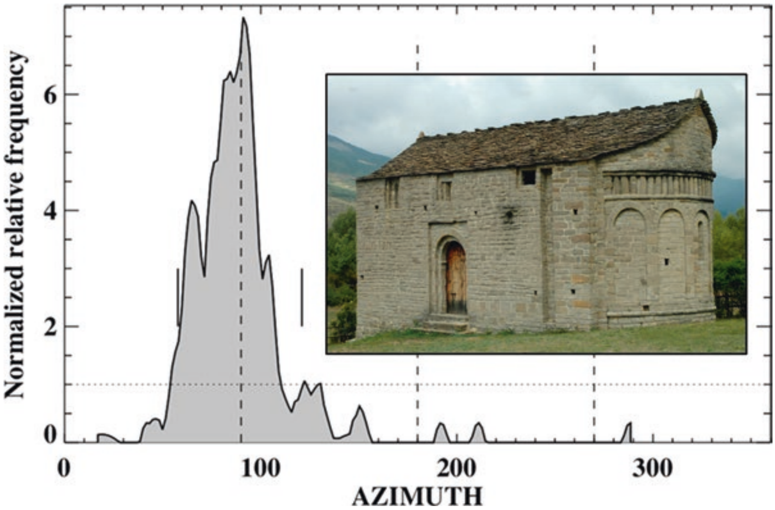

Fig. 10 Azimuth histogram for the orientation of 167 pre-Romanesque churches across the Iberian Peninsula (inset: the Mozarabic church of San Juan de Busa, Huesca). The largest concentration of orientations is towards the eastern half of the horizon with a maximum at due-east. Diagram adapted from González García and Belmonte (2015)

This outcome is quite robust, given the number of churches measured: 167 in total (Fig. 10). Indeed, it would be interesting to test these conclusions thorough investigation of the orientation of the early Romanesque churches in the same geographical area. Further investigation along the *Camino de Santiago* is being carried out in order to analyse whether there was a persistence or a change of the orientation customs of the religious buildings erected in the new style coming from the other side of the Pyrenees. In conclusion, the ‘equinox’ seems to have many faces.

There is a place in the Mediterranean region where the different possibilities for the term ‘equinox’ are extraordinarily manifested: the rose city of Petra. Research in the area evidenced the probable role of astronomy in the orientation and design of Nabataean sacred buildings, which mixed with the analysis of ethnohistoric, ethnographic and epigraphic sources, suggested that Nabataean religion, and its related architecture, could have a pilgrimage component. This could be related to major festivals and a well-developed lunisolar calendar. This phenomenon persisted under Roman rule and the adoption of a new—Julian type—calendar for the province of Arabia. Indeed, a concept close to the equinox, or the ‘entering of the sun in the sign of Aries’, played a major role in the design of these calendars. The Khirbet et Tannur almanac is a nice example of this phenomenology (Belmonte, González García, & Rodríguez-Antón, 2019, and references therein).

Recently, direct observations at various sunsets in March 2018 on days close to the spring equinox have made it possible to verify and somehow qualify earlier outcomes at Petra (Belmonte, González García, Rodríguez-Antón, & Perera Betancor, 2020). For example, on the one hand, the sunset ‘equinoctial marker’ at the Urn Tomb could justify its conversion into the Cathedral of Petra in the fifth Century AD, since the day midway between the solstices or even March 25th Julian apparently are the dates marked on site, although, on the other hand, the precise equinoctial alignment of the Obelisks in Jabal Madbah at sunrise in the astronomical equinoxes could have been used as a perfect milestone for timekeeping and calendar control.

However, it is at Al Madras where Nabataean ingenuity may be most evident (Fig. 11). The observation of spring and autumn equinox sunsets on top of Jabal Haroun, the highest peak in Petra neighbourhood and probably a very important sacred spot for the supreme Nabataean god Dushara, could have acted as the perfect harbinger of the main pilgrimages and feasts to be celebrated in the lunar months of Nisan and Tishri, as confirmed by later ethnohistoric and even ethnographic sources. Al Madras has usually been considered as a secondary suburb of Petra, but these outcomes suggest it was among the most important sacred sites in the city. The day midway between the solstices could also be considered as an alternative, but a true equinoctial alignment seems a much better candidate (Fig. 11). Al Madras equinoctial phenomenology is indeed paradigmatic. It strongly suggests that people in the Middle East were able to determine the precise moment of the astronomical equinox and use it for architectural and symbolic purposes.

Fig. 11 Above: Spring Equinox (March 21st 2018) sunset behind Haroun's shrine when the sun declination was 23 arc minutes, as observed from Al Madras main high-place. The circle represents the sun at 0° declination when the border of the solar disk would set tangent to the present shrine (arrow). Dashed line indicates the top of the observed solar disk. Solid line indicates the edge of the disk for $\delta = 0°$ while dotted-dashed line indicates the top of the corresponding solar disk. Below: The high place where the image was obtained. This is the apex of the Al Madras sacred area in Petra (Jordan), a sacred site for Dushara. Figure by the author, based on images by courtesy of José Ricardo Belmonte

2.3 *Beyond Equinoxes*

The situation is not so clear for other cultures around the planet. The equinoxes were probably known in early China (Pankenier, 2018: 47), but the four-part division of the world in the typical of Chinese city planning seems to be more centred in the realm of the Celestial Emperor in the northern skies than in sunrise at due-east or sunset at due-west.

The situation would apparently be different in India, where Surya Puja temples ought to be considered (Malville & Swaminathan, 1996). In these temples, often orientated to the east, the rising sun is expected to illuminate the sancta sanctorum of the temple at certain key moments of the annual festival, perhaps at the 'equinoxes'.

However, a recent analysis of the orientation pattern of more than one hundred Indian temples shows otherwise (Aller & Belmonte, 2015). The sample includes Hindu and Jaina temples, the latter being mostly orientated north. Of Hindu temples, 74 (82%) of them were orientated within the solar range, with a maximum close to due east, a fact apparently supporting 'equinoctial' orientations (Fig. 12).

However, this is misleading when one goes into the details. For example, the substantial temples of the Chola Dynasty are facing 94° in Gongaikondacholapuram but only 74° in Tanjore. This fact is still more remarkable for the wonderful temples of the Chandela Dynasty at Kajuraho (Fig. 12), since they are predominantly orientated

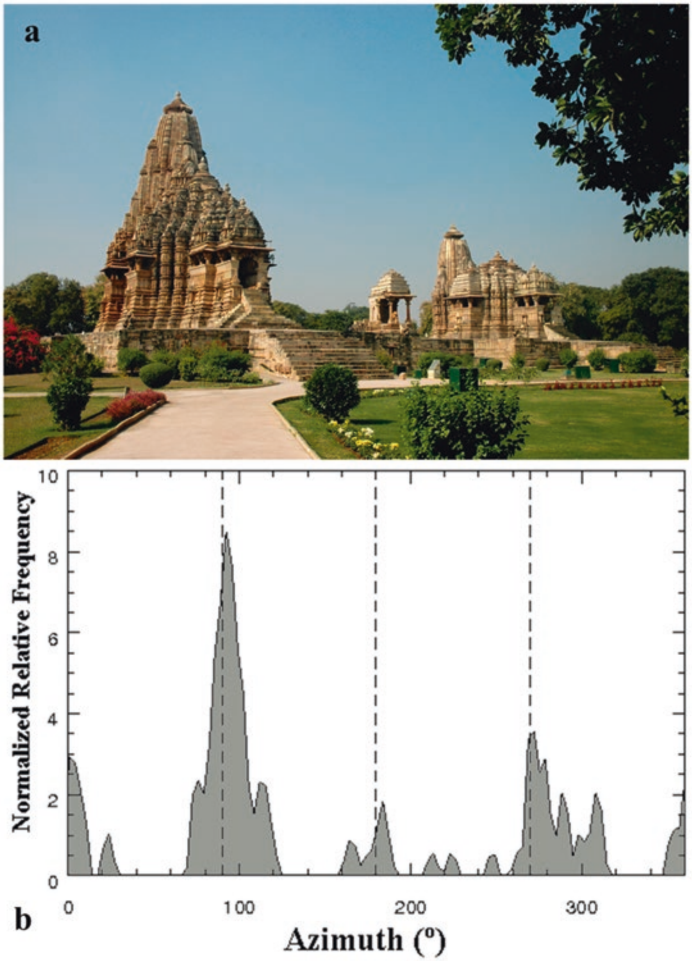

Fig. 12 (**a**) Kandariya Mahaveda and Devi Jagadambi temples in Kajuraho (India; Chandela Dynasty, tenth century AD). These are among the 107 Hindu and Jaina temples measured by the author in November 2007. (**b**) Azimuth histogram of this group, with 74 temples located within the solar range. Notice the peak concentration close to east. Diagram by Juan A. Belmonte

in an interval between 93° and 100°, far from due-east and the equinox. They face a conspicuous chain of mountains in the eastern horizon instead. Actually, only a few shrines of the Hoysala Dynasty in Karnataka, like the Vishnu temples at Somnathpur or the Hoysaleshvara Temple at Halebid are orientated close to due-east (88½° and 91½° respectively) to flat horizons, and hence quite far from any of the different alternatives for 'equinox' discussed in this article for Mediterranean cultures.

Several 'alien' cultures could be explored searching for equinoxes, but I would like to concentrate in only two. The first is the case of Easter Island or Rapa Nui. Liller (2000) proposed that several of the ceremonial platforms or ahu with standing statues or moai of the island were orientated either to the solstices or to the equinoxes, even qualifying them as 'solar observatories'. However, Edwards and Belmonte (2004) performed a new analysis of these sites using data from both archaeo- and ethnoastronomy. Their conclusion was that most of the equinoctial orientations could easily be re-interpreted as orientations to Tautoru (Orion's Belt, Fig. 13) one the most important asterisms of Rapanui mythology, together with Matariki (the Pleiades), and a key instruments for the control of time. Equinoctial solar observatories in Polynesia are at least problematic, if not completely spurious. Clive would certainly agree on this, as his most recent work in Hawai'i demonstrates (Kirch & Ruggles, 2019).

The second case is perhaps the most attractive and shocking. Mesoamerican studies have always contemplated the possibility of equinoctial alignments within the pre-Hispanic cultures of the region (Aveni, 1991: 338) and indeed in their sacred architecture. However, recent statistical approaches to the problem (Šprajc & Sánchez Nava, 2013, and reference therein) have clearly shown that there are patterns of orientation which are closely connected with cultural aspects of various Mesoamerican civilizations, notably with the calendar system. The equinox was not among them!

However, the nicest example of the equinox delusion in Mesoamerica is the 'descent of the serpent' equinoctial phenomenon on the Castillo (the step pyramid of the Feather Serpent) at Chichen Itza in Yucatan (Arochi, 1992). People by the thousands stand today at the site to view the light and shadow effect produced in the eastern stair of the pyramid, as the sun descends on the western sky the day of the equinox (Fig. 14). This phenomenon is today a mass event few people question (but see, e.g., Ruggles & Cotte, 2010: 272).

In astronomy there is an important factor to be taken into account to do correct research: this is the 'selection effect'. This means, not to be selective with the sample of data to be considered, taking into account all possible alternatives. This is exactly what Šprajc and Sánchez Nava (2018) have done when investigating what would happen near sunset at El Castillo several days before and after the equinoxes, when few persons were on site. What they found is astonishing! Figure 14 shows the wonderful light and shadow effect on the eastern stair on April 12th, 2018, 3 weeks after the masses have left the site. On this particular occasion, nine instead of seven light triangles are visible—one for each step of the pyramid. Nine is an important number in Mayan Mythology, seven is not. The reader can get his/her own conclusions. Corollary: do not go to observe a phenomenon like this only when preconceived ideas suggest, check alternatives.

Fig. 13 Edmundo Edwards and Juan A. Belmonte, serving as a reference scale, in front of the seven moai of Ahu A Kivi (Rapa Nui). These are exceptionally facing the sea and possibly orientated towards the helical setting of Tautoru (Orion's Belt) as would have occurred c. 1300 AD. This astronomical event was one of the markers of the New Year starting in the following new moon of the Rapanui calendar. Photographs by courtesy of J. R. Belmonte and M. Sanz de Lara

Fig. 14 Images falsifying the equinox phenomenon at Chichen Itza (Mexico). The upper image was taken the day of spring equinox when masses approach the site to envisage it. However, the phenomenology is far more impressive 3 weeks later in mid-April. Photographs by courtesy of Miguel Ángel Cab Uicab (top), Pedro Sánchez-Nava and Ivan Šprajc

So, we must agree with Šprajc and Sánchez Nava (2018) when they argue that such a popular phenomenon as the equinoctial light and shadow effect at Chichen Itza is certainly not a product of Maya ingenuity, but undoubtedly a concept of western mathematical astronomy projected to the pre-Hispanic past.

3 Conclusions: What Equinox?

It is now time to come back to the sentence opening this article: 'it would probably be helpful if the word 'equinox' were simply eliminated from archaeoastronomers' vocabulary' (Ruggles, 1997). Would it be helpful? At the cost of contradicting Clive, my personal answer is yes and no.

Evidence presented in this paper suggests that 'equinoctial' alignments are as variegated as definitions of 'equinox' we might imagine. It may express the day when the sun rises at due east for the pyramid builders of ancient Egypt. It could mean the day midway between the solstices for the ancient Iberians or the Romans. Although in Augustus' era it possibly meant the commemoration of his birthday. For early Christians it meant the Feast of the Annunciation. For the ancient inhabitants of Grand Canary and the Nabataeans there are reasonable doubts of what 'equinox' would exactly mean.

Indeed, the day midway between the solstices seems to be a very simple and intuitive concept, perhaps with more practical utility than the astronomical equinox. Can we also call it an equinox? The Romans did so. Hence, we could consider it as an open concept, depending on the cultural context we are dealing with. In fact, Hoskin (2001: 18) considers that it is impossible to discriminate the differences between day and night, light and darkness, in the relevant days due to evening and morning twilights. Hence the concept of equinox as 'equal night' is ambiguous. My preference would be to keep it with different levels of meaning and understanding. The 'astronomical equinox' should be kept only for the day when $\delta = 0°$. However, equinox (without adjectives) could be kept at a cultural level for the day midway between the solstices or a similar date, whenever the term would not be misleading. Statistical significance or textual evidence would be desirable in either case.

Finally, a few examples of other astronomical traditions have been explored. The conclusion is simple. Clive was correct: finding for other cultures a concept similar to western equinox was far from simple and can certainly 'make no sense at all' (Ruggles, 1997).

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Their Equinox: Mesopotamian Conceptions of Solstices and Equinoxes

John Steele

1 Introduction

In his well-known 1997 article "Whose Equinox?", Clive Ruggles highlights a significant methodological problem within archaeoastronomy: the imposition of modern (Western) ideas of what constitutes a significant astronomical event upon ancient and/or non-Western cultures (Ruggles, 1997). To illustrate his point, Ruggles takes the example of the equinox. Archaeoastronomers, and, according to Ruggles, increasingly archaeologists, have frequently claimed that various monuments, buildings, etc., possess "equinoctial alignments", tacitly understood to be the direction towards either the position on the eastern horizon at which the sun rises or the position on the western horizon at which the sun sets at the equinox. But as Ruggles points out, it is important to examine closely what we mean by an "equinoctial alignment", or, more fundamentally, what we mean by an "equinox". And, perhaps even more importantly, whether the culture we are studying had the same interpretation of what an equinox is as our modern definition and, indeed, whether the equinox was a meaningful and significant concept at all within their worldview.

In modern astronomy, an equinox is defined as the moment at which the sun crosses the celestial equator. At that moment, the sun will have a declination of 0°, day and night will be of equal length, and, assuming a perfectly flat horizon, the sun will rise due east and set due west. In fact, only the first of these statements is accurate in practice. Because the sun reaches the equinox at a precise moment and continues to move after it has reached it, day and the following night will only be equal if the moment of equinox coincides with the moment of sunset (and even this is not precisely true because the sun's speed is not constant); similarly, the sun will only rise precisely due east if the equinox occurs exactly at sunrise and only set due west

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J. Steele (✉)
Department of Egyptology and Assyriology, Brown University, Providence, RI, USA
e-mail: john_steele@brown.edu

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if it occurs exactly at sunset. Thus, we have three definitions of the equinox which are not precisely the same: true astronomical equinox when the sun has a declination of 0°, the day at which day and night are (most nearly) of the same length, and the day at which the sun (most nearly) rises due east or sets due west at a flat horizon. Observationally, therefore, the equinox can be determined either by direct observation of its declination using a calibrated instrument such as an equatorial ring (which requires both the concept of a celestial sphere and precise knowledge of geographical latitude), by measuring the length of day or night, or by observing the sun's rising or setting azimuth. All of these methods will have different types of uncertainties built into them: How precisely can an instrument be aligned and how accurately is a site's geographical latitude known? What tool is used to measure the length of day and night and what is its error? And how flat is the horizon and how well is the east-west line known?

The aim of this paper is to examine how one particular group—the people of ancient Mesopotamia, i.e., the area of ancient Iraq and its neighbours, during the last two millennia BC—conceived of solstices and equinoxes. Even within this group we may expect some diversity of understanding of these phenomena: the popular and scholarly conception may have different and even among the literate elite we should not necessarily expect that the authors of literary works, for example, and the scribes who wrote astronomical texts agreed on precisely what is an equinox, nor that this understanding remained constant over more than 2000 years.

I begin this paper by presenting a brief overview of Mesopotamian calendars before examining a range of textual sources which refer to solstices and/or equinoxes in order to try to answer a very basic question: in those texts, were the solstices and/or equinoxes defined calendrically, i.e., by their position in the year, temporally, i.e., by the length of daylight, or spatially, either with reference to the place on the horizon when the sun rises or sets or to the intersection of the ecliptic and the celestial equator, or by a combination of these possibilities?

2 Mesopotamian Calendars

The basic Mesopotamian calendar used over the whole of the period from which we have written evidence (late fourth millennium BC to first century AD) employed lunar months which began on the evening of the first visibility (observed or in later times often calculated) of the new moon crescent (Steele, 2011). A normal year contained 12 months. In order to keep the calendar in line with the seasons, in certain years an extra "intercalary" month was inserted, usually after either the 6th or the 12th month of the year. For most of Mesopotamian history, the decision over when to intercalate was ultimately the decision of the king, and kings could—and sometimes did—make this decision for short term gain, for example in bringing forward or delaying the payment of taxes and tributes. Several schemes providing astronomical criteria for when to intercalate are attested from the early first millennium (Hunger & Reiner, 1975; Ratzon, 2016; Hunger & Steele, 2019: 209–213), but we do not know whether they were ever used in practice. Beginning in the early fifth century BC, however, a fixed 19-year cycle of intercalation was adopted and, as far as we can tell, operated without interruption until the end of our sources in the first century AD (Britton, 2007; Ossendrijver, 2018). According to this cycle, 7 years out of every nineteen contained an intercalary month.

One result of intercalation, whether it was governed by royal decision or followed a regular cycle, was to keep the beginning of the year fairly near to the date of the vernal equinox. We should not *a priori* assume, however, that keeping the beginning of the year aligned with the equinox was the intention of the Mesopotamians: the desire may simply have been to keep the beginning of the year in the early spring and the fact that this is close to the date of the vernal equinox is a by-product of that decision.

Luni-solar calendars, especially those based upon observing the new moon crescent and which have irregular intercalation, make the calculation of things like interest on loans and the payment of rations difficult. Almost certainly for this reason, therefore, a simplified "schematic" calendar was used in many administrative and astronomical contexts. This calendar simply assumed that each month contained 30 days and that there are always 12 months in the year, making a total of 360 days (Brack-Bernsen, 2007; Steele, 2011). This 360-day calendar also appears in certain literary and religious texts where it seems to represent the "ideal" state of the universe at creation (Brown, 2000). It is important to stress, however, that this schematic 360-day calendar, although appearing frequently in early astronomical texts, never operated as a real calendar, nor was 360 days ever thought to the actual length of the year. Instead, it always acted purely as a computational device to simplify calculations.

3 The Early Second Millennium BC

Two compositions preserved in Old Babylonian copies contain the earliest references to solstices and equinoxes: a small part of a Sumerian literary composition concerning the goddess Inana (Brown & Zólyomi, 2001), and an Akkadian text which presents a scheme for the change in the length of day and night over the schematic year (Hunger & Pingree, 1989: 163–164). Neither text refers to the solstices or equinox by name but both are concerned with the length of night on one or more of the solstices or equinoxes.

The relevant part of the Sumerian composition concerning Inana is preserved in two copies. The two manuscripts show some differences, most significantly in switching the order of the two lines relevant to us. These differences do not change the overall content of the passage, however. The passage can be transliterated and translated as given below. The transliteration is a composite of the two sources as reconstructed by Brown and Zólyomi (2001) except that I have reversed the order of the two lines (following their MS B) because the text seems to make better sense ordered this way. The translation follows Brown and Zólyomi (2001) except in translating šid literally as “counted” rather than “normal”. For a detailed discussion of the reading of this passage, see Brown and Zólyomi (2001).

ud-da-ta en-nu-ug$_3$-bi 3-am$_3$ ud gi$_6$-bi-a ba-an-da-sa$_2$
i$_3$-ne-eš-ta ud-da šid-bi ba-da-tur ud gi$_6$-bi-a ba-da-bur$_2$

From today when its (i.e., the day’s) watch is 3 long, daylight is equal to night-time.
From now on the counted length of daylight becomes shorter, daylight converts to night-time.

The passage begins by stating that on a given day the day’s watch, a term which is known from other texts to be used to refer to the whole length of daylight, has the length 3. The number 3 is given without units and can be interpreted in two ways: either as a place value sexagesimal number of the kind found in mathematical texts which can be equated to a measurement value by means of a metrological table of equivalences, or, more simply, as the measurement value 3 with an implied unit. Comparison with later texts suggests that the 3 can be understood as either 3 *mina* or 3,0 (= 180) UŠ. The text continues by stating that on this date daylight is equal to night-time. Thus, both day and night are 3 in length, and the passage is therefore concerned with the date of the equinox defined temporally as day and night being of equal duration in time. The passage then states that as we move forward in time, the length of daylight becomes shorter as part of what had been day becomes night.

The second text, BM 17175 + 17284, presents values for the length of day and night at the equinoxes and the solstices. The text can be transliterated and translated as follows (the transliteration follows Hunger & Pingree, 1989: 163 but the translation is my own):

[*i-na* ^{iti}ŠE.GUR$_{10}$ UD.15.KAM 3 EN].⸢NU⸣ *u*$_4$*-mi* 3 EN.NU GE$_6$ [*u*$_4$*-mu ù* GE$_6$ *mi*]*-it-*⸢*ḫa*⸣*-ru* [*iś-tu* ^{iti}ŠE.GUR$_{10}$.KU$_5$ UD.15.KAM *a-di* ^{iti}SIG$_4$] ⸢UD⸣.15.KAM ITI 3.KAM [*i-na* ^{iti}SIG$_4$ UD.15.KAM 1 EN.NU GE$_6$ *a-n*]*a u*$_4$*-mi i-na-ap-pa*(!)*-al* [… 4 EN].⸢NU⸣ *u*$_4$*-mi* 2 EN.NUN GE$_6$

[*iš-tu* ^{iti}SIG$_4$ UD.15.KAM] ⸢*a*⸣*-di* ^{iti}KIN.^{d}INANNA UD.15.KAM ITI 3.KAM [*i-na* ^{iti}KIN.^{d}INANNA UD.15.KAM 1 E]N.NU *u*$_4$*-*⸢*mu a-na*⸣ GE$_6$ *ut-te-er* […] 3 EN.NU *u*$_4$*-mi* 3 EN.NU GE$_6$ [*u*$_4$*-mu ù* GE$_6$] *mi-it-ḫa-ru*

[*iš-tu* ^{iti}KIN.^{d}INANNA UD.1]5.KAM *a-di* ^{iti}GAN.GAN.È UD.15.KAM ITI 3.KAM [*i-na* ^{iti}GAN.GAN.È UD.15.KAM 1 EN].NU *u*$_4$*-mu a-na* GE$_6$ *i-na-ap-pa-al* [… 2] EN.NU *u*$_4$*-mi* 4 EN.NU GE$_6$

[*iš-tu* ^{iti}GAN.GAN.È UD.15.KAM *a-d*]*i* ^{iti}ŠE.⸢GUR$_{10}$.KU$_5$⸣ UD.15.KAM ITI 3.KAM [*i-na* ^{iti}ŠE.GUR$_{10}$.KU$_5$ UD.15.KAM 1 EN].⸢NU GE$_6$ *a-na*⸣ *u*$_4$*-*⸢*mi i*⸣*-na-ap-pa-al* […] 3 EN.NU *u*$_4$*-*⸢*mi* 3⸣ EN.NU GE$_6$ [*u*$_4$*-mu ù* GE$_6$] *mi-it-ḫa-ru*

[On Month XII day 15, 3 is the wat]ch of the day, 3 is the watch of the night. [Day and night are e]qual. [From Month XII day 15 to Month III] day 15 is 3 months. [On Month III day 15, 1 (of) the watch of the night] converts into day. [… 4 is the wat]ch of the day, 2 is the watch of the night.

[From Month III day 15] to Month VI day 15 is 3 months. [On Month VI day 15, 1 (of) the wa] tch of the day returns to the night. […] 3 is the watch of the day, 3 is the watch of the night. [Day and night] are equal.

> [From Month VI day 1]5 to Month IX day 15 is 3 months. [On Month IX day 15, 1 (of) the wat]ch of the day coverts into night. [… 2] is the watch of the day, 4 is the watch of the night.
>
> --
>
> [From Month IX day 15 t]o Month XII day 15 is 3 months. [On Month XII day 15 1 (of) the wat]ch of the night converts into day. [… 3] is the watch of the day, 3 is the watch of the night. [Day and night] are equal.

The text presents a scheme giving the length of day and night on the 15th of Months III, VI, IX and XII. On the 15th of Months XII and VI day and the night are said to be of equal length. As in the previous text, this length is given as three without a unit (it can again be assumed to refer to either 3 *mina* or 3,0 UŠ), and therefore corresponds to the equinox. On the 15th of Month III, day is said to be of length 4 and night of length 2. These lengths of day and night are reversed on the 15th of Month IX. Thus, the summer solstice is taken to be on the 15th of Month III and the winter solstice on the 15th of Month IX. The scheme states that between the summer solstice in Month III and the winter solstice in Month IX part of the day is converted into night, and vice versa between winter solstice and the summer solstice. Comparison with later texts makes it almost certain that the length of day and night are assumed to vary linearly between the extremes of 2 and 4 at the solstices and that the dates given in the scheme are to be understood as being within the schematic 360-day calendar. These extremes are greatly exaggerated for the latitude of anywhere within Mesopotamia and seem to have been chosen for their simplicity (Brown, Fermor, & Walker, 1999–2000).

Both the passage in the Sumerian literary text and the scheme on BM 17175 + 17284 show a concern with the length of day and night. In BM 17175 + 17284 the length of day and night is connected to four equally-spaced dates in the schematic calendar. Thus, although the texts do not name these dates as the solstices and equinoxes, it is clear that what is of interest to the authors of these texts are the occasions when day and night are of equal length or when they are their shortest and longest. For these authors, therefore, solstices and equinoxes are defined by the length of day and night and, secondarily, by equal divisions of the schematic year.

4 The Late Second and Early First Millennium BC

Table C of the fourteenth tablet of the celestial omen series *Enūma Anu Enlil* (Al-Rawi & George, 1991–1992) contains a list of length of day and night on the 15th and 30th day of each month in the schematic 360-day calendar. The date of composition of *Enūma Anu Enlil* is not known but must lie somewhere in the late second or early first millennium BC; the work was already widely known and copied by the beginning of the seventh century BC. According to this text the lengths of day and night follow zigzag functions with maximum and minimum 4 *mina* and 2 *mina*. The scheme is clearly an elaboration of that found on the Old Babylonian tablet BM 17175 + 17284 discussed in Sect. 3, extended to give values for the schematic dates of the lunar and solar opposition and conjunction. The entries for the 15th of Months III, VI, IX and XII once more refer to the solstices and equinoxes as defined by the length of day and night. For example, the entry for the winter solstice on the 15th of Month IX reads as follows:

> [DIŠ *ina* ^{iti}GAN] ⸢UD⸣.15.KAM 2 *ma* EN.NUN UD 4 *ma* EN.NUN GE$_6$
> [DIŠ *ina* ^{iti}GAN UD].16.KAM GE$_6$ *ana ur-ru i-na-pal* UD^{me} GÍD^{me} GE$_6^{me}$ LUGUD^{me}
>
> [¶ On Month IX] day 15: 2 *mina* is the watch of the day, 4 *mina* is the watch of the night.
> [¶ On Month IX day] 16: night converts to day; the days become longer, the nights become shorter.

This passage is similar to the entry for the winter solstice on the Old Babylonian tablet BM 17175 + 17284. Here, however, it is made clear that the change in the length of day and night occurs each day. Thus, the day after the solstice, part of the night is converted into day and from then on the day will become longer each day and the night will become shorter.

Another text relevant to our discussion dating to the late second or early first millennium BC, which was again widely known and copied by the early seventh century BC, is MUL.APIN (Hunger & Steele, 2019). MUL.APIN is a compendium of astronomical and astrological material including several lists of stars, schemes for intercalation, the intervals between synodic phenomena of the planets, the length of night and the duration of visibility of the moon, and the length of the shadow cast by a gnomon, and celestial omens. Like all of the other texts discussed so far, at the core of all of the schemes in MUL.APIN lies the 360-day schematic calendar.

The scheme for the length of night, and by extension for the length of day, in MUL.APIN is identical to that found in tablet 14 of *Enūma Anu Enlil* with one crucial exception: the dates of the solstices and equinoxes are shifted by one month in the schematic calendar to the 15th day of Months I, IV, VII, and X. References to the length of day and night at the solstices and equinoxes appear at several places in MUL.APIN: in the list of the dates of the first appearances of stars at lines I ii 43, I iii 2 and I iii 9 (summer solstice, autumnal equinox and winter solstice only); in the shadow length scheme at lines II ii 21, II ii 25, II ii 31, and II ii 35; and in the scheme for the length of night at II ii 43, II ii 50, II iii 8, and II iii 8. Like everything we have encountered do far, these entries do not make an explicit reference to the solstice and equinox, but implicitly refer to them be singling out the dates of the longest and shortest day and equal length day and night for special treatment. For example, the shadow length scheme is presented for these four dates during the year and then a short procedure explains how it can be extended to the other months of the year.

Another part of MUL.APIN, lines II I 9—II I 21, provides additional information about the solstices and equinoxes beyond simply giving the dates when the day is longest, shortest, and of equal length of the night (Hunger & Steele, 2019: 142–145):

> DIŠ *ina* ^{iti}ŠU UD.15.KAM ^{mul}KAK.SI.SÁ IGI.LÁ-*ma* 4 MA.NA EN.NUN *u*$_4$-*mi* 2 MA.NA EN.NUN GE$_6$ ^{d}UTU *šá ina id* ^{im}SI.SÁ KI SAG-DU ^{mul}UR.GU.LA KUR-*ḫa* GUR-*ma ana id* ^{im}U$_{18}$.LU *u*$_4$-*mu* 40 NINDA.TA.ÀM *ul-ta-map-pal* UD^{meš} LUGÚD.DA^{meš} GE$_6^{meš}$ GÍD.DA^{meš}

> DIŠ *ina* $^{\text{iti}}$DU$_6$ UD.15.KAM $^{\text{d}}$UTU *ina lìb-bi* $^{\text{mul}}$*zi-ba-ni-tu*$_4$ *ina* $^{\text{d}}$UTU.È KUR-*ḫa u* $^{\text{d}}$*sin ina* IGI MUL.MUL EGIR $^{\text{mul lú}}$ḪUN.GÁ GUB-*azima* 3 MA.NA EB-NUN *u*$_4$-*mi* 3 MA.NA EN.NUN GE$_6$
>
> --
>
> DIŠ *ina* $^{\text{iti}}$AB UD.15.KAM $^{\text{mul}}$KAK.SI.SÁ *ina li-la-a-ti* IGI.LÁ-*ma* 2 MA.NA EN.NUN *u*$_4$-*mi* 4 MA.NA EN.NUN GE$_6$ $^{\text{d}}$UTU *šá ina id* $^{\text{im}}$U$_{18}$.LU KI SAG.DU $^{\text{mul}}$UR.GU.LA KUR-*ḫa* GUR-*ma ana id* $^{\text{im}}$SI.SÁ UD 40 NINDA.TA.ÀM *un-da-na-ḫar* UD$^{\text{meš}}$ GÍD.DA$^{\text{meš}}$ GE$_6$$^{\text{meš}}$ LUGÚD.DA$^{\text{meš}}$
>
> --
>
> DIS *ina* $^{\text{iti}}$BÁR UD.15.KAM $^{\text{d}}$*sin ina li-la-a-ti ina* SÀ $^{\text{mul}}$*zi-ba-ni-tú ina* $^{\text{d}}$UTU.È *u* $^{\text{d}}$UTU *ina* $^{\text{d}}$UTU.ŠÚ.A *ina* IGI MUL.MUL EGIR $^{\text{mul}}$ḪUN.GÁ GUB-*ma* 3 MA.NA EN.NUN *u*$_4$-*mi* 3 MA.NA EN.NUN GE$_6$

> ¶ On the 15th of Month IV, the Arrow becomes visible, and 4 *mina* is the watch of the day, 2 *mina* is the watch of the night. The sun, which rises in the north with the Head of the Lion, turns and keeps moving down towards the south 40 NINDA per day. The days become shorter, the nights become longer.
>
> --
>
> ¶ On the 15th day of Month VII, the sun rises within the Scales in the east, and the moon stands in front of the Stars behind the Hired Man, 3 *mina* is the watch of the day, 3 *mina* is the watch of the night.
>
> --
>
> ¶ On the 15th of Month X, the Arrow becomes visible in the evening. 2 *mina* is the watch of the day, 4 *mina* is the watch of the night. The sun, which rises in the south with the Head of the Lion, turns and keeps coming up towards the north 40 NINDA per day. The days become longer, the nights become shorted.
>
> --
>
> ¶ On the 15th day of Month I, the moon stands in the evening within the Scales in the east, and the sun in the west in front of the Stars behind the Hired Man. 3 *mina* is the watch of the day, 3 *mina* is the watch of the night.

In addition to giving the standard values for the length of the day and night on the dates of the solstices and equinoxes found elsewhere in MUL.APIN, each section also comments on the position of the sun as it rises on those dates. The two sections for the equinoxes state that the sun rises in the east with the constellation the Scales (Libra) at the autumnal equinox and sets in the west between the constellations the Stars (Pleiades) and the Hired Man (in Aries) at the spring equinox. The moon is said to be in the same position but at the opposite equinox, which is as we would expect since in the schematic calendar the equinox is on the 15th day of the month and so the moon and sun are in opposition. The references to east and west use the terminology *ina* $^{\text{d}}$UTU.È and *ina* $^{\text{d}}$UTU.ŠÚ.A which literally refer to the rising and setting sun and seem to be used to refer to the general easterly and western horizons rather than the points due east and due west. The same terminology is used elsewhere in MUL.APIN to indicate whether a planet is rising in the east or the west. For example, line II II I 61 reads (Hunger & Steele, 2019: 148–149):

> DIŠ $^{\text{mul}}$*dele-bat lu ina* $^{\text{d}}$UTU.È *lu ina* $^{\text{d}}$UTU.ŠÚ.A IGI.LÁ-*ma* 9 ITI.MEŠ *ina* AN-*e* GUB-*ma i-tab-bal*

> ¶ Venus becomes visible either in the east or in the west, stands in the sky for 9 months, and disappears.

Thus, the phrases "rises in the east" and "in the west" here simply indicate which horizon we are looking at.

The entries for the solstices also give the position of the rising sun stating that it is in the "north", for summer solstice, or the "south", for winter solstice. Here "north" and "south" are given in terms of wind directions, which are commonly used to roughly indicate cardinal directions (Horowitz, 1998: 195–200). In the entries for both solstices, the sun is said to rise with the Head of the Lion (Leo), but this is almost certainly a textual error: the sun will rise with the Head of the Lion at the summer solstice according to the presumed date of the solstice and the first appearance of the Head of the Lion given elsewhere in MUL.APIN, but because the rising position of stars does not change over the year, at the winter solstice the sun will be a long way from the Lion. What is important, however, is that the text states that the sun rises in the north at the summer solstice and then "turns and keeps moving down towards the south", and similarly at the winter solstice, the sun rises in the south and then "turns and keeps coming up towards the north". Thus, the dates of the solstices are associated with the most northerly and southerly rising points of the sun. The text continues by stating that something changes by "40 NINDA per day". A NINDA is a unit of distance but is also used as a unit of time. Given that the statement of a change of 40 NINDA per day directly follows the statement that the sun's rising position moves to the south/north, it would be tempting to see this change as referring to the change in azimuth of the sun's rising point. However, a close study of this passage reveals that this is not the case: the 40 NINDA per day, which is equal to 0;40 UŠ and equivalent to 0;0,40 *mina* is the daily change in the length of daylight. The passages end with the familiar statements that following the solstices, the days become shorter/longer and the nights become longer/shorter.

This section of MUL.APIN, therefore, shows that an additional, but clearly secondary, characteristic of the solstices is that the sun's rising position is to its northern and southern extremes at the summer and winter solstices respectively. By contrast, the equinoxes seem to be defined only by the equal length of day and night.

5 The Neo-Assyrian Period

All of the texts that I have discussed so far present the four dates in the schematic 360-day calendar on which the length of day is either longest, shortest, or equal to the length of night, corresponding to the summer solstice, the winter solstice, and the two equinoxes respectively. These dates are themselves schematic not reports of observations—they are placed at equal divisions of the schematic year and on the fifteenth day of a month when the moon and sun are in opposition, a situation which in reality can never happen within the same year. We have also seen that one section of MUL.APIN added a secondary characteristic to the dates of the solstices, namely the extreme northern and southern rising points of the sun. However, these early texts present no evidence of the observation of the solstices and equinoxes nor do they give names for these phenomena. This situation changes in the seventh century

BC. Among the preserved correspondence between scholarly advisors and the Neo-Assyrian kings, which contains reports of observed astronomical phenomena which are important for divination and/or for the management of the calendar, we find three reports of equinoxes and one of a solstice with what becomes standard terminology to identify these phenomena. Giver the type of text these reports are found in it is very likely that they refer to observations of these phenomena.

Let us consider the three reports of equinoxes first. The three reports are all very short giving no more than the date (month and day—the year is not usually given in these texts), a formulaic statement about the equinox, and a standard closing blessing. They are all believed to have been sent by a certain Nabû'a, who lived in the city of Assur, to the king in Nineveh (Hunger, 1992; see also the discussion in Kugler, 1909–1924: 18 and Parpola, 1983: 359–361). The report SAA 8 140 is typical:

> UD.6.KÁM *šá* $^{\text{iti}}$BÁR *u*$_4$*-mu ù mu-ši šit-qu-lu* 6 DANNA *u*$_4$*-mu* 6 DANNA *mu-ši* $^{\text{d}}$PA $^{\text{d}}$AMAR.UTU *a-na* LUGAL BE*-i-ni lik-ru-bu*
>
> The 6th day of Month I. The day and the night were in balance: 6 *bēru* is the day, 6 *bēru* is the night. May Nabû (and) Marduk bless the king, our lord!

The other two reports are identical except that SAA 8 141 gives a date of the 15th of Month I and the date is broken away on SAA 8 142. The fact that the reports give different dates for the equinox implies that these reports are discussing equinoxes in different years and that these are not the schematic dates in the 360-day calendar given in texts such as MUL.APIN but observed dates of the actual equinox in the civil calendar.

The key phrase in this report is "the day and the night were in balance". The verb *šitqultu* is the Gt form of *šaqālu* "to weigh/balance" and is used to indicate that the subjects of the verb are equally balanced. In this case, the subjects are day and night and the text goes on to clarify that their being balanced means that they are both of the same length, namely 6 *bēru* (a *bēru* equals 30 UŠ and is equivalent to two equinoctial hours). It is clear, therefore, that the equinox is here defined by the day and the night being of equal length. As we will see, the term "in balance" becomes the standard way of referring to equinoxes in later texts.

One report, SAA 8 207, written by an unidentified scholar and sent to the king contains a reference to a solstice (Hunger, 1992). Unfortunately, the report is damaged and we do not know which month, and therefore which solstice, is being referred to. The relevant part of the report reads as follows:

> [… UD].⌈15$^{?}$⌉.KÁM ŠÚ [*sin* N]U IGI *šamaš* GUB
>
> […] the 15th$^{?}$, the setting [of the moon was n]ot seen. The sun stood (still).

The phrase "the sun stands (still)" (*šamaš* GUB) is used in later texts to refer to a solstice (both winter and summer) and must refer to the same phenomenon here. The logogram GUB is used to write the verb *izuzzu* which means simply "to stand". In astronomical texts it can have a number of different meanings including being used to indicate that the moon or a planet "stands" (i.e. is visible) in the sky or to indicate that a star or constellations is in a fixed position relative to the other stars. The word must have another meaning here, however. It seems most likely that it refers to the rising point of the sun appearing to stand still for several days at its most northerly or southerly point at the solstice. Thus, this terminology for the solstice seems to give priority to the rising point of the sun rather than to the extremes in the length of day and night. This conclusion is somewhat supported by the absence of a reference to the length of day or night in this record, in contrast to the case of the equinoxes recorded in contemporary texts where the lengths of day and night were stated explicitly.

6 Observational Texts from the Late Babylonian Period

The Astronomical Diaries and related observational texts dating from the sixth to the first century BC regularly record the dates of the solstices and equinoxes using similar terminology to that found in the Neo-Assyrian texts just discussed (Sachs & Hunger, 1988: 26). Equinoxes are again denoted by the term *šitqultu* "balanced" (this is usually written logographically LÁL-*tim*, rather than syllabically as was the case in the Neo-Assyrian texts), but without the accompanying statement that day and night are both 6 *bēru* in length. Solstices are again denoted by *šamaš* GUB "the sun stood (still)".

The majority of reports of solstices and equinoxes in the Astronomical Diaries are followed by the phrase NU PAP "not watched for". Sometimes this phrase is accompanied by a reference to bad weather which prevented the sun from being seen. In these cases the date given for the phenomenon must therefore have been calculated or estimated in some way. Various schemes are attested in cuneiform texts of this period for calculating the dates of the solstices and equinoxes in the civil calendar. One scheme ties the dates of these phenomena to the 19-year intercalation cycle (Neugebauer, 1948, Slotsky, 1993, Hunger & Pingree, 1999: 151–152). According to this scheme the date of the summer solstice increases by 11 days every year except for the 19th year of the cycle where it increases by 12 days. The dates of the autumnal equinox, summer solstice, and spring equinox are calculated from the summer solstice by adding 3 months and 3 days, 6 months and 6 days, and 9 months and 9 days respectively onto the date of the summer solstice. Thus, the solstice and equinoxes are spaced evenly through the calendar year. All reports of solstices and equinoxes in the Diaries dating from the beginning of the fourth century BC onwards agree with this scheme. Almost all of these reports are denoted as "not watched for", but the dates of those without this remark are also in agreement with this scheme suggesting that during this period at least the solstices and equinoxes were always calculated rather than observed. An extension of this scheme provided calculated dates for the first appearance, acronychal rising, and the last appearance of Sirius and selected other stars (Hunger, 2014; Sachs, 1952).

7 Solstices, Equinoxes and the Zodiac

The zodiac—the division of the band through which the sun, moon, and planets move, into twelve equal length parts (“signs”) each containing 30° (denoted in Babylonian texts using the linear-measure unit UŠ)—was developed in Babylonia sometime during the second half of the fifth century BC (Britton, 2010; Steele, 2007, 2018). Although no texts explicitly link the solstices and equinoxes to positions in the zodiac, an implicit connection is made in schemes which link the length of day to the position of the sun in the ecliptic. Three such schemes are currently known. All three are what can be termed “rising time schemes”, which operate by assigning a certain time interval to the time it takes for a given stretch of the zodiac to rise (Neugebauer, 1953; Rochberg, 2004; Schaumberger, 1955; Steele, 2017).

The first scheme links the rising of stretches of the zodiac to the time intervals between the culmination of certain stars known as *ziqpu* stars. It is based upon an earlier calendar based scheme which associates the setting of the sun on dates in the schematic calendar with the culmination of the same stars. This calendar based version of the scheme is itself constructed from the simple function for the length of day and night given in MUL.APIN and therefore places the equinoxes and solstices, defined by the length of day, on the 15th of Months I, IV, VII, and X in the schematic 360-day calendar. This calendar-based scheme is then transferred across to the zodiac simply by equating the date in the schematic calendar with the equivalent position in the zodiac which is then taken to be the position of the sun (e.g. the equivalent of the 1st day in Month I is 1° in Aries). As a consequence, the sun is taken to be at 15° in Aries, Cancer, Libra, and Capricorn on the days of the equinoxes and solstices.

The second and third schemes are embedded within the so-called Lunar System A and Lunar System B systems of mathematical astronomy. In both systems, the length of day is computed from the sun’s position using a table which is based upon different rising time schemes. In System A, the days on which day and night are equal and the days when day is longest and shortest, take place when the sun is at 10° of Aries, Cancer, Libra, and Capricorn. In System B, they take place when the sun is at 8° of Aries, Cancer, Libra, and Capricorn. A further, poorly attested lunar system, Lunar System K, places them at 12° of Aries, Cancer, Libra, and Capricorn (Ossendrijver, 2012: 115).

We therefore have four traditions for the placement of the position at which the sun is at the solstices and equinoxes: at 15°, 12°, 10°, and 8° of Aries, Cancer, Libra, and Capricorn. Despite their being incompatible, these four traditions co-existed. I take this as evidence that positions in the zodiac never became the primary definition of the solstices and equinoxes.

8 Conclusion

Main aim in this paper has been to gather the evidence for how the solstices and equinoxes were conceived by scholars in ancient Mesopotamia. This evidence clearly shows that the primary definition of the solstices and equinoxes was linked to the length of day and night: the solstices were the days on which the day was either longest or shortest, and the equinoxes were the days when day and night were of equal length. The dates of the solstices and equinoxes were considered to be equally spaced through the year, either at 3 month intervals in the 360-day schematic calendar or on dates in the real luni-solar calendar which correspond to equal divisions of the solar year (the Babylonians never distinguished between the tropical and sidereal year and so it is appropriate to talk merely of the solar year). A secondary definition of the solstice and equinoxes was therefore calendrical. In addition, solstices were also defined as the date on which the sun rose at its most northerly or southerly point on the horizon, providing a tertiary definition of the phenomenon. Equinoxes, however, do not seem to have shared this tertiary definition referring to the rising point of the sun.

Given that the primary definition of the solstices and equinoxes related to the length of day and night, it is appropriate to ask how the Babylonians were able to identify when these phenomena took place. What evidence we have of Babylonian time measurement suggests that water clocks were used to measure intervals of time in astronomical contexts. These water clocks, however, were far from accurate: studies of Babylonian timings of eclipses show that timings of more than a few hours often had errors of up to half an hour (Fermor & Steele, 2000; Steele, 2000). Thus, determining when day and night were of equal length or when the day was longest or shortest would have presented many challenges for the Babylonian astronomers and likely produced quite inaccurate results. Similarly, although the position on the horizon where the sun rises at its most northerly or southerly point can fairly easily be measured, because the sun's rising point changes very slowly around the solstices deciding when the sun had reached this point is very difficult. It is therefore not apparent how the Babylonians observed these phenomena.

Observations or solstices and equinoxes must have been made at least occasionally, however. As discussed in Sect. 5, we have four reports of solstices or equinoxes contained in repots sent to the Neo-Assyrian king, and as noted in Sect. 7, although most reports of solstices and equinoxes found in the Late Babylonian Diaries and related texts were computed according to a fairly simple scheme, at least some reports of these phenomena dating to before the fourth century BC seem to refer to observations rather than computations. Furthermore, the 19-year scheme for the dates of the solstices and equinoxes which operated after the fourth century must also have been based upon at least one observation to provide a start date for the scheme. The scheme places the solstices and equinoxes at equally spaced intervals in the solar year. However, because the sun's velocity is not constant, the solstices and equinoxes are in fact not equally spaced: in the late first millennium BC, the interval between the spring equinox and the summer solstice was about 2 days longer than that between the summer solstice and the autumnal equinox, for example. Thus, comparing solstice and equinox dates given by the Babylonian scheme with modern computation we should find differences in the accuracy of the dates of the four solstices and equinoxes. Indeed the dates of the autumnal equinoxes are consistently closer to the dates given by modern computation of the moment of the astronomical equinox than for either of the two solstices or the vernal equinox (Kugler, 1909–1924: 606). This fact might suggest that the scheme was tethered to an observed autumnal equinox in some year, although we cannot exclude the possibility that it is just chance that the dates of the autumnal equinox agree better with modern computation. Whether it was an autumnal equinox, the vernal equinox, or either of the two solstices, however, we still do not know how the date of that phenomenon was determined.

All of the reports of solstices and equinoxes in the Astronomical Diaries simply state the date on which the phenomenon took place. Interestingly, these are always recorded as daytime events, highlighting their connection with the sun; none are recorded as having taken place during the night. Short time measurements of when during the day the solstice or equinox occurred are never given. This contrasts with the situation in later Greek astronomy: the solstices and equinoxes reported in Ptolemy's *Almagest* occur both during the day and night and are usually accompanied by a statement of the approximate time of day when the phenomenon took place (Perdersen, 1974: 129). The reason, of course, is that for Greek astronomers such as Hipparchos and Ptolemy the equinoxes were defined by the sun being at one of the two points of intersection of the ecliptic and the celestial equator and the solstices as the points separated from the equinoxes by 90° on the ecliptic. For the Babylonians, defining the solstices and equinoxes in terms of the length of day and night, a time during the day when the phenomenon occurred would be meaningless. In essence the solstices and equinoxes lasted for the whole day, rather than a specific moment.

This discussion of the way in which the solstices and equinoxes were defined in Mesopotamia has hopefully provided one clear example of the importance of not assuming that astronomical concepts are not universal. Even in the case of astronomies where there is clear evidence of extensive contact, such as between Babylonian and Greek astronomy, underlying concepts can be subtly different and we must not impose our understanding of one conception onto the other culture (for a similar example, see my discussion of the differences between Greek and Babylonian concepts of the zodiac and the ecliptic in Steele, 2007).

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The Hopi Calendar and Some Archaeological Correlates of Horizon Markers

Stephen C. McCluskey

> *We follow [the days] on calendar, but they follow on rocks, by markers.*
> *Elsie Clews Parsons (1920)*
> *Hopi cosmology is utterly entrenched in the proximate landscape; it is not a cosmology, like that of a world religion such as Christianity or of a nomadic society such as the Navajo, which is easily transportable from one geographic locale to another.*
> *Peter Whiteley (1989: 84)*
> *Then the sun rises at the "announcement point" [tingappi]. And when it has risen at that marker [tuvoyla] there, the person who announces Wuwtsim alone knows it, and therefore people learn of it after he has announced it.*
>
> *Anonymous Hopi (Malotki, 1983: 453–454)*

1 Introduction

Since I began studying Hopi astronomy, I have been trying to unravel the details of the horizon calendars of the major Hopi villages. Documentary sources, academic publications, and fieldwork at Hopi provided many clues to the calendars, which led to a general understanding of the framework of the First Mesa horizon calendar (McCluskey, 1990). However, as late as 1996, when Clive Ruggles and I visited Walpi Pueblo to see its scarcely perceptible horizon calendar, I still did not fully understand the details of the planting calendar at First Mesa.

Each Hopi village regulates the times of planting and of some ceremonies using observations of the Sun at natural markers on its own local horizon (Ellis, 1975). This discussion primarily considers the horizon calendar used at the First Mesa

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S. C. McCluskey (✉)
Department of History, West Virginia University, Morgantown, WV, USA
e-mail: stephen.mccluskey@mail.wvu.edu

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villages of Walpi, Sichomovi, and Hano, the latter having been formed by eighteenth-century Tewa immigrants from the Rio Grande Valley. Most of the agricultural and ceremonial activities of the First Mesa villages were regulated from Walpi Pueblo (Crow Wing, 1925; Parsons, 1926: 210). Occasionally we will draw on the less completely documented horizon calendars from Second Mesa (Forde, 1931: 386, Fig. 6b) and Third Mesa (Voth, 1901: 149–152; Titiev, 1938; Malotki, 1983) for comparative insights.

The topography of the Hopi country consists of flat topped mesas that have been deeply cut to form steep-sided valleys. When seen from the valley floors, the relief of the horizon is quite irregular, but when seen from a mesa top, the horizon seems almost flat, with only slight irregularities. Such minor irregularities as mounds, notches in the distant horizon, or the apparent intersection of different ridges that define the horizon are most commonly used as calendric markers. There are a few exceptions to this general pattern, where distant high mountains provide more prominent, isolated horizon markers. The relatively inconspicuous Hopi horizon markers differ from the more prominent markers noted in other archaeoastronomical studies (e.g., Thom & Thom, 1980) and can be taken as representing the least prominent markers known to regulate an astronomical calendar.

2 Types of Markers

Horizon markers are known as tuvoyla (Malotki, 1983: 435, 440), a generic term that applies tomany different kinds of markers (Hopi Dictionary Project, 1998: 697). We can distinguish three particular kinds of Hopi horizon markers: agricultural, ceremonial, and cosmological markers. The agricultural markers, specifically called uyispior naatwànpi (planting points),[1] are common Hopi knowledge (hopinavoti) and are frequently described in the ethnographic literature. Usage examples given for the Hopi word "wuwani'yta, have an understanding of," use the same form for "one who understands the nature of the sun's movement" and "one who understands the workings of an automobile, car mechanic" (Hopi Dictionary Project, 1998: 761), suggesting that the sequence of markers to determine the days of the planting season may not be highly restricted knowledge.

The days of ceremonies, which fall outside the planting season, are determined by distinct observations of the Sun at specific markers, of the phases of the Moon, or of the state of the crops, the details of which are specialized religious knowledge (*wimnavoti*). This esoteric learning (*meewànpi*) is closely held by the leaders of individual rituals and rarely communicated, even to leaders of other rituals,[2]

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[1] *Uyispi*is related to *uyis*, at planting time, (Malotki: 1983, 393–403), while *naatwànpi*relates to the broader concept of *natwani*, cultural or agricultural practices related to the renewal or rejuvenation of life. (Hopi Dictionary Project: 1998, 307–308).

[2] See Reed's discussion (2018: 127–134) of the place of restricted knowledge (*meewànpi*) in various forms of Hopi traditional knowledge. See also Hopi Dictionary Project (1998: 829, *s.v.* knowl-

although occasionally "the people" criticized the observations of these leaders, insisting "they must watch the sun very closely" (Crow Wing, 1925: 101–102). The markers used to determine ceremonial days have only been described in a few rare cases (Zeilik, 1985: S89–S92; McCluskey, 1990: S2–S3, S7–S9).

The four solstitial directions are indicated by cosmological markers, are the named directions for the Hopi and, with the above and the below, have long been recognized as providing a basic organizing framework to the Hopi cosmos (Geertz, 2003; McCluskey, 2015). This cosmological framework is known to all initiated Hopi (McCluskey, 2010: 16–17) and has now become common knowledge among students of the Hopi. The Hopi recognize two kinds of cosmological markers: one is a series of four ritually important natural places which symbolically mark the four directions; the other are direction markers, which accurately mark the places and times of solstitial sunrise or sunset, either on the exact date of the solstice or as an anticipatory marker a few days in advance of the solstices (Zeilik, 1987; McCluskey, 1990).

Observations of the Sun at these agricultural, ceremonial, and cosmological markers provide the detailed structure of the Hopi solar calendar.

3 The Ethnographic Evidence

The identification of the geographic position of horizon markers, the determination of their use, and the consideration of their precision for astronomical observations depends on several different kinds of ethnographic evidence.

3.1 Lists of a Sequence of Markers

The markers on First Mesa's eastern horizon have frequently been described by ethnographers between the 1890s and the 1930s. Alexander Stephen (1893b) wrote a detailed description of these markers in a letter to J. W. Fewkes; his list was incorporated with modifications in Fewkes (1897: 258–259) and in Stephen (1936). Parsons (1920) collected a list of nine plantings which "they follow on rocks, by markers;" she subsequently published (1933: 59–60) their names and general characteristics based on her field work in the 1920s and that of a local Tewa consultant whom she called Crow Wing. All nine of Parsons's markers were identified with the ordered sequence of plantings. Seven of the thirteen horizon markers listed by Stephen and Fewkes can be associated with planting observations.

These lists (Table 1) were collected in different research contexts. In the late 1890s Fewkes and Stephen were investigating the Hopi calendar and its place in

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edge) and Ferguson et al. (2015: 258).

Table 1 Early Lists of Hopi Horizon Markers. Names from Stephen's (1893b) and Parsons's (1933) lists spelled as in original sources; dictionary names provided for comparison with modern Third Mesa orthography (entries in brackets are compounds constructed from dictionary entries)

Hopi dictionary	Stephen's eastern landmarks	Parsons's planting calendar
Taawaki(var. Tawaki): Sun house	1. *Tawaki*: Sun's house	
[Masnamuru]: gray ridge	2. *Masnamüzrü*: gray wooded ridge	
[*Pavöntsomo*]: young corn plant hill [*Koyongqötö'uyisti*]: turkey head planting	3. *Pavüñ'tcomo*: young corn mound	1. *Koyöngkopĕöisti*: turkey's head
	4. *Hoñwitcomo*: derivation obscure; hóñwi, erect	
[*Neveqtsomo*]: side by side hill	5. *Nüvéktcomo*: standing side by side	2. *Nevechumuvayama*: two buttes standing together
Pölmo'okiwta: be hunched over	6. *Pülhomotaka*: a multi-hunch-backed-man	3. *Pölhumuvayama*: round hill
Kwìitsala: narrow neck of mesa top	7. *Kwitcála*: a gap; a narrow mountain pass	4. *Atkyaöisti*: way down planting time
		5. *Pövaimükpöveöisti*: when the wash spreads it
	8. *Taíovi* (?)	
Töötölö: grasshopper		6. *Telĕoitó*: grasshopper planting
Isso'wùuti: coyote woman		7. *Iswurtixöito'*: coyote bitch planting
Owatsmo: rocky hill with boulders all around.	9. *Owátcoki*: rock mound house	8. *Owatsmutix*: rock hill planting
Natalhötsi: a hole through which an opening can be seen at the other end.		9. *Natalöitstix*: rock with hole all the way through
Wunasaqa: ladder made of lumber.	10. *Wü'nacakabi*: wü'na, pole; cáka, ladder	
[*Wakaspaa*]: cow spring	11. *Wakácva*: cattle spring	
[*Pavawkyayki*]: swallow house	12. *Paváukyaki*: swallow house	
Tuyqa: point of a mesa *Hopoqki* northeastern country [at the summer solstice cardinal direction]	13. *Tü'-yü-ka*: the cape *Ho'pokyüka*: summer solstice	

Hopi cosmology; their lists surveyed the major landmarks marking sunrise on the Eastern horizon from winter solstice to summer solstice. Stephen (1893b) added the two cardinal points on the Western horizon: *po-nó-tü-wi,* belly wrinkle, the place of summer solstice sunset, and *lü-há-vwü tcó-tco-mo*, testicle mounds, the place of winter solstice sunset, which are not given by Fewkes. Parsons and Crow Wing were less concerned with cosmology than with the place of the planting calendar in Hopi society, so their lists itemize every stage in the planting cycle, noting minor planting markers separated by as little as Four days. This difference in focus is reflected in the names given to the markers. When a marker has a similar name in both lists, the name is a physical description of the marker; when a marker is unique to Parsons or the same marker has different names in the two lists, Parsons's names frequently end with forms similar to *-öisti,* variants of the terms *-uyis* and *-úyisti,* planting time[3] (Malotki, 1983: 393–400); when a marker is unique to Stephen and Fewkes, or has different names in the two lists, Stephen's names focus more on the physical description of the marker and do not refer explicitly to a planting event. One example of this difference is that Stephen names one site *Owátcoki,* rock mound house, while Parsons names the same site as *Owatsmutix,* rock hill planting. We should recognize that the names appearing in our sources reflect the concerns of the ethnographers who collected the data. Fortunately, our diverse sources provide complementary Hopi perspectives on their horizon calendars.

There are similar lists of horizon markers from the Third Mesa village of Oraibi. One list appears in a transcription of a planting song transcribed by H. R. Voth (1901: 149–152), which lists the names of 11 sunset markers and 10 sunrise markers; many of Voth's markers also appear in a list of 12 sunrise markers prepared by Titiev (1938). These lists have been further discussed in Malotki's (1983: 432–434) detailed linguistic analysis of Hopi temporal concepts. Although these sources provide sequential lists of the horizon markers, they only provide sufficient details to establish the location of a few of these markers.

3.2 Horizon Diagrams Created by Ethnographers or Native Observers

In the 1890s Alexander Stephen drew several horizon diagrams (Fig. 1; Stephen, 1893a, 1936: Maps 4, 12), which clarify the topography and provide measured magnetic azimuths to some of the local landmarks, including two planting markers. Additional horizon diagrams were published by C. Daryll Forde (1931: 386–387) some of which drew on his own field work in the 1930s and the 1913 field notes of Barbara Freire-Marreco and her Tewa consultant, Leslie Agayo. Figure 2 by Agayo associates planting of specific crops with eight horizon markers while Forde (Fig. 3) gives magnetic bearings from an unspecified location, apparently a field located in the valley of Polacca Wash, to six horizon markers, four of which Forde associated with preparing fields or planting crops. Forde also provides (Forde, 1931: 386, Fig. 6b) a "native drawing" of planting markers from the village of Shungopavi on Second Mesa which depicts ten horizon markers from winter to summer solstice, three of which are also used as planting markers in the First Mesa calendar. Titiev

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[3] Parsons does not give names ending in the uncommon term *uyispi*, planting place (Malotki, 1983: 435), which ends with the nominalizing suffix *–pi*, indicating a place (Hopi Dictionary Project, 1998: 409, *s.v.* *–pi* **1**).

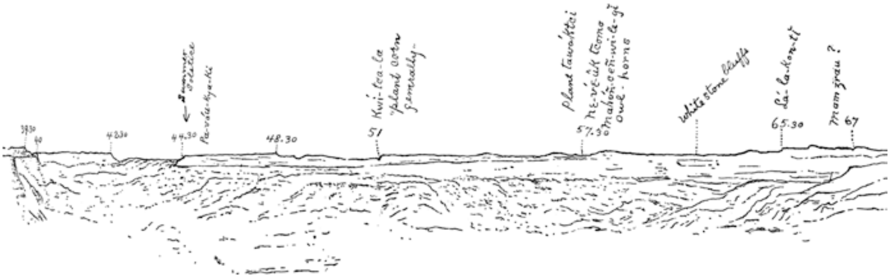

Fig. 1 First Mesa Eastern Horizon from Hano by Alexander Stephen, ca. 1893. (Stephen, 1936: Map. 12). Horizontal scale digitally warped to fit Stephen's magnetic azimuth measurements. Reading from right to left, the more significant markers include two unnamed markers for the autumn Mamzrau and Lalakonti festivals; the marker for the planting of sweet corn, *Nevéûktcomo* or *Mahóñceñwilegĭ* (Owl Horns); the marker for the beginning of general corn planting *Kwí-tca-la*; and the marker for the summer solstice, *Pa-vaú-kya-ki* (Swallow House). Public domain

Fig. 2 First Mesa Eastern Horizon by Leslie Agayo, Tewa Corn Clan, obtained by Barbara Freire-Marreco (later Mrs. Robert Aitken) ca. 1913 (Forde (1931: 387). Reading from right to left, the dashed line indicates the path of the Sun from the winter solstice at *a* to the summer solstice at *p*; the upper lines from *a* to *c* and from *f* to *p* indicate significant details on the local horizon; the remaining elements depict local topography. Point *a* indicates winter solstice sunrise marked by IV, *Kwaatipkya* (Eagle Point); *h* through *j* indicate various early planting points; *k, Pelühomo* (perhaps Fewkes's (1897) *Pavüñ'tcomo*); *l,* Owl Horn Lane (Stephen's (1893b) *Neveqtsomo,* Between Two Mounds); *m,* main corn planting; *n,* the lane (Stephen's *Kwí-tca-la*); *p,* water cellar—point of rocks promontory, summer solstice position

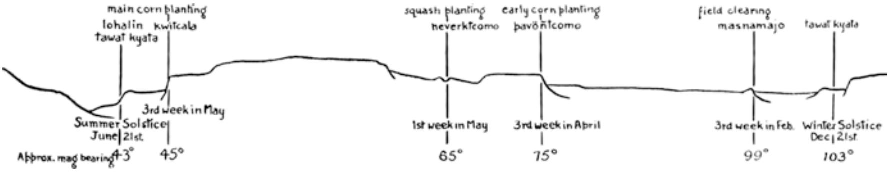

Fig. 3 First Mesa Eastern Horizon from the Valley Floor (Forde, 1931: 386). The horizon details, which contrast significantly with the Sun-watcher's view shown in Stephen's diagram drawn from the mesa top, correspond roughly to the view from a field in the valley of Polacca Wash. Figures 2 and 3 republished with permission of John Wiley & Sons, from C. Daryll Forde, Hopi Agriculture and Land Ownership, *Journal of the Royal Anthropological Institute*, vol. 61, 1931; permission conveyed through Copyright Clearance Center, Inc.

(1938) gives a diagram by Jim Kewanytewa of the sunrise planting markers at Oraibi on Third Mesa.

3.3 Systematic Records of Planting Dates

Parsons (1920) provided the dates of planting at her nine named markers, presumably for the year 1920 and Crow Wing (1920–1921, 1925) gave the dates of planting in 1921 at eight of those nine markers. These two records of Hopi observations are generally consistent and according to Parsons (Crow Wing, 1925: 120, n. 184), Crow Wing's further memoranda of planting and solstice dates for the period 1921–1924 were consistent to within a day or two. Searches of the Parsons archives at the American Philosophical Society have not located these records.

3.4 Interpretation of the Ethnographic Evidence

These planting dates, when combined with astronomical calculations of sunrise and satellite imagery, make it possible to explore the regions indicated by the computed azimuths of sunrise. Google Earth provides several powerful tools to locate the horizon markers. One is its computation of elevation profiles along lines from the presumed location of an observer in the computed direction of sunrise. The highest point on the elevation profile indicates the point on the horizon that is a possible horizon marker. Once such a candidate marker has been identified, its height and geographic coordinates and the height and coordinates of the observing station can be extracted from a map and used to compute a precise azimuth of sunrise or sunset on the recorded dates and a precise distance to the marker.[4] Google Earth's ground view provides a second tool, allowing us to compare the appearance of the horizon (labeled at azimuths corresponding to the planting dates) with the appearance of the horizon markers in drawings from the ethnographic literature, see Fig. 4. In many cases, the name of the marker provides a description that can be compared with the resulting imagery.

Since Sun's houses (*Tawaki*) marking the solstices have been described as being short distances across the valleys on either side of First Mesa (McCluskey, 1990), it has commonly been assumed that, with few exceptions, the ethnographically attested planting markers would also be found in similar locations, which would put them atop the mesa some 9–13 km from the villages of First Mesa. While this is the case for the Third Mesa village of Oraibi (Voth, 1901: 149–152; Titiev, 1938), at First Mesa those horizon markers whose geographic locations have been identified

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[4] The National Geodetic Survey (2012) has produced a useful program for these computations, INVERS3D, which is available as FORTRAN source code, as a PC executable file, or for online interactive computation.

Fig. 4 First Mesa Planting Markers. Google Earth ground view; vertical exaggeration 3:1. White lines indicate planting markers, either computed from dates of plantings in 1921 (Crow Wing, 1925) or other identified markers

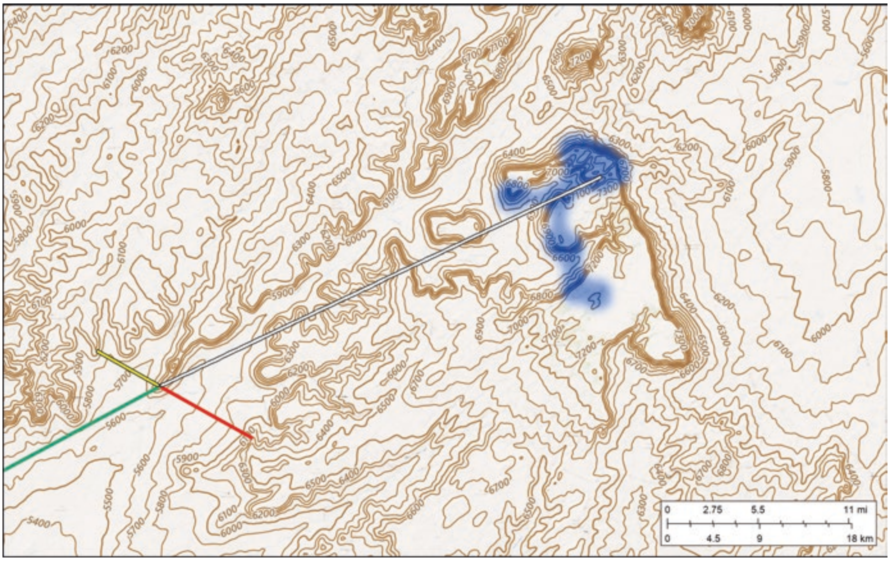

Fig. 5 Map of region of First Mesa Horizon Markers. Lines from First Mesa indicate cosmological direction markers, reading counter-clockwise from four o'clock position: winter solstice sunrise marker, summer solstice sunrise anticipatory marker, summer solstice sunset marker, and winter solstice sunset anticipatory marker (in San Francisco Peaks 127 km to the southwest). Shaded area indicates the general region of Balakai Mesa where calendar markers have been identified. Base map shows contour intervals in feet; from USGS, *The National Map*

(Fig. 5) lie at more distant points that define the horizon, varying from 40 to 50 km from the First Mesa villages.

Since the highest points on elevation profiles in the directions of sunrise on the recorded planting dates indicate that the points defining the horizon on those dates lie at similar distances, it can be assumed that those named horizon markers which have not been precisely identified also lie on the distant horizon. This continuous series of ten distant horizon markers is admirably suited for highly precise observations anticipating the solstice.[5]

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[5] It is worth noting that a change of the observer's position by 800 m (the distance from Red Cape, at the south end of Walpi, to Hano Village) changes the azimuth of these markers by less than 0.6°.

Table 2 Attributes of First Mesa Planting Markers

Name	Type	Distance (km)	Angular width	Angular height
Pavöntsomo young corn mound	Mound	45	0.55°	2.0′
[a]***Hoñwítčmo*** (alternate)	Mound	40	–	–
[a]***Hoñwítčmo***	Mesa edge	40	–	–
Neveqtsomo two mounds side by side	Gentle “u” notch	40	0.70°	1.0′
[a]***Pülhomotaka*** multi hunch-backed man	Group of mounds	40	1.83°	1.6′
Kwiitsala narrow neck of a mesa top	Notch	50	0.10°	3.6′
Pövaimükpöveö^{i}sti	Notch	50	0.55°	3.1′
Telĕo^{i}tó Grasshopper planting	Overlapping notch	40	–	–
Iswurtixö^{i}to’ Coyote Bitch planting	Mound	50	0.47°	2.5′
[a]***Owatsmutix*** Rock Hill planting	Group of mounds	45	–	0.5′
[a]***Natalö^{i}tstix*** Rock Hole Through planting	Group of mounds	45	–	–

Markers are listed sequentially beginning with early plantings and ending before the summer solstice, thus they appear from right to left on the horizon calendar. Angular heights were computed using different simple refraction models with no significant change in the results. Distances are approximate, rounded to the nearest increment of 5 km.

[a] The exact location of starred markers is uncertain; alternate identifications are given for *Hoñwítčmo.*

4 The Planting Markers of First Mesa

The First Mesa planting markers are at the edge of Balakai Mesa, which is generally some 40–50 km away from the Sun-watchers. It may be significant that this mesa edge formed part of the boundary, described in 1938 as marking the limits of the land claimed by the people of First Mesa (Whiteley, 1989: 28). The markers for the First Mesa planting calendar extended to, and may have defined, the limits of this claim of Hopi territory. Table 2 summarizes the principal attributes of these markers, although it deliberately rounds the distances of markers to the nearest 5 km and excludes their exact physical locations, which are culturally sensitive.

The following brief descriptions provide the appearance of the markers, the ethnographic evidence supporting their locations, the planting activities that they regulate, and the appearance of the markers as seen from Walpi Pueblo.

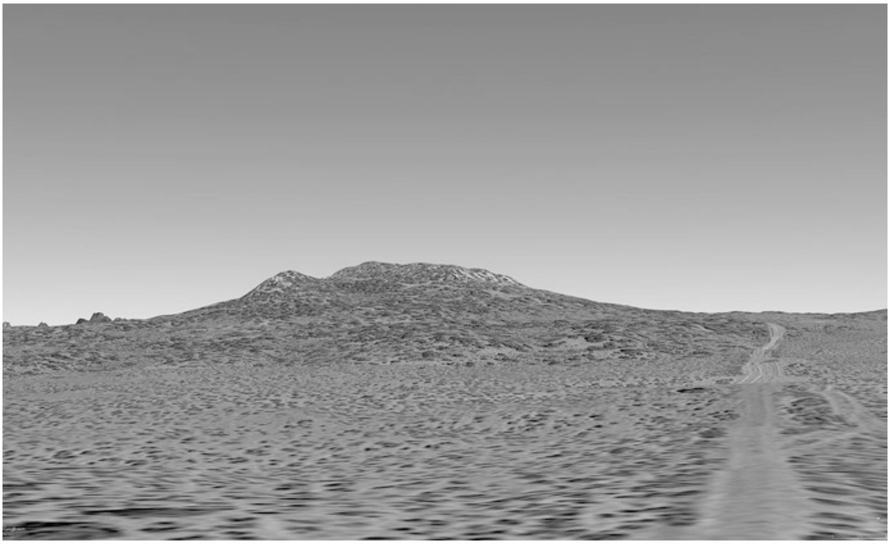

Fig. 6 *Pavöntsomo* from trail. Google Earth ground view, vertical exaggeration 3:1

4.1 **Pavöntsomo** ***(Young Corn Mound)*****/Koyöngkopĕö^{i}sti** ***(Turkey's Head)***

This mound, extending about 800 m from northeast to southwest, rises about 25 m above the general surface of the mesa. Stephen and Fewkes describe it as "located on the old wagon trail to Fort Defiance, a little beyond the head of Keam's Canyon." The mound is just north of what is now an unpaved dirt road (Fig. 6), and about 10 km (6 miles) beyond the Keam's Canyon drainage area. Stephen (Map 12) describes "white stone bluffs," Forde associates *Pavöntcomo* with early corn planting, while Agayo's horizon diagram depicts a mound at this point which he calls *Pelühomo* (rock becomes a mound) and describes it as a marker for early corn planting and watermelon planting. Forde's Second Mesa horizon calendar identifies a similarly named and located marker, which it names in the plural form, *Pavüntcotcomo*, young corn mounds; this may refer to the other mounds found in the vicinity. Parsons calls this marker *Koyöngkopĕö^{i}sti* (Turkey's head) and, like Crow Wing, describes it as marking the early planting of corn for the katsinas. *Pavöntsomo* is close to the azimuth inferred from Crow Wing's planting dates.

4.2 Hoñwítčmo *Uncertain Location*

The identification of this planting marker is uncertain. It is only mentioned by Stephen and Fewkes, who place it between *Pavöntsomo* and *Neveqtsomo*, but give no further details. Stephen gives its etymology as: "Hoñ-wítč-mo; Hoñ'-wi, pl. of Wü'-nü, erect;" Stephen's glossary (Stephen, 1936: 1319) gives *wü'nü* as "vertical, upright" and Benjamin Whorf's annotation to the glossary gives *wene'fte* as "comes to a standing position, arises." The *Hopi Dictionary* gives *hongva* as the plural of "stand up, get to a standing position," while -*tsmo* is the singular combinative form of *tsomo,* hill. Seen from Walpi, *Pavöntsomo* is separated from *Neveqtsomo* by 8.0°; within that space there is a place 1.4° to the right of *Neveqtsomo* where the distant edge of the mesa begins to rise above a closer ridge line; alternately there is a small upright mound 1.3° to the left of *Pavöntsomo.* Since none of our recorded planting dates or measured azimuths include this site, we lack evidence to resolve this identification.

4.3 Neveqtsomo *(Two Mounds Side by Side)*

The location of this marker is taken as the center between two mounds, which lie about 560 m apart on a north-south line and rise about 10 m above the general surface of the mesa. This marker is almost universally described by some form of this name, although Fewkes contradicted Stephen's translation by reading *neveq*, side by side, as *nuvaq*, snow, and interpreting the Hopi term as "snow mound." Stephen's horizon diagram labels this marker both *Nevéûktcomo* and *Maho'ñsheñwilegĭ* (Owl Horns); Agayo's horizon diagram calls it Owl Horn Lane. The USGS National Map shows an Owl Hat Point within 1.5 km of the marker. It is variously described as marking a time to plant sweet corn, squash, gourds, or melons. Besides being a planting marker, *Neveqtsomo* also marks the *Niman* festival in August, when the Sun rises there on his return to the south (Stephen, 1893b). The marker is close to the azimuth inferred from Crow Wing's planting dates.

4.4 Pülhomotaka *(Multi Hunch-Backed Man)*

Stephen describes this marker as "a series of curves thus ~~~~, a multi-hunched-back-man". The marker is also named by Fewkes and Parsons but with no further specification as to its appearance or location. Stephen and Fewkes associate it with corn planting by the Patki (Water) clan. Agayo's diagram indicates an unnamed gentle undulation in this region which he associates with the main corn planting on level fields. Parsons associates *Pülhomotaka* with the second planting of watermelon. Crow Wing mentions that there would be a second planting of watermelon five days after *Neveqtsomo*, although he was occupied with other ritual activities on that date. Stephen's description suggests that this marker is an extended region on the horizon rather than a single point. Besides being a planting marker, Stephen (1893b) notes that the assembly before the Snake-Antelope Festival occurs when the Sun rises at *Pülhomotaka* on his return to the south. This series of curves is probably a series of mounds atop a ridge located between *Neveqtsomo* and *Kwiitsala*. Although the group of mounds making up this marker has been located, the marker itself spans almost 2° and the specific marker used to establish the planting date cannot be precisely located.

4.5 Kwiitsala *(Narrow Neck of a Mesa Top)*/Atkya'ùyisti *(Way Down Planting Time)*

The topography of *Kwiitsala* is complex; it is a notch in the horizon formed by the two sides of a steep, curved valley cut into Balakai Mesa. Seen from First Mesa, the defining edges of the notch are scarcely separated, yet along the line of sight they are separated by about 5 km. The left edge of the notch is about 5 km farther from Walpi Pueblo than the right edge. The ridge over which the Sun rises is even farther up the valley, about 50 km from Walpi.

Kwiitsala is found in all the ethnographic accounts; it is one of the first planting markers Stephen mentioned in his correspondence with Fewkes (Stephen, 1893a), giving its magnetic azimuth, an etymology, and the fact that it marks the beginning of general corn planting. Crow Wing and Parsons name it *Atkyaö'sti*, or "way down planting time", describing it as the first day of corn planting. The meaning of their term can be related to the Hopi directional term *atkya*: below, lower, or the valley floor,[6] and *'ùyisti*: planting time; from which we might interpret *Atkya'ùyisti* as time for planting in lower fields. Agayo's horizon drawing depicts "the lane" as a marker for later corn planting in the washes in spring; he understands the term "the lane" as a notch in a mesa top as he uses the same term elsewhere (Forde, 1931: 396) to describe the gap (*wala*) separating the villages from the rest of First Mesa.[7] Forde describes *Kwiitsala* as marking the time of main corn planting. The marker is close to the azimuth inferred from Crow Wing's planting dates and to Stephen's measured bearing to the notch; Forde's measured bearing differs significantly, but it is uncertain where he took his measurements. Forde's Second Mesa horizon calendar also uses this notch, which it calls *Wokwalca*, the large gap or large pass. The topography of the notch is so distinctive that there is no reason to doubt its identification.

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[6] Malotki (1979: 151–152) notes that the Hopi morpheme *?oo-* (above) can be identified with the upper surface of the mesa and the morpheme *?at-* (below) with the desert unfolding beneath the mesa plateau.

[7] Compare the dictionary definition of lane: "A narrow way between hedges or banks; a narrow road or street between houses or walls" (OED Online 2019).

4.6 Pövaimükpöveö^{i}sti *(When the Wash Spreads Planting[8])*

Parsons's name for this marker appears to refer to a planting in a field where the wash spreads, reflecting a common location of Hopi fields at the mouths of arroyos, so that rainwater running down these washes spreads over the fields (Bradfield, 1971: 17–19; Forde, 1931: 361–366). Crow Wing associates it with a planting in the Sun-watcher's field, the date of which yields a computed azimuth that can be associated with a distinctive notch on the horizon. The notch as depicted by Stephen in his horizon diagram (Fig. 1) is not as sharply defined as the narrow notch at *Kwiitsala*; Forde's Second Mesa horizon calendar calls this notch *Walcahoya*, the small gap or small pass.

4.7 Telĕo^{i}tó *(Grasshopper Planting)*

The significance of Parsons's name for this marker is uncertain; it is not descriptive and is not a clan name, as there is no Grasshopper clan in Stephen's (1936: 1067–1073) list of clan names. Its use to mark the specific date of planting associates it with the place on the horizon where Smoke Signal Point overlaps the more distant parts of Balakai Mesa to form a notch.

4.8 Iswurtixö^{i}tó *(Coyote Bitch Planting)*

The significance of Parsons's name for this marker, which we may also translate as Coyote Old Woman, is uncertain. It may be a clan name, referring to the Coyote maternal family of the Kokop (fire spindle) clan (Stephen, 1936: 1068, 1071) but Crow Wing (1925: 91) notes that it marks a planting for the Eagle family of the Reed clan. The computed azimuth for this planting date indicates a subtle rise on the horizon, which is probably this marker. The exact location of this marker calls for further investigation.

4.9 Owatsmutix *(Rock Hill Planting)*

The planting date indicates a region on the north edge of Balakai Mesa where there are a series of mounds extending over some 700 m. There is a widespread scatter of large boulders in the area, making it difficult to define the intended rocky mound.

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[8] I have modified Parsons's translation to reflect the Hopi name's reference to a planting (*-ö^{i}sti* = Hopi Dictionary, *uyisti*).

Crow Wing’s (1920–1921) manuscript names this “stone fall planting,” which may indicate the scatter of boulders below a rocky mound.

4.10 Natalö^{i}tstix *(Rock Hole Through Planting)*

Parsons glosses this marker as Perforated Rock. Since the Sun moves very slowly along the horizon in the days leading up to the solstice, this planting marker is not very far from the previous Rock Hill planting. It is probably a particular mound in the group of rocky mounds associated with Rock Hill planting.

5 Archaeological and Ethnographic Correlates

Such a well-documented and well-defined set of horizon markers identifies attributes of horizon markers that can, in turn, be used as correlates for evaluating other sites that archaeological studies suggest may have been used to establish a horizon calendar. We will consider three such correlates for which the Hopi horizon markers provide evidence. The first is the distance of purported horizon markers from the observer; the second is the form or shape of the markers, which is related to the markers’ perceptibility and precision; and the third are the markers’ names, which only become applicable when we have ethnographic or historical evidence for the names that can be traced back to the culture associated with the markers.

5.1 Distance as an Archaeological Correlate

If we consider the distance to the planting markers as a means to identify potential archaeoastronomical sites, we find that the distance to these markers depends on the topography of the particular village where the Sun-watcher makes his observations. At Walpi on First Mesa, the distance to the planting markers ranges from about 40–50 km. At Shungopavi on Second Mesa, which shares a number of planting markers with Walpi, the few identified markers are from 55 to 75 km distant. The recorded sunrise and sunset planting markers at Oraibi on Third Mesa, which have not been identified precisely but are only located in general on the nearby ridges that define the local horizon, are only some 6–12 km from the village. Finally, some well-attested cosmological horizon markers have been found to be as distant as 127 km from Walpi Pueblo (McCluskey, 1990: S5–S7). Although the distance to the Hopi calendar markers varies significantly with the topography surrounding the particular village, the markers are consistently on the most distant visible ridge.

The great distance to the markers enables more precise observations of the direction of sunrise or sunset, and consequently of the day when the Sun arrives at this

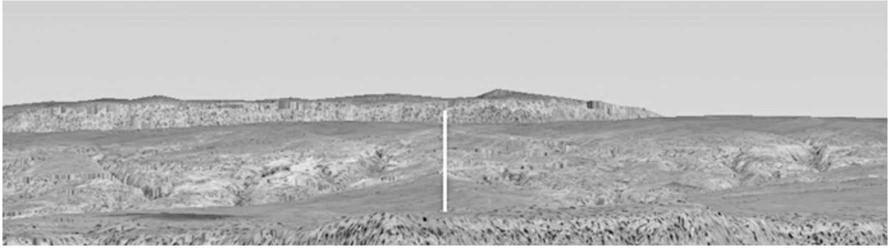

Fig. 7 Neveqtsomo (Two Mounds Side by Side). Google Earth ground view; vertical exaggeration 3:1

marker. One of the markers, *Neveqtsomo* (two hills side by side) illustrates this effect (Fig. 7). Seen from First Mesa, the highest points of the two hills appear to be separated by about 42 arc min. It takes about two days for the Sun to traverse this distance along the horizon, indicating that the place of sunrise can be determined with at least this precision. Estimates of the Sun's rising at the low point between the two hills would allow for even greater precision.

5.2 Form of the Marker as an Archaeological Correlate

Thom and Thom (1980) proposed a typology of horizon markers or foresights, as they called them. Seeking to establish highly precise astronomical observations, they proposed a model in which the form of the marker governed the way the upper or lower limb of the Sun or Moon appeared to graze the markers on the horizon. Most of the calendar markers used by the Hopi can be placed in the Thoms' type V, where the Sun "appears or disappears behind a small irregularity in an otherwise relatively flat part of horizon." A few markers fall in other categories: *Kwiitsala*, for example, might be considered as a variant of type I, where the "limb reappears momentarily in a notch" (Ruggles, 1983: S9) and the cosmological marker for winter solstice sunset is a valley in a distant range of mountains (McCluskey, 1990: S5–S7) that can be placed in type IIIa. Thus we find that the majority of the markers used in this well-documented horizon calendar would fit into a category that Ruggles (1983: S27) considered to be least effective. The flat surfaces and occasional vertical edges provided by the mesas of Hopi country differ from the more irregular profiles found in surveys of British megalithic sites. When we couple this with the steeper rising and setting of the Sun at Hopi versus British latitudes (35° N vs. 55° N), the Thom model is not strictly applicable to the Hopi case.

Our approach to the form of the markers, as summarized in Table 2, is to consider their general shape, for example a mound, a notch, or a more complicated shape, and two elements of their dimensions: the angular width of the marker, as measured from one extreme azimuth to the other, and the angular height or the marker, as measured from its lowest to its highest point.

The angular width is an indicator or the precision with which a single site may yield a precise observation. The least precise site in our data is the series of mounds called *Pülhomotaka,* which spans a range of almost 2° in azimuth; the most precise site in our data is *Kwiitsala,* which spans an azimuth range of only 6 arc min.

In all cases the angular height is significantly less than the angular width. *Kwiitsala,* the most prominent of the markers, has an angular height of 3.6 arc min. Such a compact, well defined site seems to have been favored by Hopi observers, as *Kwiitsala* appears in both the First Mesa and Second Mesa planting calendars. One factor that reinforces the visibility of markers with small angular height is that they are found in a sequence of regular planting markers. The presence of a sequence of markers may be taken to increase the likelihood of markers that would be considered marginal if considered in isolation.

Three First Mesa planting markers, *Pavöntsomo, Kwiitsala,* and *Pövaimükpöveöisti* also appear in the horizon calendar for Shungopavi on Second Mesa, under the names *Pavüntcotcomo*, *Wokwalca*, and *Walcahoya.* These shared markers are all characterized by an angular height in excess of 2 arc min when seen from Walpi Pueblo, or in excess of 1.4 arc min when seen from Shungopavi.

The two hills of *Neveqtsomo* stand only some 10 m above the local terrain; an observer at First Mesa would see them protruding only 1 arc min above the horizon line. This is very close to the limit of visibility and, as Fig. 7 indicates, they are scarcely visible even with considerable magnification and a vertical exaggeration of 3 to 1. And yet these mounds are widely named in the ethnographic literature as planting markers, and Forde (1931: 384) noted that the name *Neveqtsomo* was one of two markers that would be known by “a well-educated Hopi of Walpi” to have a “precise significance.” Although *Neveqtsomo* is only scarcely visible to an uninformed observer, it was recognized by the Hopi as an important part of the planting calendar.

5.3 Names as Ethnographic Correlates

The ethnographic sources provide us with an extensive sampling of the names associated with the markers in the Hopi planting calendar, which indicate the kinds of names that we can expect to find in other horizon calendars. There are four independent sets of names collected at First Mesa by Stephen (1893b) and Fewkes (1897: 258–259), by Agayo and Freire-Marreco (Forde, 1931: 387), by Crow Wing (1925) and Parsons (1920, 1933), and by Forde (1931: 386, Fig. 6a); additional sets of names were collected at Second Mesa by Forde (1931: 386, Fig. 6b) and at Third Mesa by Voth (1901: 149–152) and Titiev (1938). In two of the three cases where the same marker is used at both First and Second Mesa, the markers have distinctly different names at First and Second Mesa, indicating that the planting calendars of nearby villages had a degree of independent development.

The names of these markers (Fig. 8) can provide additional evidence for identifying and locating specific places of sunrise or sunset. The most common names (50%) describe the marker itself, for example *Neveqtsomo*, two mounds side by

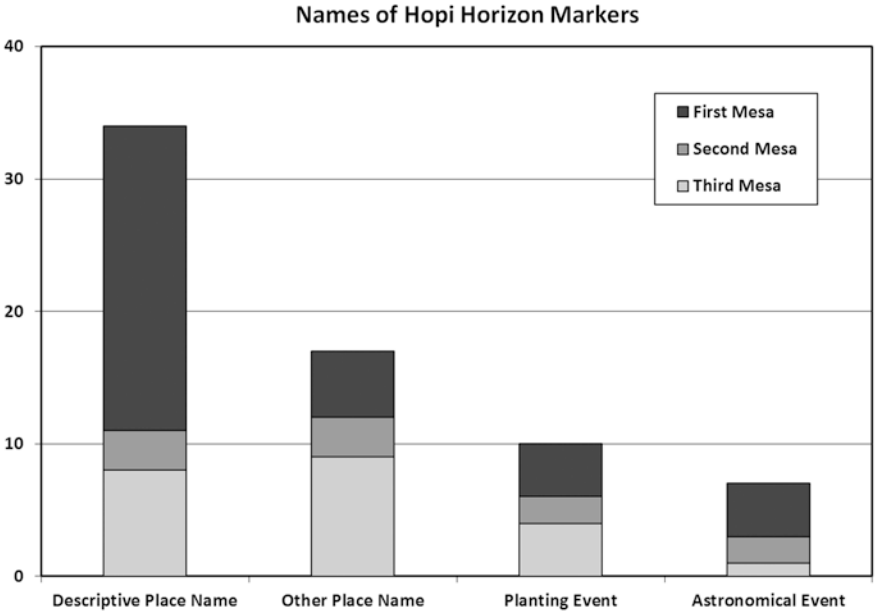

Fig. 8 Types of Names of Hopi Horizon Markers

side; *Kwiitsala*, a narrow neck of a mesa top; or *Natalöitstix,* Rock Hole Through Planting. In some cases the name is sufficiently descriptive to assist the Sun-watcher's observations; in other cases the name refers to such a small detail (a perforated rock) that the description alone does not suffice to identify the marker. The next most common kind of name (25%) is a specific name of a marker that doesn't describe its physical attributes, such as *Polìi-ki*, Butterfly House; *Angwuski,* Crow House; or *Lohalin,* Fish Spring (Navajo *łóó'háálį́* (Linford, 2000: 106)). Names of specific plantings such as *Pavöntsomo,* Young Corn Mound (a specific crop); *Akpitö,* Late Planting (description of a planting), and *Iswurtixöito',* Coyote Bitch Planting (a named planting) form the next 15% of the planting calendar. Markers named after astronomical events are rarely found (10%) in the horizon calendar. There are two *Tawaki* or *Tawat Kyata*, Sun's Houses, marking summer and winter solstice sunrise; in one account the direction of the summer solstice is called *Ho'pokyüka,* the place to the northwest. These unique astronomical names refer to the places where the Sun turns back in his annual travels along the horizon and they thereby identify the places where the Sun rises or sets at the solstices. The rarity of astronomical or calendric references indicates that their absence in the name of a potential horizon marker is not satisfactory evidence against the validity of the marker itself.

6 Conclusions

We must now consider how to apply the correlates derived from the Hopi horizon markers to evaluate the significance of purported archaeoastronomical sites.

The distances found for Hopi horizon markers vary widely from about 5–127 km, depending on the topography of the particular village, so we cannot specify a specific distance criterion; rather any site within this range of distances could be considered acceptable as a potential astronomical marker. The one limiting aspect of the distance correlate is that all agricultural or ceremonial horizon markers[9] are found at the most distant part of the local horizon. Any potential natural marker less than 5 km from the observer, or which does not define the limits of the local horizon, must be considered suspect.

To the extent that the form of Hopi horizon markers is strongly influenced by the local topography of the Hopi country, which yields a horizon of relatively flat plateaus and deeply incised valleys, we cannot insist on the subtle relief found in most Hopi horizon markers. Other, more striking forms of horizon markers are found among the Hopi horizon markers and are *a priori* more acceptable. The surprising result of this investigation is that scarcely perceptible horizon markers, near the limits of human perception, cannot be ruled out as potential astronomical markers.

In ethnoastronomical investigations, we may find a culture's names for sites that are potentially horizon markers. As with the form of a horizon marker, the name of a marker is not determinative. However, given the rarity of astronomical names in the Hopi examples, a name that corresponds to a potential astronomical observation would be a strong indicator of the astronomical use of a horizon marker.

The Hopi horizon calendars, especially the very well-documented calendar of First Mesa, clearly meet Cotte and Ruggles's (2011: 271–272) criteria for the most credible category of archaeoastronomical site: one that is generally accepted within the scholarly community. Although some details of these calendars remain to be determined, there is no doubt whatsoever that the Hopi horizon markers were used to mark the passing of time. It would not be unwarranted to claim that the First Mesa planting and ceremonial markers establish the most well-documented solar horizon calendar known. The correlates derived from these markers provide criteria in response to Ruggles's (2015) call for "more sophisticated methods to assess archaeoastronomical credibility [that]… reflect the current state of theory and practice in the discipline."

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[9] The two cosmological markers of the Sun's Houses, where ritual offerings are deposited at the solstices, are not the most distant points at the solstitial directions (McCluskey, 1990).

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Signs, Not Phenomena: *Moqoit* Cosmo-politics and Alternative Experiences of the Sky

Alejandro Martín López

1 Awaiting Visitors

Since 1999, I have conducted fieldwork among the Southwestern Chaco *Moqoit,* paying particular attention to their experiences and conceptions of the celestial space. I was struck, from the very beginning, by the fact that each time I visited my *Moqoit* interlocutors, I was told that my arrival was expected and they already knew a visitor would come from afar that day. The unexpected appearance of certain birds or the unusual behaviour of domestic animals are interpreted as *señas* (*signs* in English), *netanec* in the *Moqoit* language, of a forthcoming visit.

Within the scope of the celestial phenomena I was studying, the same word, *netanec,* came up repeatedly. Meteors, eclipses, the positions of the Milky Way and a large number of celestial phenomena and entities are also considered *señas* by the *Moqoit.* They carry messages concerning important issues, such as rain, the death of leaders or even changes in the world order.

The central role that signs play in the *Moqoit* life is a common denominator in conversation topics as diverse as health, precarious family economy, political decision-making, love life, or the upbringing of children.

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A. M. López (✉)
Facultad de Filosofía y Letras, Instituto de Ciencias Antropológicas, Sección de Etnología, Universidad de Buenos Aires, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Buenos Aires, Argentina

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Time has revealed that this concept, which permeates all dimensions and scales of the *Moqoit* life, is key to understanding their experience of inhabiting, especially with regard to the sky. Its analysis requires abandoning the distinction between nature and society. In this direction, the present work seeks to explore the particularities of the *Moqoit* cosmos and its eminently social and political character, based on the category of *señas*. It aims to show that a sophisticated experience and conceptualization of the sky, one that does not abide by many of the basic assumptions of Western science, is possible.

2 The *Moqoit*

The *Moqoit* (*mocovíes* in Spanish)[1] inhabit the Southern Great Chaco region of the Argentinian Republic. They belong to the *Guaycurú* linguistic group, as do the *Qom* (*Tobas*),[2] *Abipones*, *Pilagás* and *Caduveos*. These groups must be conceived as part of the same 'ethnical chain' (Braunstein, 2003: 19).[3] From the banks of the Bermejo river, in the northern area of the Argentine province of Chaco, the *Moqoit* gradually moved south during the colonial period. Before the arrival of the *criollos*, they were organized into groups of related families who travelled while carrying out hunting and gathering activities. During the seventeenth century, they incorporated horses and cattle. With the Urízar expedition, in 1710, the *Moqoit* shifted the centre of their area of action to Corrientes and Santa Fe (Argentina). The Jesuits founded missions such as San Javier (1743) among the *Moqoit*.

At the end of the nineteenth century and the beginning of the twentieth century, the advance of colonizers towards the Chaco region from Santa Fe caused many *Moqoit* to return to the south of the current province of Chaco. Both the *Moqoit* who remained in Santa Fe and those who moved to Chaco were gradually forced to enter

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[1] In their own language, (*Moqoit la'qaatqa*), the term *Moqoit* refers to the group that is currently called *Mocoví* in Spanish. Since colonial times, they have been designated with a wide variety of names in Spanish-written documents, such as: *mbocobí*, *moncobys*, *amocobies*, *mbokobí*, *mocoit*, *mokoilasseek*, *bocovíes*, *amokebit*, *mosobíes*, *moscovi*, *mokowitt*, *mokovit*, etc. Today, the members of this community use both the terms *Mocoví* and *Moqoit* to designate themselves, although in recent years the preference for the term *Moqoit* has grown, as a form of cultural vindication. For that reason, we choose the latter to address them here. As it is the most widely used today, the alphabet of A. Buckwalter's *Vocabulario Mocovi* (Buckwalter, 1995) will be used for the transcription of *Moqoit* terms (see the Appendix). When transcribing *Moqoit* or *Qom/Toba* words collected by other authors, however, we will keep their chosen alphabets.

[2] The term with which the members of this group designate themselves in their own language is *Qom*. We will use that word when referring to them, but if quoting other works, we will keep the original term and add *Qom* in brackets.

[3] That is to say, a cluster of ethnical groups with languages and cultures seemingly connected to each other, comprising a sort of 'chain', along which a gradual series of variations occur. This derives in spatially contiguous groups being relatively similar—for example, speaking mutually intelligible dialectal variants—while groups that are further apart in the 'chain' present significant differences—for example, they speak mutually unintelligible dialectal variants.

the labour market, fulfilling harvesting or weeding tasks at logging camps and ranches (Soich, 2007). The abrupt transformations increased tension in the region (Gordillo, 1992). Towards the beginning of the twentieth century, and in this context of exploitation, the *Moqoit* led several uprising movements that carried an important cosmological component (San Javier, 1904; Florencia, 1905; Napalpí, 1924; Zapallar, 1933) and culminated in fierce repression (Bartolomé, 1972; Cordeu & Siffredi, 1971; Radovich, 2014; Salamanca, 2010). By the end of the late 1970s, the presence of non-Catholic Christian churches (Iglesia Evangélica Unida, Iglesia Cuadrangular, etc.) began to gain importance among the *Moqoit* communities (Altman, 2010). This gave place to the local resignification of Reformed Christianity, which is currently a factor of utmost importance in the organization of many *Moqoit* communities. The present-day *Moqoit* population consists of 17,339 people in the Argentine provinces of Chaco and Santa Fe and 671 people in the rest of the country (Figs. 1 and 2). This means a total 18,010 people for the entire country (INDEC, 2015).

The fieldwork which will be referred in this article was carried out between 1999 and 2019 in three rural communities (Colonia Cacique Catán, Colonia Juan Larrea, El Pastoril and Colonia Aborigen Chaco) and one urban community (San Bernardo), all located in the province of Chaco (Figs. 3 and 4). A wide variety of ethnographic techniques was employed: participant observation; structured and semi-structured interviews (both individual and in groups) with a large number of community members (men and women; children, youth, adults and the elderly; leaders, ritual specialists and people who do not occupy central roles in the community's leadership networks); and observation of celestial and meteorological phenomena with various members of the studied communities.

3 Cosmos and Power

As is the case in other *Guaycurú* groups, power is an axis that articulates the *Moqoit* experience of the world (Giménez Benítez, López, & Granada, 2004; Idoyaga Molina, 1995; Terán, 1994; Tola, 2009; Wright, 2008), structured mainly by the human and non-human societies that inhabit it. That is why the management of power (its acquisition, preservation and build-up) and that of asymmetrical power relations (in particular, how to relate with beings of a power greater than the own), is key to understanding their life experience. It can be held that power is in the centre of the *Moqoit* universe's economy[4]; existence itself implies the unfolding of diverse cosmo-politics[5] that organize relations within their own and among other

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[4] Here, we use the term economy in a broad sense, compatible with the concept developed by Pierre Bourdieu (1997) in his general economy of practice. Pablo Wright (2008: 107) refers to a cultural economy of space in a similar manner.

[5] The concept of cosmo-politics was posed by Isabelle Stengers (1997) to account for the multiple and diverging human and non-human worlds and their mutual articulations. Latour (2004: 454) has pointed that 'cosmos' serves here to remove the concept of 'politics' from the exclusively human

Fig. 1 Map with the location of the Chaco Region and the Argentine Republic in the context of South America

societies, either human or not. It is in this context that the *señas,* perceived as hints of the intentions of a great diversity of social beings, become crucial in the organization of the *Moqoit* experience of the world.

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sphere, and 'politics' to eradicate the notion of a given list of relevant entities from 'cosmos'. Other authors such as Marisol de La Cadena (2010) or Mario Blaser (2016) use this concept in a similar fashion. Likewise, our use of the term is related to that of Viveiros de Castro (2010), which can be linked with his comments on Amazonic shamans (Viveiros de Castro, 1996: 119–120). According to the author, the latter are characterized by their ability to 'deliberately cross bodily barriers and adopt the perspective of [other] subjectivities […] in order to manage the relationships between these and human beings' (Viveiros de Castro, 2002: 358). He sees this as a true 'political art, a diplomacy' (Viveiros de Castro, 2002: 358). In this direction, we understand *Moqoit* cosmo-politics as practices and theories on the power relations of diverse human and non-human social collectives, which structure the *Moqoit* world.

Fig. 2 Map of the area with the greatest *Moqoit* presence

For the *Moqoit*, power or *quesaxanaxa* is what makes somebody or something capable of being fertile, rich, plentiful, or of performing an efficient action. Ultimately, any special ability, feature or action requires that its agent owns the corresponding *quesaxanaxa.* This is what Cordeu (1998) would call an active or dynamic conception of power. In his definition, the asymmetric distribution of power is linked to the asymmetrical social relations among beings. This power is not only or primarily something that human beings own, but extends to a great variety of intentional agents. It is particularly abundant in certain beings, protagonists of the 'time of origins'. They form a heterogeneous group known as *poderosos* (beings with a significant amount of power) or *quesaxanaxaic*, deemed especially fertile, bountiful and immoderate because of the scale of their power.

Fig. 3 Example of a rural *Moqoit* community: houses of an extended family in the *Moqoit* community "Colonia Cacique Catán", Chaco, Argentina. Image courtesy of PhD. Agustina Altman

Fig. 4 Example of a *Moqoit* urban community: *Moqoit* neighborhood in the town of San Bernardo, Chaco, Argentina. Image courtesy of PhD. Agustina Altman

4 People, Bodies and Power

In the *Guaycurú* tales about the ‘time of origins’, references are made to beings who own culture and who have a social life similar to that of the *Guaycurú* themselves, but are called by the names that designate various animal species today. Thus *Qaqare* (carancho, *Caracara plancus*), *Pobé* (turkey vulture, *Cathartes aura*), *Mañic* (rhea*, Rhea americana*) and many others, are central characters in many stories. Their physical appearance is sometimes described in anthropomorphic terms, and in other cases in relation to current animal species. In any case, the change from one shape to another is usually quite fluid. Some of the most important tales describe radical changes in the life of these beings, often after a great cataclysm (such as a flood or a gigantic fire, among others). Upon such events, some of these beings adopted an anthropomorphic appearance and became the ancestors of the current *Guaycurú*. Others, with an animal or—less frequently—vegetable appearance, are the origin of the present fauna and flora. According to the classic interpretation, these tales speak of the ‘transformation’ of certain animals into ‘human beings’ due to cataclysms. In the mythical past, these are thought to have been ‘talking animals’ like those in Aesop’s fables, and later became ‘true humans’ permanently.

These readings do not fully comply with the *Moqoit* and other *Guaycurú* accounts on the corporeality of many powerful beings still present in the world, which can assume a great diversity of shapes, ranging from vegetables or animals to humans, and even meteorological and astronomical phenomena (such as rainbows, storms, lightning, and meteorites) (Giménez Benítez, López, & Granada, 2002). Some humans, such as the *pi’xonaq* or male shamans and *pi’xonaxa* or feminine shamans, also have the ability to manifest in animal or meteorological shapes. Certainly, there are also humans, animals, and plants that can only assume one shape, but even they can take on other appearances in a particularly powerful realm: dreams.

In recent years, studies on corporality, personhood, and the classification of living beings have flourished in Chaco (Medrano, 2013; Medrano, Maidana, & Gómez, 2011; Rosso, 2010; Suárez, 2012; Tola, 2005, 2009, 2010). Through them, we have learnt a lot about the fluidity and porosity of body limits, the relevance of fluid exchange and the way in which it carries intentions. We have also learnt that multiple intentional agents can coexist in the same body and multiple bodily regimes can be available for the same intentional agent. Beyond their rich ethnographies and interesting analyses, several of these works have adopted a view strongly influenced by perspectivism and animism, both proposed as models of ‘Amerindian thought’ by specialists in Amazonian groups such as Viveiros de Castro (2002) and Descola (2012). We believe the models built based on Amazonic ethnographies are limited when trying to apply them to the c*haqueño* groups.[6] As we have pointed for the

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[6] The dialogue with Amazonic studies is fruitful and can provide interesting elements and suggestions, but, as general interpretative models, perspectivism and animism are insufficient to account for what Chaco ethnographies show.

present case, the defining element among the *Guaycurú* is power. It is the power scale of a being which seems to define the variety of bodily regimes for which it is enabled. This explains why the beings of the time of origins, packed with power, can simultaneously adopt animal, plant, human, astronomical and atmospheric shapes. All these regimes are accessible for them, and they can transit through the most diverse cosmic spheres. However, what cataclysms do is drastically reduce the scale of power of many and with it the variety of their corporeality. Even today, and even among humans, various bodily forms are accessible to those who have enough power, or to everybody in moments of special power such as dreams or ecstasy. Celeste Medrano (2013), developing ideas from Tola (2010), called attention to the centrality of metamorphosis in the *Guaycurú* classifications of animals, and we believe that this is a crucial observation. We add, in line with a long tradition of studies in Chaco,[7] that power is the backbone of these transformations and their possibilities. That is why any classification is circumstantial and relative, as long as what is observed is not organized from the perspective of the *quesaxanaxa* at stake. As Medrano (2016) has stated, the nowadays common reference to humans/non-humans or humans/animals/non-humans/non-animals, should be understood as merely approximate. We should add that it describes, to some extent, the situation at low scales of power, where everything is more 'static'. However, when power rises, like the temperature of a substance on fire, everything becomes more fluid, and the divisions setting apart these categories vanish. Something similar occurs with the cosmos as a whole, including time and space.

5 Power and Space-Time

The shape of physical space is, from the *Moqoit* perspective, strongly modeled by the social trajectories, capitals, and relations among the beings, both human and not, that inhabit it. For the *Moqoit*, physical space is an embodiment of a social field[8] of cosmic scale. Given this group understands social relations as something mainly defined by power, those especially powerful beings called *quesaxanaxacic,* and their links with other beings, have a crucial role in shaping the world.

Therefore, to understand the cosmos as it is described and experienced by the *Moqoit*, we must rethink the structure of 'three main levels'; *'laua,* the central plane that the *Moqoit* inhabit; the underworld; and the sky or *piguem*. This structure has been extensively observed in various *Guaycurú* groups (Cordeu, 1969–1970; Miller, 1975; Terán, 1998a). However, as Wright (2008: 17) suggests,[9] these levels should not be understood statically. Their defining feature seems to be the existence of

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[7] Authors like Cordeu (1998), Wright (2008), Ceriani Cernadas (2008), Citro (2008) and Gordillo (1999), can be mentioned, among others.

[8] Following Bourdieu.

[9] Wright refers to the *Qom*, case, but both groups are strongly related and their conceptions on this matter present numerous similarities.

differentiated domains and the nature of the relationships between them, rather than their exact number or their specific sequence. The same person can set these domains in a vertical or horizontal arrangement (Wright, 2008: 145–149). Indeed, these cosmological models are relational and situational constructions (*Ibídem*: 150), as was suggested for the classification of beings that inhabit the cosmos.

The sky is conceived as the quintessential place of resource abundance and plenty, inhabited by particularly powerful beings. These beings are predominantly feminine, which is related to the assumption that this place is particularly fertile. The brightness of the stars is explained through the notion that the luminosity of beings is proportional to their power. On the other hand, multiple connections exist between the celestial domain and water, which reinforces its connection with the abundance of goods and resources. In fact, almost all of the water available in this region of Chaco is rainwater.

The three world levels are interconnected through a gigantic tree named *nallagdigua,* which is also a path, a river and a dust whirlwind.[10] The *pi'xonaq* and *pi'xonaxa, Moqoit* shamans, climb this tree in their dreams to complete their 'initiation'. This tree-path-whirlwind is the biggest of a system of tunnels that connects different parts of the *Moqoit* cosmos. Any land depression that accumulates rainwater, especially if it does it permanently, is thought of as one of many other gates to this kind of passages.

Among the powerful non-humans are the *dueños* (*neloxoỹac* in *Moqoit*; owners, caretakers or guardians) of diverse spatiotemporal spheres and vital resources. They grant or deny human access to the latter. Something similar occurs with the institutions and agents of the *criollo* world, perceived as entities of great power with which it is necessary to ally in order to obtain resources. The need to resolve the daily challenges that these unequal relationships beget, has led this group to put a great effort into reflecting about the management of asymmetric power relationships.

The *encuentros* (*neuane'e'*[11]; *neuañiguit,*[12] meetings or encounters in English) with these powerful beings structure relations and people, and are thus dangerous but necessary. Moreover, the local space-time in which the *encuentros* take place has itself properties linked to the power of the beings in question (López, 2017). For this reason, the encounter with beings of great power takes place in a space-time that recreates the characteristics of the time of origins, when these beings shaped the world. Certain places in the *Moqoit* ethno-territory,[13] such as the bush, the sky, the path, the water, the night, and the dreams realm, are distinctively conducive to such encounters. When the asymmetry is such, that no violent action of the less powerful

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[10] In the past, humans obtained their food in this river, effortlessly. This happened in the time of origins, when humans also adopted animal shapes. A lack of reciprocity put an end to that era.

[11] To meet it, know it, see it in person.

[12] Met in the path.

[13] We understand ethno-territory as a 'socially built spatiality, linked primarily to collective identity' (Toledo Llancaqueo, 2005: 17). It is a 'lived reality, the symbolic substratum where indigenous resistance and demonstrations gain meaning and structure' (Toledo Llancaqueo, 2005: 22, translation is ours; see also Barabas, 2006).

would allow obtaining what is needed, a concept becomes central: *nañan* (*entrega* in Spanish, surrender), and the associated notion of *na'deenaxac* or *na'maqataxac*.[14] This is frequently translated into Spanish as *pacto* (pact) by the *Moqoit*. The notion of 'pact' refers mainly to the relationship established with the *poderosos*, owners of the plant and animal species or of different places within the territory-such as the bush, especially if it implies a connection between a *pi'xonaq/pi'xonaxa* and a powerful being who becomes his *compañero* (companion) and *patrón* (patron). According to Buckwalter (1995) *nañan* literally means 'he gives himself up' or 'he gives it'; *nañaañiguit* means 'he gives himself up to...', and *nañaanaxac* 'its surrender, its devotion, its dedication':

> The ancient talked to the animals … conversed with it … they got together, the *pi'xonaq,* to tame that animal. (Marcelo Capanci, Colonia Cacique Catán, Chaco).
>
> […] they themselves made a pact with the god, so … that god is already assigned to that person. [That person] is committed to serve that god, and will not devote to anything else. Thus, [if seeking to calm that god] you need to find either that or that person, they have to come to … dominate that [god], tame it […] because there has already been … *pacto*, with that god. [Thus] it leaves and … it calms down. […] *Pact*, *nañaañiguit, nañan,* means to give oneself up to, to surrender. Then it is forever. (Sixto Lalecorí, Colonia Cacique Catán, Chaco).[15]

For the most powerful end of the relation, the *pacto* implies *entregarse* (giving oneself up to), as in surrendering, being tamed (i.e. deposing the hostile attitude). For the least powerful end, it means *entregarse* as in rendering service and dedication to the one that is powerful.

However, both the *pacto* and taming are not restricted to the scope of the relations with the powerful non-human beings. The notion also covers other asymmetrical relations that imply the idea of a permanent association (and consequent change of state). The pact thus works as a mechanism to regulate the link between two poles among which there is a significant power inequality. This eradicates violence from the interaction, while enabling abundance to flow from the most to the least powerful. A particular example is the link between the *Moqoit* and the *Criollos*, considered beings of power.

> Well, the untamed never surrendered, in the past. They went to one place, and lived only by hunting […] In order for them to be civilized, the white man has to go looking for them through masses, through priests. […] Then … they do [a] […] small party, or [they give us a] small help [and] then it is like if in exchange for [that] [..] we did [a] pact [with them]. I mean…, they already dominate us […], with that religion that trespasses us […] [and] that we have to accept (Sixto Lalecorí, Colonia Cacique Catán, Chaco).

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[14] *Na'deenaxac* means 'its agreement', 'its pact', 'its plan'; *na'maqataxac* means 'the pact it does', 'the agreement it does', 'its good behaviour'; and *na'maxachiguit* means 'it makes a pact with'…. (Buckwalter, 1995). This concept is used, for example, in the translation made by the *Moqoit* Roberto Ruíz and the Buckwalter couple from the Mennonite team, of the Genesis passage (Gen. 9, 1–17) on God's deal with Noe following the deluge (Ruíz, Buckwalter, & Buckwalter, 1991).

[15] If not otherwise specified, the person being interviewed belongs to the *Moqoit* ethnic group.

There are also important parallelisms between the process of taming a *poderoso* and that of *calming* or *cooling* oneself *down.* For the *Moqoit,* the exterior control of emotions is in fact an ideal of behaviour.[16]

In sum, the *Moqoit* cosmos is a place modeled by the *quesaxanaxa* of the beings that inhabit it and the asymmetrical relations between them. That is why it is a *socio-cosmos,* where the links among a wide spectrum of intentional agents shape the landscape. Perceiving the 'textures' of the cosmos, is a fundamental way to apprehend the social relations that constitute it. The quotidian experience of inhabiting is, for the *Moqoit*, a corporeal, emotional, and intellectual reading of the status of this complex weave of intentions. In another work (López, 2013) we have assessed how the *Moqoit* cosmological ideas[17] and their cosmographic representations[18] are topologies of power, which define or map from a certain perspective and in a given time this socially qualified space-time. There, we discussed how to 'feel' or experience these space-time 'textures' equals interpreting the intentions of those other beings, packed with power, with whom it is essential to bond. Among the *Moqoit,* this is not just an intuition, but involves intellectual reflection, as well as a cumulus of technical knowledge or 'know-how'. In this context, the concept of *señas* or *netanec* is central. This complex term refers to a wide range of manifestations resulting from the activity of the intentional agents that populate the *Moqoit* cosmos. Voluntary and involuntary, the *señas* manifest the intentions of those who produce them and in turn allow others to 'read' their desires, appetites, fears, and emotions. In this work, as we have already mentioned, we seek to delve into the analysis of this category.

6 *Señas* (Signs): Hints and Messages

In a socialized universe as the one described, the beings and phenomena that European illustrated traditions would qualify as 'natural' are part of a complex interweaving of meanings. Beyond their belonging to very different *Moqoit* categories of beings, they are all inscribed in a wide net of hints that convey intentions.[19]

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[16] Among the *Aymara*, Gilles Rivière (1997: 44) points out that the term *pampachana* serves both to account for the interpretation of the signs of 'nature' and to speak of the search for cosmic and social balance reestablishment.

[17] Cosmological ideas are the notions that make up explicit formulations about the universe as a whole, the beings that inhabit it and the relationships that link them.

[18] Cosmographic representations are descriptions of the shape and regions of the universe often conveyed in graphic supports (such as diagrams, drawings, or maps).

[19] This does not mean that for the *Moqoit* this is the only dimension of all beings and phenomena. These are classified by the *Moqoit*, as well as by other *Guaycurú* groups, in different ways (see, for example, Medrano, 2013) and can therefore be addressed by analyzing other dimensions. However, their character as potential signs, that is, as bearers of meanings and intentions, is fundamental due to the general *Moqoit* idea that cosmos is eminently social. We devote to this particular and crucial aspect in this work.

They do not only hold the potential of delivering messages for those who know how to read them, but they are also carriers of intention and might. Thereby, many events, objects, plants, or animals are referred to as *señas* (*netanec*).[20] This word accounts for both the involuntary 'hints' or 'traces' of behaviour and intentions that diverse beings leave behind,[21] and the voluntary 'messages' with which they seek to intentionally communicate their intentions to others, including humans. The signs are thus potent events (*letanaxanaxac* or *lehuanaxanac*) to be interpreted and on which discernment (*retanta* or *ne'pelanxanta'a*) must be applied.[22] They do not enable to just 'predict', 'guess', or 'speculate' future behaviours or events, but also to understand what has already happened and imbue it with meaning. The socio-cosmos described by our *Moqoit* interlocutors is in constant demand of hermeneutic action.[23] This notion lacks a sense of separation between nature and culture, fundamental for European conceptions of the environment.

The *señas,* as concurrent and complex systems of multiple and contradictory meanings, enable the negotiation of a whole diversity of interpretations, as Gilles Rivière (1997: 42–43) suggests for the *Aymara*. They are thus transformed in a method to manage what in other way would escape human control, allowing to give answers to incorrect human previsions, which are framed in a truth that is always relational and evaluated in action (Rivière, 1997: 37). We agree with this author's affirmation that any 'mistake', far from being thought of in absolute terms, can be corrected by negotiation and exchange (Rivière, 1997: 44). Signs and their meanings are always subject to processes of negotiation and confrontation between the involved interlocutors, which is why there is a true *political economy of signs* strongly linked to disputes for leadership and legitimation. Those negotiations and disputes articulate in shamanic logics, which make strong emphasis on the authority of the spoken word, endorsed by public displays of power. In these logics, *evidentiality*[24] functions as the main a criterion of truth.

A wide selection of examples of the use of this category among the *Moqoit* will be presented ahead. We will also draw upon examples from other *Guaycurú* groups,

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[20] In *Moqoit*, *netanec* means 'its sign' or 'signal of something', 'its mark'; *Netanqa,* 'its various signs'; *netanqaipi,* 'its many signs'. In our fieldwork, we have documented their use, for example, to designate the signs of the presence of a powerful being, or the birds that warned the ancient leaders of the proximity of enemies. These meanings are conveyed in the Buckwalter dictionary (Buckwalter, 1995) and also in the translation that the *Moqoit* Roberto Ruíz and the Buckwalter couple of the Mennonite team made of various passages of the New Testament (Mt. 16, 1–4; Lc. 21, 7–25) referring to messianic and climate signals (Ruíz, Buckwalter, & Buckwalter, 1988).

[21] As happens with the broken branches and tracks of an animal that moves through the bush, that help the hunter identify it species, heading and intentions. In fact, the *Moqoit* understand that the animals themselves and other world inhabitants carry out similar acts of interpretation.

[22] See Buckwalter's dictionary (1995; Buckwalter & de Buckwalter, 2004).

[23] Following Ricoeur (1983 [1965]).

[24] It is important to bear in mind that the *Guaycurú* languages place evidentiality (that is, the distinction between what they witness directly and what is only known by indirect references) at the center of their way of thinking about time and space (López, 2009a: 182–188; Gualdieri, 1998: 289; Messineo, 2003: 166–171).

especially the *Qom*, due to the important linguistic and cultural similarities between them, also observable in the subject matter we address. The examples we will provide come from my own fieldwork, as well as other ethnographic studies, writings by intellectuals from the groups themselves, and historical sources. As can be deduced from what has been discussed in the previous sections, and as was the case for the previously mentioned cosmographies or 'maps' of the cosmos, there is no fixed and abstract order to follow when presenting such examples. Any categorization that the *Moqoit* interlocutors provide us must be understood as the result of a given circumstance, responding to the interests of the person who devises it at that time.

This is not due to a lack of systematicity, but precisely because these practices and knowledge deal with the interpretation of the intentions of various agents with whom the interlocutor is related in dynamic ways. As was stated regarding classifications in other realms, any *Guaycurú* classification is circumstantial and relative as long as it is not seen from the perspective of the *quesaxanaxa* at stake. Because of this, we have chosen to organize the examples following a criterion that we believe will reveal the key role of power in structuring the *Moqoit* universe. To achieve this, we will present the examples based on the spatial and temporal scales involved, since they depend directly on the scale of power of the intervening beings. Therefore, we will go from the great signs linked to exceptional events, of great importance for the cosmos as a whole, to the daily signs that foretell visits or rains, and that are fundamental for everyday decision-making.

7 Cosmic *Señas*

The first group of signs we will address are those referring to the great changes of the temporal cycle, or *changes of era*. These are large-scale events, which affect the cosmos as a whole. The mythical stories mention various cataclysmic events of the past, preceded by different *señas*.

The references to this kind of accounts are very extensive for the Chaco area. Here, four main motives predominate: *the fire, the cold, the darkness,* and *the deluge* (Giménez Benítez, López, & Mammana, 2000). Each of these events provoke 'the death' and metamorphosis of beings. Commonly, they are the violent reaction of diverse powerful beings or of the owner of the sky, *Qota'a*, offended by people breaching the rules of reciprocity or the impositions of the relationship with him (Cordeu, 1969–1970; Susnik, 1984–1985). The testimony of the Jesuit Guevara accounts for one of the most significant signals, linked to the sun:

> They conceive the sun as a woman, and call it *gdazoa*, that means partner. They narrate several tragic adventures about it. Once it fell from the sky, and so deeply touched the heart of a *mocobí*, that he tried to lift it, and tied it, so that it would not fall again. The sky endured the same fatality: but the ingenious and robust *mocobís*, raised it and placed them again on their axes with the tips of sticks.

> The sun fell a second time, either because the ties were not robust enough, or because time weakened their strength. It was then when fire floods spread everywhere, and flames that burned and consumed everything: trees, plants, animals and men. Few *mocobís*, to take cover from the fires, dove into rivers and lagoons and turned into capybaras and caimans. Two of them, husband and wife, sought refuge in the eminence of a very tall tree, from where they watched rivers of fire flow, flooding the surface of the earth; but a flare snatched unexpectedly, scorching their faces and turning them into monkeys. From them, the species of these ridiculous animals was born (Guevara, 1969 [1764]: 562).

The notion of the sun as a sign of changes of era holds validity to this day:

> Each year the young do not realize that when the sun leaves, it goes further north and when in returns it goes further south, this was not the case before, and nobody realizes. [My aunt Erminda] kept track with a plant and recently it was further north. Some do realize, others do not. I asked my aunt why she had said that, and she answered that this was how it would be tomorrow, that to the south the sun would go down lower and lower, there would be more heat and people would die or the antichrist would come. With the sun, the earth can explode (Martina Lalecorí, Colonia Cacique Catán, Chaco, 2010).[25]

Martina's account refers to the traditional importance of the observation of the extreme points of the annual movement of the sun, the solstices, for the *Moqoit*. A broadening of the arch of possible positions on the horizon is associated to a cataclysmic change of conditions on earth. The evangelical influence leads to the idea of a change in the world to be expressed with a vocabulary akin to the book of Apocalypse.

Eclipses were seen as events when both sun and moon were at risk of death, attacked by celestial dogs (Lehmann-Nitsche, 1924b–1925: 70–71, 1927: 150). The *Moqoit* tried to scare them away by making noise. Other versions suggest that lunar eclipses were interpreted as signs that *Luna*—moon, masculine for the *Moqoit*—was attacked by *Sol*—sun, female for the *Moqoit*—(Wilbert & Simmoneau, 1988: 14).

In this sense, Orlando Sánchez provides an interesting *Qom* example[26]:

> … a day full of omens adverse climates due to the METEOROLOGICAL CHANGE that causes a different climate change full of electrical charges in the atmosphere that they never experienced before (Sánchez, 2004: 13)?
>
> … people began to notice changes in the sky the earth from the stars, and some planets unleash luminous objects with great speed and the auroras changed their shadowy reflections, the clouds changed their colors as announcing phenomena or catastrophes and the Milky Way—*So Nqa aic Qatar Mañic*-, expands the rays or strange reflections loaded with storms and signs of earthquakes, thunders and hail out of this time and the prediction of eclipses the relative position of the earth and the sky seem to march together and they start to infuriate the telluric forces of the lands and make their movements felt, a more remarkable thing was the appearance of the celestial bodies and their exits and entrances are highly accelerated and the masses of radioactive minerals enter into a state of fusion, from this

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[25] Interview by Agustina Altman, personal communication.

[26] Given the *Moqoit*, *Toba* and *Pilagá* belong to the same linguistic group and their peoples present close cultural, social, and historical relations, we will use data from these groups throughout this work to support our analysis.

> point the men of yesteryear contemplated the action of the ultraviolet rays that were totally elevated (Sánchez, 2004: 13).

With a vocabulary imbued with scientific notions, taken from the school environment, the text by Orlando Sánchez defines the status of this reading of the sky and earth phenomena. The terms with which he refers to the stars show the relevance of observing their movements, especially heliacal risings and settings.

In our fieldwork, we have frequently been told that the next change of era must be accompanied by a change in the *camino* (path) or *nayic*, that is, the Milky Way. That the current one 'enters' (*dentre*) and another 'leaves' (*salga*) is a *seña* of a change of era. This was expected for '2000', and also for '2003'. These dates were highly inspired by the expectations of the surrounding culture regarding the millennium, as well as by the long millenarian tradition within the evangelical movements. Nevertheless, the expectations about a change of era leading to the end of the domination of the *criollos* over the aborigines, accompanied by cosmological signs, follow a long tradition. It had a strong influence in the Chaco uprisings of the first half of the twentieth century (Cordeu & Siffredi, 1971).

In this context, an account on the mythical origin of the current hardships of the *Moqoit*, refers once again to the *señas*. The *Moqoit* tell a story called "*La Seña*", where their people gradually retrieved the goods that appeared (marked with *señas* indicating what could be taken) by the 'old, ancient or large algarrobo tree'[27] (*Mapiqo'xoic*) and distributed them equally. This paradisiacal situation was interrupted when they took more than they should have taken. Here we transcribe one of the most complete versions that we have collected[28]:

> Before, riches were given to the aboriginal brothers […] [In that time] two brothers were wandering in the bush. They found a cloth [by a tree] and a sign could be seen [in it], [a line]. [They understood] that sign [indicated] they had to distribute what appeared [there] among all [each day] … […] The following day it is said money [appeared] … Money that the ancients did not know. Money on this side [of the line], money on this [other] side, of the line. And that line [means] they have to take [what is] in that side [of the line] and leave the rest. And they have to distribute it among all. The following day: a pen on this side, a pen on this [other] side … with tamed animals. The following day, again, it is said they found little hats, on this side and on this [other] side, little hats. And it all seemed calculated … as … if the Lord was providing [for each and every one]. At the following day, [there are] weapons, […] daggers or bayonets […] Afterwards, commodities on this side, on this [other] side, fully stocked [there was enough for everyone]. Afterwards [on the day that followed] one pot [on each side]. At the following, spoons […] But [after] a whole week, [people] broke the whole sign [because they wanted] to take everything [disregarding the sign indication]. Ahhh! … Look, if [they had] taken moderately [if they had not taken more than what was indicated by the sign] … [On the next day] gold would have appeared [but because of the transgression nothing appeared]. (Marcos Gómez, Colonia Cacique Catán, Chaco, 1999).

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[27] *Prosopis nigra*

[28] For the sake of clarity, we have simplified repetitions and expressions, without altering the account's meaning.

This tale features the traditional *Moqoit* idea of the cosmic tree as a source of free abundance, as mentioned by Guevara. However, in this case, the abundance is not of fish and water, but of the commodities obtained from the *criollos*: pots, fabrics, tools. This story is linked to an interesting asterism, formed by a combination of stars (ξ_1, ξ_2, ο, π, ρ_1 and υ Sagitarii, which comprise the crown of the tree, and several weak stars which delineate the trunk) and the dark spots of the Milky Way (which shape the roots) (Figs. 5 and 6). Once again, this tale relates the image of a tree to the primal abundance of goods, as do the accounts about the world tree. The '*La Seña*' account draws attention because the goods under consideration are manufactured by *criollos* (López & Giménez Benítez, 2009). Thus, the reason for the loss of the original abundance and the introduction, in the mythical time, of the shortages in the *Moqoit* life, now serves to give meaning to the inequality relations between *criollos* and aborigines.

Fig. 5 Silhouette of the old *algarrobo* tree asterism, *Mapiqo'xoic*, formed by a combination of stars joined by imaginary lines, small faint stars and dark areas in the Milky Way

Fig. 6 Old algarrobo tree asterism, *Mapiqo'xoic*

8 *Señas* of the Annual Cycle

Another important set of signs refers to the annual cycle. Since ancient times, (Dobrizhoffer, 1967–1969 [1783]: Vol. II, Chap. VIII, 77–78; Canela cited by Lehmann-Nitsche, 1927: 151) the reappearance around June—after a period of invisibility—of the stellar group known as the Pleiades in academic astronomy and as *Lapilalaxachi* by the *Moqoit*, is a sign of the 'proximity of fruits' and the forthcoming abundance of rhea chicks (Lehmann-Nitsche, 1927: 77–79). It is also a sign of the beginning of the year (Giménez Benítez et al., 2002; López, 2009b). The accounts we have collected sustain this idea and point to *Lapilalaxachi* as the announcer of the frosts that lead to the subsequent germination of seeds. Other testimonies suggest that in the same moment of the year, the reappearance of the central star of the group called 'Orion's belt' in *criollo* astronomy, is a sign that good weather is approaching and the pastures are beginning to grow (Lehmann-Nitsche, 1927: 77–79).

Other works (Terán, 1998b: 242) mention that the song of the bird called striped cuckoo (*Tapera naevia*)[29] between November and January, is a sign of the beginning of the year for the *Moqoit*, but announces disease or plague if its song is too insistent. We have been able to collect testimonies that show that the flowering of the Roman cassie (*Acacia caven*) and the *garabato* (*Acacia praecox*), between the end of August and the beginning of September, is a *seña* of the renewal of the year and the proximity of spring. This sign has been identified in recent times with the beginning of the year (Citro, 2006: 33; López, 2009a). Buenaventura Terán collected testimonies that refer to the beginning of the year being marked with the flowering of the Roman cassie and the reappearance of the red pileated finch.[30] This time implies a renewal of the sun and the moon, which is assimilated to the star renewal that occurs in the changes of era (Terán, 1998a, 1998b: 240). Arenas (2003: 183) points out that the *Tobas* (Q*om*) consider that the great amount of lightning in this period generates the needed 'change' in the trees, so that they go from being without foliage to bearing fruit after a few months.

An account by Virgilio Leiva, *Qom*, (Messineo & Dell'Arciprete, 2003: 34) narrates how the striped cuckoo 'announces' the maturity of fruit. He mentions that 'the song of the striped cuckoo means that fruits are ripe', but this transcends a mere proclamation. Leiva holds that 'the striped cuckoo sings to the fruits so that they mature soon', 'it never sleeps, it does not eat, it does not drink, it does not rest until it dies', since with its singing it 'gives life to the fruits of the trees.' At the end of this task it 'rests by putting its spirit in the ground', 'is somewhere', 'waits for the next year', and once again it 'appears to sing'. Thus, singing is not simply an announcement, but part of the maturing process. It is thanks to the song of the striped cuckoo, through which the bird gives its life up, that the fruits ripen. The song seems to transfer life and power from the bird to the fruits. In the *Moqoit* version collected by Terán, the striped cuckoo looks for his lost wife during the 3 months in which it sings, and remains with her for the rest of the year. Arenas (2003: 184) indicates a similar function is assigned to the creamy-bellied thrush (*Turdus amaurochalinus*) among the *Tobas* (*Qom*).

Terán mentions that, for the *Moqoit* that he interviewed in San Javier (Santa Fe) and in Pastoril (Chaco), the cicada[31] is the owner of ripening. Its song causes fruits to ripen, especially watermelon, corn and the fruits of algarrobo tree. Likewise, the cicada remains '7 months underground and three looking at the world' (Terán, 1998b: 244–245).

A third animal is named by Terán as an indicator of annual cycles, through its seasonal absence and presence: the gold tegu (*Tupinambis teguixin*).[32] For about 6 months, during cold weather, it remains underground, but with the storms that mark the end of the cold season in late August—locally referred to as the Santa

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[29] *Cuckoo* in *Moqoit* (Wilbert & Simmoneau, 1988: 72–75).

[30] *Lesotr'aikolék* in *Moqoit*.

[31] *Nekogek* in *Moqoit*.

[32] C*hilkayk* in *Moqoit*.

Rosa storm—it surfaces again (Terán, 1998b: 246–247). The fork-tailed flycatcher (*Tyrannus savana*) goes 'north with the sun' in the winter and returns in the summer (Terán, 1998b: 248).

Arenas (2003: 188) mentions that among the *Toba (Qom),* the appearance of the white monjita (*Xolmis irupero*)[33] is a sign of the arrival of the cold season. According to the *Tobas* (*Qom*) (Arenas, 2003: 189), the rhea (Rhea americana),[34] the pampa's fox (Lycalopex gymnocercus),[35] and the chalk-browed mockingbird (Mimus saturninus)[36] also emit characteristic cries in this season.

For the *Toba* (*Qom*), the song of the laughing falcon (*Herpetotheres cachinans*)[37] in August, marks the beginning of the north wind season and therefore the lack of water (Arenas, 2003: 191–192). It coincides with the laying of the rhea and the Chaco chachalaca eggs (*Ortalis canicollis*).[38]

9 *Señas*, Leaders and Decisions

When speaking of the leaders of old, it is frequent to hear mentions of their ability to see and interpret *señas* and communicate with different 'helpers' or 'companions', both during wakefulness and sleep, who advised them of the closeness of game or enemies. The *Qom* leader *Nachicyi* or Juan Zorrilla said the following, speaking to Orlando Sánchez about his father[39]:

> My father was a great shaman (natural doctor), quintessential seer, he knew all the secrets of white men, even the most concealed of nature and human beings, of everything that happens abnormally and events in relation to strange people, and bad intentions were revealed to him, nothing was hidden from him. (Sánchez, 2009: 320–321)

An account of the *Qom* Máximo Jorge (Messineo & Dell'Arciprete, 2003: 29) mentions that the famous *Qom* leader *Meguesoxochí* had a little bird, called *vi'ic*, that told him what would happen. The theme of the leader's 'companion' animals, especially birds, but also jaguars and serpents, is recurrent in *Guaycurú* groups. These animals are powerful beings associated with the leader. They provide him with many of the attributes needed to conduct his people in difficult circumstances: mainly, abilities to locate resources and detect approaching enemies. Terán mentions that the *Toba* (*Qom*) designate small, grey birds as messenger birds or *viri nolka* (Terán, 1985: 11). They are also called the 'Nowet birds' and considered

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[33] *Palr'olr'ó* among the *Moqoit*, according to Martínez-Crovetto (1995).

[34] *Mañic* for the *Moqoit*.

[35] *Nowar'air'a* for the *Moqoit*, according to Martínez-Crovetto (1995).

[36] *Pi'xonaxa* in *Moqoit*.

[37] *Kaoó'* in *Moqoit*, according to Martínez-Crovetto (1995).

[38] *Qochiñí* in *Moqoit*, according to Martínez-Crovetto (1995).

[39] Juan Zorrilla's father, *Dashiloqshy*, was active during *Meguesoxochí*'s last days. He had a *Moqoit* half-brother (Sánchez, 2009: 320–321).

shaman messengers (Terán, 1994: 42–43). The *Qom* leader Augusto Soria affirmed that, according to his grandfather, *compañero (*companion) of the famous leader *Meguesoxochi*, the last words of that leader before being captured by the army were that if a small pigeon announcing his coming did not arrive, it would mean something bad had happened to him (Sánchez, 2009: 259). The *Moqoit* testimonies that we collected also assert that the bird called *Qom loo* tells people that visitors will arrive or an enemy is pursuing them. Although its call is easily heard, it is hard to see. The *Rufous Browed Peppershrike* (*Cychlaris gujanensis*), *pisaxasaia* in *Moqoit*, is another bird that may announce visits. The *osi* is a little bird whose whistle in the bush announces the proximity of a Gray Brocket (*Mazama gouazoubira*) to the hunter. If the white woodpecker (*Melanerpes candidus*), *paro'* in *Moqoit*, 'gleefully' cries and flies up and down, people will come from far away. According to Martínez-Crovetto (1995: 88), for the *Tobas* (*Qom*), the flight of the great black hawk over houses (*Urubitinga urubitinga*),[40] announces 'violent acts' (war, revolution or murder) 'outside the indigenous area', or the presence of troops coming to attack them. The same author points that for the *Pilagá*, it forebodes 'something bad'. When the great kiskadee (*Pitangus sulphuratus*)[41] sings flying over the houses, it means the authorities are soon to come looking for someone. According to Jolis, the gloomy song of the owl that he calls Great Dago, advises the *Toba* (*Qom*) of the proximity of enemies (Jolis, 1972 [CA 1789]: 175).

The visit of a 'messenger' can come about in dreams. The *Qom* leader *Nachicyi* or Juan Zorrilla, told Orlando Sánchez what follows about his father:

> […] my father surprisingly summoned his people to share the news that a bird spirit, called *Bochaxat* in *Toba,* brought him at night. This being turns into a woman to contact him when dangers for his people or a death threat are near (Sánchez, 2009: 332–333).

The *Nanaicalo* is a powerful non-human being that tends to manifest as a gigantic snake. It is associated to waterholes and rainbows and manifests through storms, hail and wind. He is especially sensitive to the presence of pregnant or menstruating women close to water. Certain signs can reveal its presence. A *Moqoit pi'xonaq* advised his nephew as follows:

> Son, when you see the wasp […] called *lechiguana*[42] […] it means [that] the *Nanaicalo* [is] close…

And also:

> [That depression], [some] fifteen hundred meters away […] it never dries […] [That is why] people used to say that maybe there is something there [some powerful non-human being]. (Marcos Gómez, Colonia Cacique Catán, Chaco, 2002)

According to Marcos, the unusual behaviour of wasps and the fact that a waterhole never dries are signs of a powerful presence.

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[40] *Olé'* in *Moqoit,* according to Martínez-Crovetto.

[41] *Retokí'* in *Moqoit,* according to Martínez-Crovetto.

[42] *Brachygastra lecheguana.*

Another *Moqoit* described the signs that appeared close to the Laguna de la Virgen, before the *Nanaicalo* was tamed:

> It is said a mild wind blew there, which grew in speed by the minute, with increasing pressure, until a, let's say, wind with earth, arose and did dust storm (Sixto Lalecorí, Colonia Cacique Catán, Chaco, 2002).
>
> Other versions speak of a wind that carried snails (Juan Capanci, Colonia Cacique Catán, Chaco, 2002).

Augusto Soria and Orlando Sánchez also mention the 'reading' of the environment as '*seña'* in the context of the hostile relations with the *criollos*.

> For the signalling of roads they cut tree branches, that with their tip indicated a single direction, either North, South, East or West; and other signs that indicated the proximity of lakes, rivers, water sources; while other signs indicated the dangers of ferocious animals and also the areas guarded by soldiers of the different fortlets controlling the frontier (Sánchez, 2009: 282–283).

We have collected an account that speaks of a *Moqoit* attempt to return to the south, to Santa Fe, the place from where many *Moqoit* got to the Chaco in the early half of twentieth century, running away from the army. The account shows how an intense hail was a '*seña'* that warned the *Moqoit* to stay in that province.

> [The ancients] say that between Santiago [and Santa Fe there is] a kind of ditch, like [a] hole […] [which is] a sign… [that the *Moqoit*] should not cross. They do not cross, neither here nor there. […] [We] aborigines [have lived] here [in the Southwestern Chaco] since 1917, when [the grandparents who went from Chaco to Santiago and from there to Santa Fe] returned […] They returned […] because [they] ran into […] a hail […] Because, these people […] say that they crossed that [ditch] … and a sign [appeared], like smoke, […] a sign that they don't have to go any further, they have to go back [to Santiago]. And […] they returned … more than a thousand people who [had left] from Chaco [and] were already arriving in Santa Fe. But since they [found] that … fog or white drizzle […] they hit the road back. [Because that was a] sign [pointing] they should not move forward. […] There is a … qu[een] of the earth [a powerful non-human female being]. And […] an aborigine says that he arrived, talked with that, lady [a powerful non-human], […] the greatest there is […] [who] sees what is coming. And this aborigine […] [who was like] a guide in front of [the group that marched to Santa Fe], [and who was himself a person with] power […] went inside that hole, [where that] lady [powerful non-human] was, [and] conversed [with her]. [She said to him]: well, brother […] there is danger here ahead; […] you have to return […]. And [that is why] they crossed to […] [the] border [area between] Chaco and Santiago […]. And it is said they arrived here after the '22 (Marcos Gómez, Cacique Catán, Chaco, 1999)[43]

Agustina Altman collected the account of a similar episode:

> [When I was young] I went to Hermoso Campo with my family, for work, and the weather changed there. Everything turned black and an earth storm arose and something similar to a giant ant appeared. It was the father of the ants,[44] and a 'warlock' [*pi'xonaq*] started to sing and everything calmed down. Then he told us we had to leave because, if it came back, it could cover us all with dirt. Candy-sized pebbles fell from the sky (Sixto Lalecorí, *Moqoit* from Colonia Cacique Catán, Chaco, 2010).

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[43] To facilitate understanding, we have simplified repetitions and expressions, without altering meaning.

[44] *Chinaq Leta'a*, the father or owner of ants.

These limitations to mobility are evidently linked not only with the *criollos* and their institutions, but also with the relations with powerful non-human beings. This is so, because no success or special advantage that any human group has is understood without the existence of a successful pact with powerful non-human entities.

10 *Señas* of Everyday Life

In the *Moqoit* daily life, the presence or behaviour of animals is often invoked as a 'sign' of specific events. Among the *Guaycurú* peoples, a 'strange' or 'out of the ordinary' character determines the 'non-human' nature of a being, or helps differentiate between the habitual representatives of a species and their *dueño* (owner) (Wright, 1994). Pointedly, the *unusual* behaviours of various animal species are taken as 'signs'. The animal in question *chooses* to 'communicate' a message to a human, which implies its volition and a bond with its interlocutor. This places the 'encounter' in the realm of the relations with the *poderosos*.

In this context, when a visitor arrives to a *Moqoit* house, it is common for those who live there to comment they already knew he was coming. In general, they report that the appearance of certain birds near the dwelling, earlier that day or in the previous days, announced their visit. For Martínez-Crovetto (1995: 118–119) the fluttering of a hummingbird (*Chlorostilbon lucidus, Hylocharis chrysura, Heliomaster furcifer*), *llimar'añichí* in *Moqoit*, inside a house or above people, indicates the arrival of visitors. Listening to the song of the laughing falcon (*Herpetotheres cachinans*), *Kaoó'* in *Moqoit*, is a sign that a group of people will move (Martínez-Crovetto, 1995: 113).

Other birds are a sign of approaching rains, such as the '*valdero* bird', *Zohololo* in *Moqoit*. According to Martínez-Crovetto (1995: 123), this is also the case of the Common Potoo (*Nyctibius griseus*), *Qapáp* in *Moqoit*, when it cries on hot nights. The referred laughing falcon can also foretell a change of time for the *Moqoit* (Martínez-Crovetto, 1995: 113). According to the *Tobas* (*Qom*), the flight of the Roseate Spoonbill (*Ajaia ajaia*)[45] announces great rains, and the night flight of the Greater Flamingo (*Phoenicopterus ruber*)[46] the increase in the flow of streams and marshes (Martínez-Crovetto, 1995: 100–101). For the *Moqoit,* the cry of the Giant Wood Rail (Aramides ypecaha) or *Wataá'*, announces bad weather or drizzles (Martínez-Crovetto, 1995: 113).

For the *Toba* (*Qom*), the Great Kiskadee announces a row between a couple when it cries one single time in front of their house (Martínez-Crovetto, 1995: 89–90), but foretells joy if it emits its characteristic whistle. Similarly, the night flight of the Limpkin (*Aramos guarauna*)[47] over the houses, accompanied by a

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[45] *Dololé* in *Moqoit*, according to Martínez-Crovetto.

[46] *Napaloló* in *Moqoit* according to Martínez-Crovetto.

[47] *Rokoró* in *Moqoit* according to Martínez-Crovetto.

hoarse cry, announces to the *Toba* (*Qom*) that someone will become ill by a spell (Martínez-Crovetto, 1995: 92). Ceaseless singing for several days of the Golden-green Woodpecker (*Piculus chysochlorus*),[48] announces bad luck for the *Toba* (*Qom*) *mariscadores* (local name for gatherers and hunters of small animals) (Martínez-Crovetto, 1995: 95). The cry of the Grey-necked Wood-Rail (*Aramides cajanea*)[49] indicates death by stabbing or by shamanic 'harm' among the *Toba* (*Qom*) (Martínez-Crovetto, 1995: 99). For the *Moqoit* peoples, when the Burrowing Owl (*Speotyto cunicularia*) or *Kichiguiguít* cries strangely for several nights next to a house, it forebodes illness or sadness for some of its inhabitants. If the same is done by the Short-eared Owl (*Asio flammeus*), *Kotelala'* in *Moqoit*, it announces a disgrace as disease or death (Martínez-Crovetto, 1995: 107). Martínez-Crovetto (1995: 106–107) also points out that among the *Toba* (*Qom*), the strange behaviour close to dwellings of the Tropical Screech-Owl (*Otus choliba*)[50] and the Stygian Owl (*Asio stygius*) announces the proximity of death. The Guira Cuckoo (*Guira guira*) or *Nachororó* is considered a foreteller of misfortunes for the *Moqoit* (Martínez-Crovetto, 1995: 119), but according to Terán (1998b: 249), the song of this bird also prompts reconciliation between separated *Moqoit* couples, especially in April with the arrival of the cold weather. According to this author (Martínez-Crovetto, 1995: 19), the cry of the Common Potoo, *Kapáp* in *Moqoit*, announces misfortune if close to houses, but if in the forest, it means the bird is fulfilling its function of 'owner' of the fruits of the bush and bird chicks (Terán, 1995: 19). The nightly song of the Smooth-billed Ani (*Crotophaga ani*),[51] similar to a female cry, forewarns the *Toba* (*Qom*) of the death of a spouse (Martínez-Crovetto, 1995: 119–120) and it is thought of as the assistant of a 'witch' (Arenas, 2003: 396).

Several other animals are extensively referred to as *señas*. Martínez-Crovetto (1995: 35) mentions that the granular toad (*Bufo granulosus*), *Nedép Lapaqaté* en *Moqoit*, announces floods with a croak 'like a cornet'. The song or sight in the paths of the two-colour common oval frog (*Elachistocleis ovalis bicolor*) means the same for the *Toba* (*Qom*) (Martínez-Crovetto, 1995: 35).[52] Likewise, the sight of army ants (*Eciton sp.*) or *Layor-r'ái Lalóq*, foretells rain for the *Moqoit* (Martínez-Crovetto, 1995: 79), or a move for the *Toba* (*Qom)* if invading a dwelling's *patio* (yard). Coming across a painted coral snake (*Micrurus corallinus, M. frontales*),[53] would advise, for the *Toba* (*Qom*), of the encounter with a beautiful girl (Martínez-Crovetto, 1995: 31).

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[48] *Oí'* in *Moqoit,* according to Martínez-Crovetto.

[49] *Shelkáik lemík* in *Moqoit,* according to Martínez-Crovetto.

[50] *Kolr'olkóq* in *Moqoit,* according to Martínez-Crovetto.

[51] *Nawí* in *Moqoit,* according to Martínez-Crovetto.

[52] *Tok naló* in *Moqoit*, according to Martínez-Crovetto.

[53] *Yigué'* in *Moqoit*, according to Martínez-Crovetto.

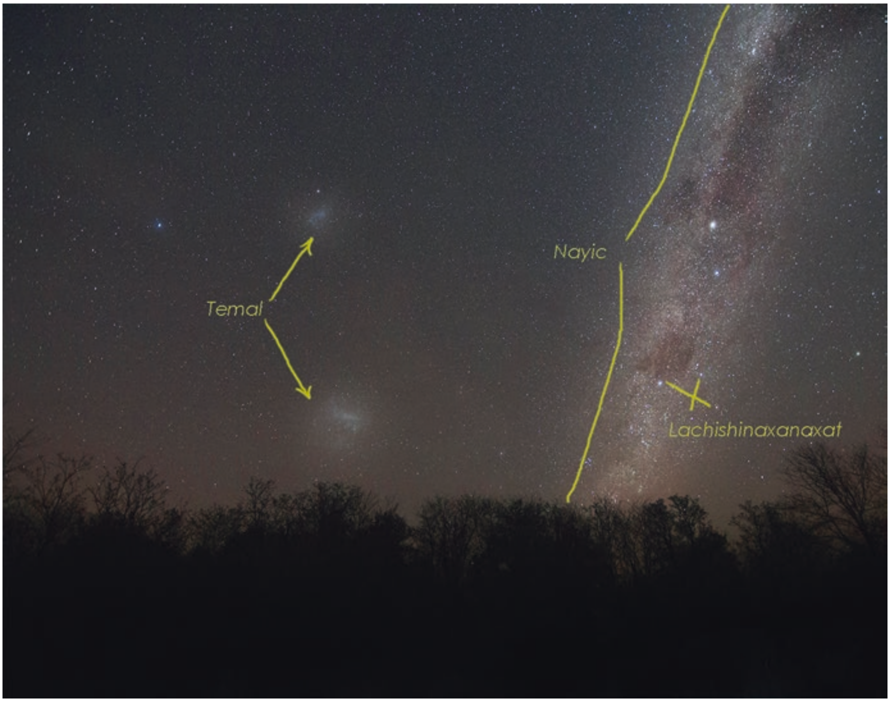

Fig. 7 Some of the asterisms that work as *señas* (signs) for *Moqoit* people

The stars and sun are generally referred to as *señas* of the ancients in the sky, which allowed them to foresee storms and helped them find their way. The asterism that in academic astronomy is known as 'Southern Cross' and that the *Moqoit* call *Lachishinaxanaxat*, is deemed a 'signal' of the South, helpful for orientation (Giménez Benítez et al., 2002). The same happens with the 'Magellanic clouds', called *Temal* or *Los pozos* (The waterholes) by the *Moqoit* (Fig. 7) (Giménez Benítez et al., 2002). The Milky Way itself, known by the *Moqoit* as the *Nayic* or path, is also considered a 'sign' for orientation (Giménez Benítez et al., 2002; López & Giménez Benítez, 2008). The changes in the brightness of stars and luminous areas of the *Temal* are linked with atmospheric changes and the prevision of fortune in the unfolding year. Thus, according to some, 'when the *Temal* are close to Argentina' they indicate rains (from November to January) (Fig. 8).

> When the sun has just risen, you need to go close to a *mistol* (*Zyzyphus mistol*), *na'la* in *Moqoit,* and you need to watch if exudation falls from it, to know if it will rain or not (Marcos Gómez, Colonia Cacique Catán, Chaco, 2002)

Fig. 8 Meteorite "El Chaco"in the Parque Provincial de los Meteoritos, Chaco, Argentina. It is a hexahedrite unearthed a few meters from where it is now located, in 1981. Its weight is about 29 tons

11 *Señas* and Luck

Since beginning of our fieldwork we have noticed that meteorites occupy a central role in the culture of the Southwestern Chaco *Moqoit* communities. This is partly because the renowned meteoric dispersion of Campo del Cielo is located in this region, and a great number of metallic meteoric fragments are frequently found lying on the ground and many of them have been found by the people since pre-Hispanic times (Giménez Benítez et al., 2004; López, 2009a) (Figs. 8, 9, 10 and 11).[54]

Among the *Moqoit* of this area, meteorites are understood as stars that have fallen from the sky (*Huaqajñi Najñi*). Their sight announces significant rains or droughts and in exceptional events, the death of a *Pi'xonak* (shaman). On the other hand, as is the case for the *Chiriguanos* (Lehmann-Nitsche, 1924a–1925), the *Moqoit* call *Huaqajñi la'tec* (excrement of stars) to a variety of small fungi that are related to meteorites.

A recurring idea is that meteoric fragments are the '*suerte del paisano*' (luck of the aborigine) (Giménez Benítez et al., 2004; López, 2009a). The *Moqoit* believe that upon impact with earth, these objects sink and then slowly ascend, so the person for whom they are destined ends up finding them on the surface. Owning one of these fragments confers luck, which must be understood in several ways: on the one hand, the meteorite is a sign of the fortune of having been chosen; on the other hand, the luck or fortune of this choice lies in its ability to generate wealth. The wealth-producing capacity of meteoric fragments is a manifestation of the power that they

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[54] The Campo del Cielo meteoric dispersion is approximately 100 km long and 3 km wide. It is characterized by a surprising concentration of large metallic meteorites and the arrangement of perfectly aligned impact craters in a N60 ° E direction. They correspond to the fragmentation of a metallic meteoroid some 5800 ± 200 years ago.

Fig. 9 Meteorite "Gancedo" in the Parque Provincial de los Meteoritos, Chaco, Argentina. It is a hexahedrite unearthed in the area in 2016. Its weight is just over 30 tons

Fig. 10 Small meteoric fragments inside the site museum of the Parque Provincial de los Meteoritos, Chaco, Argentina. They are hexahedrites of the same dispersion as the larger pieces already mentioned. Many of these pieces are found above the soil surface or at shallow depths in the bush and fields of the area. All the meteorites in Argentina are protected by law as natural and cultural heritage

Fig. 11 *Moqoit* people next to the "El Chaco" meteorite in the Parque Provincial de los Meteoritos, during the "*Marcha al meteorito*" (March to the meteorite), October 2009. Image courtesy of Mag. Esteban González Zugasti

confer to humans who encounter them, as intermediaries of the *poderosos*. Furthermore, touching or rubbing meteoric fragments transmits strength and resistance. These fragments are thus included within a wide set of power-bearing objects that are given the generic name of '*santitos'* (little saints figurines), *Nqolac* in *Moqoit*.[55] These '*santitos'* can also be crosses, statuettes of Christian saints or other objects. It is said that in the past, some introduced these objects under their chest's skin, protecting themselves from bullets. As in the case of meteoric fragments, the protection conferred by these objects is related to the 'powerful being' involved, and they are found in the field by those who are destined to find them. In regional Spanish, the *Moqoit* sometimes refer to the power carried by these objects with the Christian term '*bendición*' (blessing).[56] Particular types of power-bearing items are thunder stones (*Soxonaxa Naqa*'). These present very striking analogies and contrasts with the meteoric fragments. Like the latter, their origin is linked to the celestial sphere; they are objects that look like stones, charged with power and linked to water (not only because of their relationship with thunder, which produces them, but because their manipulation summons rain). Unlike meteoric fragments (which bring luck), thunder stones are hard to tell apart and even harmful if the one who manipulates them is not a *pi'xonaq*.[57]

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[55] Pastor Buckwalter's dictionary translates this term as 'ídolo'(idol). (Buckwalter, 1995).

[56] *Nqouagaxa*: its blessing, favor or received privilege (Buckwalter, 1995).

[57] Even if Buckwalter affirms these are objects of power (according to him, they provide strength in the handling of the ax), he does not refer to that restriction (Buckwalter, 1995).

12 Meteorites: *Señas* of Identity

In this context, a central role is played by the meteoric masses of Campo del Cielo (and especially the largest fragment visible today: '*El Chaco*') in the territorial and cultural claims of the Southwestern Chaco *Moqoit*.

For example, a *Moqoit* demonstration took place in 2009, demanding territorial and cultural rights (López, 2011; González Zugasti, 2012). It was called 'March to the meteorite' and its epicentre was the Meteorite Provincial Park (near the city of Gancedo, Chaco) (Fig. 11). Beyond the general demands of the protesters, a focal point was the significance of the territory where the meteorites lie for their culture. Its 'property' was not demanded, but the possibility of access and care was. They strongly put forward that the event that had taken place there was a concrete experience, a sign, of the presence of a particularly important power or *quesaxanaxa*. A specific might, linked to powerful beings from the sky with whom the *Moqoit* claim to have pacts, fundamental for their own constitution as a group.

Notably, the first half-length film made by young *Moqoit* is titled '*La nación oculta en el meteorito. Una historia del pueblo* Moqoit' (The nation hidden in the meteorite. A history of the *Moqoit* people) (http://www.youtube.com/watch?v=X1odIHeRQSU).[58]

Another recent event describes the *Moqoit* struggles, and their efforts to bring their culture and the Campo del Cielo meteorites to light as true *señas* of identity. In 2012, the opposition of many *Moqoit* prevented the 'El Chaco' meteorite from being transferred to Germany for an artistic exhibition.[59] Although this opposition was also held by many national and international experts (including cultural astronomers) and NGOs, the resistance of the *Moqoit* was decisive in preventing the meteorite from being taken out of the province.

In their demonstrations, the *Moqoit* stressed that the meteorite is not only significant to their history and identity, but also powerful and linked to beings with which the ancient *Moqoit* established pacts in the past. Therefore, meteorites are dangerous objects to handle. In fact, many *Moqoit* posed that the earthquake that had occurred in Japan back then was undoubtedly connected to the concern of the *poderoso* linked to the meteorite at the possibility of the transfer. Even the *Moqoit* leaders, whom the provincial authorities sought to persuade, pondered their support in terms of the pros and cons in a negotiation between the conflicting interests of two powers: provincial and national politicians, and sky beings.

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[58] It was written and directed by the *Moqoit* intercultural bilingual teacher and 'cultural promoter' Juan Carlos Martínez, and carried out within audiovisual production workshops organized by the *Dirección de Cine y Espacio Audiovisual* of the province of Chaco, in collaboration with the *Centro de Formación y Experimentación Cinematográfica de Bolivia.*

[59] dOCUMENTA (13), in Kassel, Germany. This is one of the most renowned contemporary art exhibitions today. Since 1955, it has been held every 5 years in Kassel. The last one, its 13th edition, took place in September 2012.

13 Conclusion

Throughout this work we have assessed how the environment encloses, for the *Moqoit* of the studied communities, a complex weave of messages to be interpreted. In fact, many *Moqoit* equate the ability of the ancients to 'read' these signs to the current ability to read books. But, caught in the associations of a literate culture, we may understand that this 'reading' of the environment means decoding a message that merely describes certain events that have occurred or are yet to come. In truth, however, the 'reading' of the ancients is deeply rooted in oral culture, where words are not external entities, but alive and powerful, carrying intent and acting effectively upon the world. That is why in the *Moqoit* conception it coheres that the environment, far from our own notions on nature, is a 'social space'. In other words, it is not just a semantic field, but a true bundle of intentions. For this reason, it is not only necessary to read and interpret it, but also to find channels of action, which entail many other relationships.

This is so because the *Moqoit* cosmos is, as we have discussed, an authentic socio-cosmos. Its structure and evolution are fundamentally forged by the relationships between the various human and non-human societies that inhabit it. There is therefore no place for a distinction between nature and society, since the world itself is defined by being social.

The collectives that comprise the world have their own agendas, appetites, desires and interests. Furthermore, they are asymmetrically related, since power is not distributed evenly. Asymmetric power relations are a constant in the *Moqoit* cosmos. This has led to their theoretical reflection being cosmo-political above all. In it, knowledge deals with the management of these relationships and implies awareness of the correct interpretation of the *señas* or *netanec*.

It is in this context that the idea of a *pact*, as a mechanism for managing unequal power relations, becomes the nucleus around which an entire ethnoterritoriality is built, one in which the 'strange', the out of the ordinary, becomes a signal of might. Here, once again, our own assumptions can lead to us noticing contradictions. Among the *Moqoit,* the world is *seña* not only when it manifests itself in sudden and unpredictable phenomena, such as a meteorite or the sight of an unusual bird, but also in regular ways, such as in the rhythmic movement of the stars or the timely blossoming of the *aromos*. For the *Moqoit*, both the exceptional unpredictability and the stunning regularity, are seen as unusual events that require the presence of an extraordinary power and are therefore worthy of special attention and care.

In this sense we can notice that the conception of 'physical laws' as exact regularities that is for us the very foundation of the functioning of the cosmos, is not in line with the *Moqoit* socio-cosmology. On the contrary, these kinds of 'laws' are, for the *Moqoit*, exceptional regularities that require extraordinary amounts of power. The same is true for sudden and very exceptional events. The 'norms' in the socio-cosmos *Moqoit* are approximate regularities, in the same sense that we usually say 'that person' usually do this or that. The 'norm' in this case is a *habitus*, a custom, a certain regularity in their behaviour. As can be seen, in one case we have a root-metaphor based on the image of a machine, while in the other, the metaphor is based on social relations.

This *Moqoit* vision of the environment and its unusual manifestations transforms the latter into exceptional ways of sanctioning and legitimizing behaviours. They do not only guide and limit human action towards the future, but also the past, which enables to reread and confer meaning to what has already happened.

The described notions, as we have shown throughout the chapter, are applied in everyday life to interpret events and guide actions. In the same direction, the political reflections we mentioned do not only apply to the establishment of relationships with the non-human societies that share the cosmos with the *Moqoit*. Connections with other human groups are also part of the *Moqoit* cosmo-politics. Human management of power is seen as a specific case of power management in general. Since humans are not the most powerful entities that inhabit the world, their abilities, their 'luck' and their wealth depend on pacts made with powerful nonhumans. For all these reasons, the *Moqoit* reflect upon their links with the surrounding society and especially with the state in the wider context of their cosmological thinking. As we have pointed out in several examples, the submission to the rules of the game of the *criollo* world is seen as an integral part of the current *Moqoit* situation in the cosmos and as a consequence of successes and mistakes of the *criollos* and their respective cosmo-political strategies. This situation determines, for example, the kind of pacts with non-human beings to which the *Moqoit* can aspire today. Similarly, the dominant situation of the *criollos* is understood as a result of pacts they themselves have with non-human societies, such as the Christian entities led by the Holy Spirit. However, this situation is not seen as permanent, and signs of the propitious moment to reverse it are awaited. Various options for human and non-human pacts are constantly being explored.

As we pointed out when defining cosmo-politics, the term stresses that the assessment of conflicts among diverse human groups requires questioning hegemonic notions on humanity and its environment; in particular, the separation between nature and society. On the other hand, we must avoid both the *a priori* reduction of the political to the merely human, and the assumption that the inclusion of non-human agents implies the dilution of relations of human domination and their economic and political mechanisms. *Moqoit* cosmo-political thinking poses a world in which both dimensions are substantially intertwined. It is not a 'confusing and mystifying' or 'exotic' rationale; on the contrary, it is a very concrete approach to a universe in which humans are not the only beings with appetites and desires.

We believe that this case can help us appreciate that different cultures construct knowledge about the sky and other areas of existence based on experiences and models of a different nature than those held by Western science. Therefore, to address this topic academically, we are impelled to deconstruct the assumptions on which our experience of the world is grounded, in order to understand those cultures according to their own logics.

Appendix: Vocabulary Table

Consonants	POINT	Labial		Alveolar		Palatal		Velar		Uvular		Glottal	
	MODE	sd	sn	sd	sn	sd	sn	sd	sn	sd	sn	sd	sn
	Plosive	**p**		**t**	**d**	**ch**	**y**	**c / qu**	**g / gu**	**q**	**x**	**´**	
	Fricative			**s**		**sh**						**J**	
	Tap			**r**									
	Lateral			**l**		**ll**							
	Nasal	**m**		**n**		**ñ**							
	Glide	**u / hu / v**				**ỹ**							

Vowels	Front		Central		Back	
	Short	Long	Short	Long	Short	Long
Close	**i**	**ii**				
Mid.	**e**	**ee**			**o**	**oo**
Open			**a**	**aa**		

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Sun, Sea, and Sky: On Translating Directions (and Other Terms) in the Greek Geographers

D. Graham J. Shipley

1 Introduction

The terms which a language community employs to denote natural phenomena (such as the astronomical or the atmospheric), and to express the relationships between them, raise particular issues when they are to be rendered meaningful in another cultural frame of reference.[1]

The present paper arises from the author's role as editor of a collection of over thirty geographical writings translated from ancient Greek, ranging from the early archaic period (late eighth century BC) to late antiquity (sixth century AD or later).[2] Most of them are incomplete; many are anonymous or are attributed to an author about whom nothing is known.[3] Despite a chronological range of some 1200 years

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[1] It is a pleasure to offer this study to my colleague of 30 years Clive Ruggles, whose pioneering work, combining mathematics, ethnography, and archaeology, has radically altered our understanding of how past cultures endow the landscapes around and above them with distinctive schemes of meaning. I thank the editors of the volume, the anonymous readers, Prof. Dr. Kai Brodersen, Dr. Dorothea Stavrou, and for overall guidance Prof. Richard Talbert. Translations are mine unless otherwise indicated.

[2] Shipley forthcoming.

[3] At the time of writing the following authors and texts are included, in approximate date order (* indicates verse, † a Latin version of a Greek work). **Archaic:** Homeric *Catalogue of Ships* (from *Iliad*, book 2); Aristeas; Skylax; Hekataios; Hanno. **Classical:** Hippokrates, *Airs, Waters, and Places*; Pseudo-Skylax. **Hellenistic:** Pytheas; Dikaiarchos; Herakleides Kritikos; Timosthenes; Eratosthenes; Mnaseas; Skymnos; Agatharchides; Hipparchos; *anon., *Iambics for King Nikomedes* ('Pseudo-Skymnos'); Artemidoros; Poseidonios; *Dionysios son of Kalliphon. **Roman:** Menippos; Isidoros; Pseudo-Aristotle, *On the Cosmos*; anon., *Circumnavigation of the*

D. G. J. Shipley (✉)
School of Archaeology and Ancient History, University of Leicester, Leicester, UK
e-mail: graham.shipley@leicester.ac.uk

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and a wide variation in their scientific or literary aims, they display a remarkable degree of consistency in how they use terms related to directions of the compass.

It is good practice when translating that, as far as possible, different words in the original language should be rendered by different words in the new language; and that a given word should be represented always, when practicable, by the same word. The translator needs to establish carefully how sets of related terms are to be handled; and the juxtaposition of multiple sources in one volume gives an opportunity to formulate ‘rules of engagement’ to ensure consistency and give readers a true basis for comparison. Such sets of terms include those for harbours and other stopping-points for ships, and those for seas and oceans; in considering both of which we shall see that it is no simple matter to match Greek terms to English, particularly when, as in the latter case, modern British English offers no rich store of familiar alternatives.

Particular problems arise, however, with the cardinal directions. (1) First, Greek has two words in common use for each, whereas English has only one. Accordingly, translators generally employ each of the four terms ‘north’, ‘east, ‘south’, and ‘west’ to represent two Greek words, usually without indicating which one stands in the passage being translated. Is it possible to indicate in some way which term has been translated? (2) Second, unlike the four English terms, the eight Greek terms also have non-directional meanings in their own right, and can keep those original meanings in non-directional contexts. Is it unavoidable that we should conceal the alternative senses of a Greek word by silently using two different words to represent it in English: sometimes a directional term, sometimes not?

The second problem is perhaps less serious than the first; translators are used to judging when to represent one foreign word by different English words depending on the context, as very often the semantic range of a term does not exactly coincide with that of a single English word. The first problem is more thorny. We may make a text seem artificially familiar if, in so crucial an aspect as this, we translate different Greek words by the same English word without indicating that we have done so. Yet that is the practice of most translators of Classical works when faced with two Greek words that mean the same thing in English. This paper explores the extent to which a more nuanced response to the sources is possible.[4]

2 Anchoring the Past

Direction terms are not the only area in which ancient Greek possesses a larger set of terms than current British English.

Erythraian Sea; Pseudo-Plutarch, *On Rivers*; Arrian, *Circumnavigation of the Black Sea*; *Dionysios Periegetes; Agathemeros; Dionysios of Byzantion; anon., *Stadiasmos*. **Late antique:** *†Avienus, *Ora maritima*; †anon., *Expositio*; Markianos, *Circumnavigation of the Outer Sea*; †anon., *Hypotyposis*; Pseudo-Arrian, *Circumnavigation of the Black Sea*.

[4] The focus of this brief investigation is exclusively upon translation into English.

For example, a place where a ship can pause its journey may be designated by a range of different terms, of which the most common in geographical writings are (1) λιμήν (*limēn*), (2) ὅρμος (*hormos*), (3) σάλος (*salos*), and (4) ὕφορμος (*hyphormos*). The last two will be less familiar to readers of ancient Greek than the first two, occurring as they do almost exclusively in texts concerned with navigation or maritime geography.

1. *Limēn* (plural *limenes*) is conventionally rendered 'harbour', as it is in the formerly standard Greek lexicon 'LSJ' (Liddell–Scott–Jones)[5] and in the new *Brill Dictionary* edited by Montanari[6]; appropriately so, for in the geographical texts it seems to cover enclosed embayments of significant size (whether natural or artificial) with a settlement adjacent or nearby.
2. *Hormos* (pl. *hormoi*), derived from the verb εἴρω (*eirō*), 'fasten', connotes safety, so 'anchorage' is one common rendering. Yet LSJ gives a wider definition: 'roadstead, anchorage, esp. the inner part of a harbour or basin, where ships lie'. First, it must be observed that *hormos* is not used specifically of the 'inner parts' of harbours, at least in geographical writings, though it is more flexible than *limēn*.[7]

   Next, 'roadstead' is a surprising translation: it is defined in the latest edition of the *Concise Oxford Dictionary*[8] as equivalent to 'road', sense 3: 'a partly sheltered stretch of water near the shore in which ships can ride at anchor'. This will be familiar to those who visit the Roseland peninsula in southern Cornwall (a favourite destination of our honorand's family and mine), separated from the ancient Royal Navy port of Falmouth by a complex of deep-water sea inlets known as the Carrick Roads. It does not, however, seem to overlap with *hormos*, which from its use in geographical texts appears to refer not to offshore water but to a coastal feature offering accommodation for vessels, often without an adjacent settlement or any manmade facilities.

   Perhaps surprisingly, LSJ does not include 'mooring' among the possible meanings of *hormos*, despite its derivation from *eirō*; but 'mooring' suggests attaching a vessel to a permanent manmade structure (such as a jetty) or to a buoy (something the ancients did not use, as far as I am aware),[9] while as a noun it further connotes the space a single vessel may occupy. In both respects *hormos* clearly has a wider field of meaning than 'mooring'. Nor is 'mooring' used as part of English place-names, whereas 'anchorage' is: not only, for example, the

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[5] Liddell and Scott 1940.

[6] Montanari 2015.

[7] For *hormos* Brill gives 'harbor, cove, port, anchorage basin, anchorage, moorage', which indicates the spread of meaning.

[8] Stevenson and Waite 2011.

[9] Stevenson and Waite 2011, s.v. moor^2: 'make fast (a boat) by attaching by cable or rope to the shore or to an anchor'. Wikipedia s.v. Mooring (9/5/20): A mooring is any permanent structure to which a vessel may be secured. Examples include quays, wharfs, jetties, piers, anchor buoys, and mooring buoys.'

state capital of Alaska but also in historians' renderings of ancient place-names such as Myos Hormos, 'Mussel Anchorage' (also the name of the accompanying settlement).

Although a phrase such as 'small harbour' might do justice to some instances of *hormos*, we do not know that places called *hormoi* necessarily accommodated fewer ships than those referred to as *limenes*. Accordingly, 'anchorage' is a good compromise, as long as we let readers know that it does not necessarily imply that a ship would need to drop anchor there rather than be tied up. (In later sources, such as the anonymous *Stadiasmos*, section 45, we encounter terms such as ἀγκυροβολία, *ankyrobolia*, 'place to cast anchor'.)

3. *The* terms 'road' and 'roadstead', already introduced, better suit *salos* (hardly ever used in the plural and then mostly metaphorically), which is related to the verb σαλεύω (*saleuō*), 'undergo a tossing motion', often a violent one. More appropriately than in the case of *hormos*, the dictionaries concur in making *salos* a piece of open but safely sheltered water.[10] Since 'roads' in this sense will probably be unfamiliar to readers who do not sail, and would need explaining in a translation, *salos* had better have 'roadstead' reserved for it. It is less familiar than some terms, but a quotation from the first paragraph one of the most famous novels in English, *Frenchman's Creek* by Daphne Du Maurier (perhaps not coincidentally set near Falmouth), justifies its adoption: 'When the east wind blows up Helford river the shining waters become troubled and disturbed and the little waves beat angrily upon the sandy shores. […] The open roadstead is deserted, for an east wind makes uneasy anchorage'.
4. *That* leaves *hyphormos* (pl. *hyphormoi*), a compound of *hypo*-, 'under', and *hormos*: a 'sub-anchorage', then. In practice, what? Once more we need to modify the dictionaries' recommendations: LSJ simply gives 'anchorage', obscuring the distinction between *hormos* and *hyphormos*, while Brill offers 'place of anchorage, port', even though in geographical texts a *hyphormos* is clearly a minor locality whereas 'port' implies some degree of organization. On this occasion a phrase of two words may be the best solution: 'minor anchorage'.

This cluster of words may serve to highlight several issues: the tendency of lexicons not always to define terms adequately in relation to one another; the need to consider whether or not to employ familiar English words in an unfamiliar sense (such as 'road') or to employ unfamiliar terms at all ('roadstead'); and the desirability of following lexical distinctions present in Greek, as far as possible, when choosing words in a translation.

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[10] LSJ offers 'open roadstead, roads, [as] opp[osed to]. a harbour'; Brill 'anchorage, mooring, *usu. Opp. to* λιμήν harbor'.

3 Down to the Sea in Ships

Another such cluster raises similar problems, with the additional complexity that it indicates the poverty of contemporary English as well as the overlapping denotations of certain Greek terms.

Geographical sources normally refer to large bodies of water (other than inland lakes) by one of three terms: θάλασσα (*thalassa*),[11] πέλαγος (*pelagos*), and πόντος (*pontos*). The same body of water may be defined by a different term in different contexts. For example, the 'Sicilian sea' is sometimes a *pelagos*,[12] sometimes a *thalassa*.[13] The Black sea, properly the *euxeinos* ('hospitable') *pontos*, can also be the 'Pontic *thalatta*'.[14] Today's Arab–Persian gulf is usually the *Persikos kolpos*[15] but sometimes the *Persikē thalassa*.[16]

A fourth term, ὠκεανός (*ōkeanos*), is reserved for the outer Ocean that surrounds all of Europe, Asia, and Africa. It would be bizarre not to employ 'ocean' (or Okeanos or Ocean) to translate it; but this, if unavoidable, deprives us of a familiar term for large bodies of salt water such as those we call the Atlantic and Indian Oceans (in Greek, these are not 'oceans' but subdivisions of the one and only Okeanos).

'Sea' is an extremely scalable word in English: it can denote a relatively small enclosed body of water (Aral sea, Black sea, Caspian sea), a division thereof (sea of Azov), an inlet of the outer ocean (Baltic sea), a marginal segment of the outer ocean (North sea, Irish sea, Weddell sea), or even the largest enclosed sea in the world, the Mediterranean sea. In several of the cases just mentioned, the word 'sea' is often omitted in English when the body of water is named (e.g. the Caspian, the Baltic, the Mediterranean).[17]

Unfortunately, 'sea' is also effectively the only familiar English term available with which to translate the other three words. The famous thesaurus of Roget in modernized versions is of little help.[18] Accordingly, it is usual to find *thalassa*,

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[11] Or θάλαττα, *thalatta*, in Attic (Athenian) Greek.

[12] e.g. Ps.-Aristotle, 3; Strabo, 6. 2. 1.

[13] Dionysios Periegetes, 401 (poetic).

[14] Strabo, 1. 3. 4.

[15] e.g. Strabo, 16. 3. 2, *kolpos* meaning 'gulf', 'bay'.

[16] e.g. Agathemeros, 3. 12.

[17] LSJ and Brill both translate θάλασσα (*thalassa*) as 'sea'. For πόντος (*pontos*) Brill gives 'sea, open sea', replicating LSJ's 'sea, esp. open sea', after Homer 'chiefly used of special seas [. . .] but Hdt. has also ὁ πόντος' [*ho pontos*] 'for the sea, 4.99, 177'; at those places Herodotos describes peninsulas as projecting ἐς τὸν πόντον, *es ton ponton*, 'into the open sea'. For πέλαγος (*pelagos*) LSJ gives 'the sea, esp. high sea, open sea', Brill 'sea, usu. Open sea, deep sea', which illustrates the difficulty of distinguishing the last two in translation.

[18] In the edition by Dutch (Roget and Dutch 1962), §343 Ocean includes 'sea, blue water, salt w., brine, briny; waters, billows, saves, tide, wave; [. . .] main, deep, deep sea; high seas', but otherwise contains mostly poetic, jocular, or technical terms. The shorter edition by Browning (Roget and Browning 1982), §341 Ocean, offers a subset of the above.

pelagos, and *pontos* all rendered as ‘sea’ in translation, without further comment. Can we do better, such as by reserving ‘sea’ for one of the three and devising phrases for the others, or by reviving less familiar English terms?

Thalassa is by far the commonest word, and is used differently from the others. One may say in Greek, for example, that imperial Athens was powerful ‘by land and by *thalassa*’ but not ‘by land and by *pontos*’ or ‘by *pelagos*’. Likewise, while Herodotos once refers to ‘the *thalassa* of the Euxeinos Pontos’ (2. 33. 4) and the poet Apollonios of Rhodes uses the phrase ‘*pelagos* of the *thalassa*’ (*Argonautika*, 2. 608), neither of those phrases would work the other way round. Perhaps significantly, *thalassa* is commonly derived from ἅλς (*hals*), ‘salt’, suggesting a mass of a particular substance.

Pelagos, the second most common term for ‘sea’, is etymologically linked by LSJ to Latin *plaga* in the sense of ‘region, quarter, tract’. So ‘open sea’ or ‘wide sea’ would make sense (rather as in the modern term ‘pelagic’, meaning belonging to the deep or open sea). Whereas ‘wide’ is sometimes applied in Greek to *pontos*, ‘open sea’ would be a distinctively English usage. It is a little awkward when a specific place-name stands before it, such as the *Sikelikon* (Sicilian) or *Ikarikon* (Icarian) *pelagos*; but the phrase could in these cases be hyphenated if necessary, as in ‘the Sicilian open-sea’.

In contrast, the Brill dictionary links *pontos* to Latin *pons*, ‘bridge’, and Sanskrit *pánthāḥ*, ‘path’, ‘way’, ‘means’; it seems that, at least originally, it connoted passage or movement. The term ‘seaway’ might thus be used, but its meaning in modern English is sometimes too specific (equivalent to ‘sea lane’), alternatively denoting a rough sea or the space one vessel in motion must allow to another (cf. ‘leeway’, ‘sea room’). There is the additional complication that our Black sea[19] is the Greeks’ ‘Euxeinos Pontos’, also called simply ‘Pontos’ or indeed ‘Euxeinos’ (Euxine in English), which it would seem strange to designate a ‘seaway’. In default of ready alternatives, the practical compromise may thus be to use ‘main’, which despite its old-fashioned overtones is listed in the two modern editions of Roget cited above.[20] I have previously employed ‘main’ for *pelagos* in my edition of Ps.-Skylax’s *Periplous* (*Circumnavigation*).[21] It happens that *pontos* as a common noun is often (among the geographers) employed in poetry (Homeric *Catalogue of Ships*; Dionysios Periegetes), as ‘main’ has been in English verse (originally as an abbreviation of ‘main sea’).[22]

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[19] In not capitalizing ‘sea’ in names of this kind, I follow the practice of the revisers of Pliny the Elder’s books on geography in the Loeb Classical Library, as set out in Talbert 2020.

[20] *COD*^{11} (Stevenson and Waite 2011) defines main^1, sense 3, thus: ‘(the main) ARCHAIC OR LITERARY the open ocean’. Despite a common assumption, the meaning does not necessarily derive from the phrase ‘the Spanish Main’, where ‘main’ in fact appears to be short for ‘mainland’, denoting the former Spanish imperial territories in the western Atlantic.

[21] Shipley 2011 ~ ^{2}Shipley 2019; e.g. at §15 ‘the Tyrrhenian main’, §58. 4 ‘the Aigaion (*Aegean*) main’, §66. 3 ‘stretching up into the main’ (of a peninsula).

[22] *Oxford English Dictionary* (3rd edition, 2000; consulted on line 5 July 2020), ‘main’, sense I.5.a, citing i.a. Tennyson, *The Princess* (1847), ‘to gaze O’er land and main’.

There is the additional problem of metonymy, as when ἅλς (*hals*), ‘salt’, is used in poetry to denote the sea, in an echo of Homeric usage such as ‘the *hals* of the *pontos*’. This, too, occurs, for example, in the poem of Dionysios Periegetes. We might replace *hals* with ‘salt sea’ (rather than, for example, the ‘briny’ of older UK speech and folk-song), though if a metrical version is desired this may not always fit. Dionysios’ repeated use of the nymph’s name Amphitrite as another synonym for the sea leaves little alternative but to reproduce it as it is, with a note of explanation. Both solutions avoid obscuring the different terms under the catch-all term ‘sea’.

This second cluster of words, then, illustrates the fluidity of usage of certain Greek terms, and again raises the question of whether to adopt expressions that may be unfamiliar to the expected readers to a greater or lesser degree.

4 Cardinal Points

The problem of selection is slightly different in the case of directional terms. As already noted, Greek has two regular terms for each of the cardinal points of the compass. The resulting eight terms, as is well known, comprise one that refers to either or both of the polar constellations (‘bears’ referring, of course, to Ursa Major and Ursa Minor), two winds (north and south), three phases of the solar day (dawn, midday, evening), and two solar phenomena (rising, setting). (There is, of course, no solar event that could signify ‘north’ in the northern hemisphere.)[23] The eight terms are shown in Table 1, together with their literal meanings and the words usually substituted for them in English.[24]

A ninth term, and a third wind, also identifies the west: but Zephyros is hardly ever used as a directional term (see Appendices), even though it was one of the four cardinal winds in early literature.[25]

The non-exhaustive catalogue in Appendices 1–2 assembles illustrative examples of words and phrases from some of the geographical authors (and from a few others including major extant historians like Herodotos, Xenophon, and Polybios). The phrases frequently comprise a preposition followed by the cardinal signifier, though a given preposition cannot always be translated by the same word. Prepositions used include *apo* (‘from’), *eis* (‘to’, ‘into’), *en* (‘in’), *epi* (with a variety

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[23] Except possibly ‘the place where the Sun sleeps’—the glow in the north during summer nights—which people in Britain pointed out to Pytheas (e.g. Geminos, *Introduction to Celestial Phenomena*, 6. 8–9).

[24] In the table, ‘pl.’ = plural. Macrons distinguish long vowels, represented by different letters from short vowels in Greek: *ē* = eta (η), *ō* = omega (ω). Final *e* is never silent. There was no distinction between lower- and upper-case letters; writing was always in what we call capitals. Dialect variations affect some terms: e.g. *ēōs* was *heōs* in Attic (Athenian) Greek, *mesēmbria* was *mesambriē* in the Ionic of Herodotos, Hekataios, etc.

[25] Cf. Hünemörder and Phillips 2006, §1a: Homer recognizes Boreas, Euros, Notos, and Zephyros.

Table 1 Greek terms for cardinal directions

	Transliteration	Literal meaning	Usual translation
ἄρκτος, pl. ἄρκτοι	*arktos*, pl. *arktoi*	Bear(s)[a]	North
βορέας	*boreas*	North wind[b]	North
ἀνατολή, pl. ἄνατολαί	*anatolē*, pl. *anatolai*	Rising(s)[c]	East
ἠώς	*ēōs*	Dawn[d]	East
μεσημβρία	*mesēmbria*	Midday	South
νότος	*notos*	South wind[e]	South
δύσις, pl. δύσεις (or δυσμή, pl. δυσμαί)	*dysis*, pl. *dyseis* (or *dysmē*, pl. *dysmai*)	Sinking(s), setting(s)[f]	West
ἑσπέρα	*hespera*	Evening	West

[a] *Arktos* is both the common noun ‘bear’ and the proper noun for one of the mythological persons associated with Ursa Minor and Ursa Major. The plural *arktoi*, in the directional sense, is occasionally used in the singular form *arktos*; cf. Appendices.

[b] Boreas also occurs as a personification of the N wind. As a common noun, it is sometimes defined by ancient writers as a NNE rather than due north wind.

[c] *Anatolē* is often plural *anatolai*, ‘risings’. See Appendices.

[d] Eos is also a personification, Dawn.

[e] Notos is directly related to words for moisture: a season can be *notios*, ‘rainy’.

[f] *Dysis*, like *anatolē*, is often plural: *dyseis*, ‘settings’. See Appendices.

of meanings for which the all-purpose preposition ‘upon’ will usually serve), *kata* (‘against’, ‘opposite’), and *pros* (‘towards’, ‘on/from the side of’). The last three have different meanings depending on the grammatical case of the noun that follows them.[26]

There seems to be no significance in the variation between singular and plural in terms such as *anatolē* and *dysis*. The plural, as in ‘towards the settings of the sun’, does not appear to indicate a less definite commitment to an exact orientation. The following extract from Agatharchides (second century BC; preserved in a conscientious summary made for the Byzantine patriarch Photios in the ninth century) suggests that the variation has little if any significance, since Agatharchides uses two different words for ‘west’ and changes the number of ‘east’ and ‘north’ between singular and plural:

> Ὅτι, φησί, τῆς ὅλης οἰκουμένης ἐν τέτταρσι κυκλιζομένης μέρεσιν, ἀνατολῆς λέγω, δύσεως, ἄρκτου καὶ μεσημβρίας, τὰ μὲν πρὸς ἑσπέραν ἐξείργασται Λύκος τε καὶ Τιμαῖος, τὰ δὲ πρὸς ἀνατολὰς Ἑκαταῖός τε καὶ Βασιλίς, τὰ δὲ πρὸς τὰς ἄρκτους Διόφαντος καὶ Δημήτριος, τὰ δὲ πρὸς μεσημβρίαν, φορτικόν, φησί, τὸ ἀληθές, ἡμεῖς.
>
> The whole inhabited world, as he (*Agatharchides*) says, is encircled in four parts—I mean east (*anatolē*), west (*dysis*), north (*arktos*), and south (*mesēmbria*). The westerly parts (*pros*

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[26] A catalogue formulated with a primary focus on names of the winds, but including also other directional words, e.g. ‘dawn’, ‘left’, ‘beyond’, is offered in the wide-ranging study of Nielsen 1945. I am grateful to Astrid Möller and Paul Christesen for enabling me to access this paper. Note also the studies of Greek winds by Neuser 1982 and Coppola 2010, focused on iconography and mythology respectively.

> *hesperan*) have been covered by Lykos and Timaios, the easterly (*pros anatolas*) by Hekataios and Basilis, the northerly (*pros tas arktous*) by Diophantos and Demetrios, and the southerly (*pros mesēmbrian*)—a burdensome task, as he rightly says—by ourselves.

The Appendices illustrate how the language of cardinal directions is varied with participial phrases such as 'setting sun' or verbal nouns as in 'sun's rising'. They also contain examples of how the nearest equivalents to our four ordinal directions (also known as intermediate or intercardinal; north-east, south-east, south-west, and north-west)[27] are indicated not, as in English, by combinations of two cardinals but in two different ways. The first alternative is to refer to a wind from a given direction, such as 'towards the Euros' (approximately a south-east wind). The second is to refer to equinoctial or solstitial sunrise or sunset, as in 'the winter settings' (approximately south-west), 'the summer settings' (approximately north-west), 'the equidiurnal' (i.e. equinoctial) 'risings' (due east), and 'the equidiurnal settings' (due west).

A famous passage, quoted from the early hellenistic admiral Timosthenes by the second-century AD geographer Agathemeros, is one of the classic definitions of the 'wind rose'. It begins with a version of Aristotle's scheme (*Meteorologika*, 2. 6) of eight cardinal and (approximately) ordinal winds (though Aristotle adds two intervening winds, leaves the SSW point blank, and identifies the name of the SSE wind as being no more than a local appellation); and moves on to Timosthenes' own twelve-wind scheme (Fig. 1)[28]:

> ἄνεμοι δὲ πνέουσιν ἀπὸ μὲν ἰσημερινῆς ἀνατολῆς ἀπηλιώτης, ἀπὸ δὲ ἰσημερινῆς δύσεως ζέφυρος, ἀπὸ δὲ μεσημβρίας νότος, ἀπὸ δὲ ἄρκτου ἀπαρκτίας. <ἀνατολικοὶ οὗτοι·> ἀπὸ δὲ τροπῆς θερινῆς καικίας, ἑξῆς δὲ ἀπὸ ἰσημερινῆς ἀνατολῆς ἀπηλιώτης, καὶ ἀπὸ χειμερινῆς εὖρος· δυσμικοὶ δὲ ἀπὸ μὲν δύσεως χειμερινῆς λίψ, καὶ ἑξῆς πάλιν ἀπὸ δύσεως ἰσημερινῆς ζέφυρος, ἀπὸ δὲ δύσεως θερινῆς ἀργέστης ἤτοι ὀλυμπίας, ὁ καὶ ἰᾶπυξ· εἶτα νότος καὶ ἀπαρκτίας ἀντιπνέοντες ἀλλήλοις. γίνονται οὖν ὀκτώ.
>
> Τιμοσθένης δὲ, ὁ γράψας τοὺς περίπλους, δώδεκά φησι, προστιθεὶς μέσον ἀπαρκτίου καὶ καικίου βορέαν, εὔρου δὲ καὶ νότου φοίνικα τὸν καὶ εὐρόνοτον, μέσον δὲ νότου καὶ λιβὸς τὸν λευκόνοτον ἤτοι λιβόνοτον, μέσον δὲ ἀπαρκτίου καὶ ἀργέστου θρασκίαν ἤτοι κίρκιον ὑπὸ τῶν περιοίκων ὀνομαζόμενον.
>
> ἔθνη δὲ οἰκεῖν τὰ πέρατα κατ᾽ ἀπηλιώτην Βακτριανούς, κατ᾽ εὖρον Ἰνδούς, κατὰ φοόνικα Ἐρυθρὰν θάλασσαν καὶ Ἀραβίαν, κατὰ νότον τὴν ὑπὲρ Αἴγυπτον Αἰθιοπίαν, κατὰ λευκόνοτον τοὺς ὑπὲρ Σύρτεις Γαράμαντας, κατὰ λίβα Αἰθίοπας δυσμικοὺς <τοὺς> ὑπὲρ Μαύρους, κατὰ ζέφυρον Στήλας καὶ ἀρχὰς Λιβύης καὶ Εὐρώπης, κατὰ ἀργέστην Ἰβηρίαν τὴν νῦν Ἱσπανίαν, κατὰ θρασκίαν Κελτοὺς καὶ τὰ ὅμορα, κατὰ δ᾽

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[27] The summer and winter sunrises and sunsets mark the ordinal points only approximately. On 21 June at the latitude of Athens (*c*.38.0° N), the sun rises at a bearing of *c*.60° (taking north as zero), which is closer to ENE (67½°) than to NE (45°); and sets at *c*.299°, closer to WNW (292½°) than to NW (315°). On 21 Dec. it rises at *c*.120° (SE is 135°) and sets at *c*.240° (SW is 225°). (Measurements from the Sky View Café app, 19/5/20.) Nielsen 1945, 11, gives slightly different figures with a range of 61° 24′ between the extreme sunrises (and likewise sunsets) at Athens.

[28] Nielsen 1945 traces the evolution of the Greek directional terms in detail, distinguishing traditional directional markers (e.g. 'dawn', 'Boreas') from 'scientific' ones (e.g. equinoctial sunrise or solstitial settings).

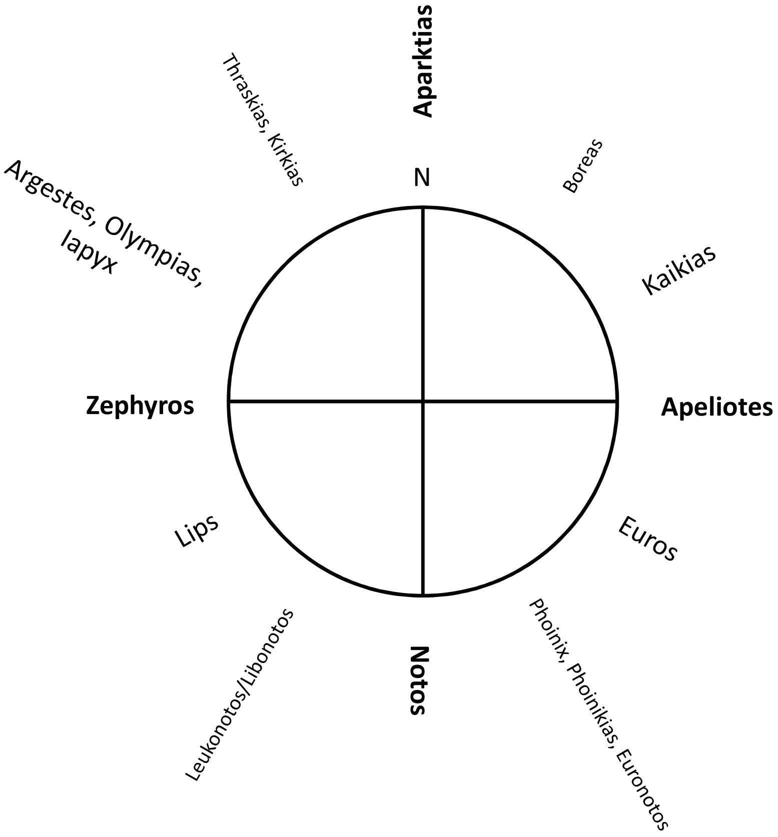

Fig. 1 Wind rose reconstructed according to Timosthenes' account

> ἀπαρκτίαν τοὺς ὑπὲρ Θρᾴκην Σκύθας, κατὰ δὲ βορρᾶν Πόντον, Μαιῶτιν, Σαρμάτας· κατὰ καικίαν Κασπίαν θάλασσαν καὶ Σάκας.[29]

> The winds that blow are: from the equidiurnal (*i.e. equinoctial*) rising (*of the sun; i.e. due east*) Apeliotes; from the equidiurnal setting (*due west*) Zephyros; from the midday (*due south*) Notos; and from the bear (*due north*) Aparktias. <The easterly winds:>[30] From the summer turning-point (*solstice; approx. NE*) Kaikias; next, from the equidiurnal rising Apeliotes (*as above*); and from the winter one (*approx. SE*) Euros. The westerly winds: from the winter setting (*approx. SW*) Lips; from the equidiurnal setting Zephyros again; and from the summer setting (*approx. NW*) Argestes or Olympias, also known as Iapyx. Next Notos and Aparktias, blowing against one another. Thus there are eight.

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[29] Fr. 3 Meyer = Agathemeros 2. 6–7 Leroy; I use Leroy's Greek text with one supplement by Meyer 2013. Angle brackets < > indicate words supplied by an editor where words are suspected of having dropped out during manuscript transmission.

[30] Meyer's supplement.

> But Timosthenes, the author of the *Circumnavigations*, says there are twelve. Between the Aparktias and Kaikias he adds Boreas (*NNE*); between Euros and Notos, Phoinix (*approx. SSE*), also called Euronotos; between Notos and Lips, Leukonotos or Libonotos (*approx. SSW*); between Aparktias and Argestes, Thraskias (*approx. NNW*), also <named> Kirkios by those living around that area.
>
> He states that the nations living at the furthest points towards Apeliotes are the Baktrians; towards Euros the Indians; towards Phoinix (*lie*) the Erythraian sea and Arabia; towards Notos the Aithiopia that is beyond Egypt; towards Leukonotos the Garamantes beyond the Syrteis; towards Lips the western (*dysmikoi*) Aithiopians, <those> beyond the Mauroi; towards Zephyros the Pillars (*of Herakles, i.e. strait of Gibraltar*) and the beginnings of Libyē[31] and Europe; towards Argestes Iberia, what is now Hispania; towards Thraskias <the Celts and their neighbours; towards the Aparktias> those Skythians that are beyond the Thracians; towards Boreas the Pontos, Maiotis (*sea of Azov*), and the Sarmatai; and towards Kaikias the Caspian sea and the Sakai.

In the last paragraph (as divided here), I have retained the wind names rather than replace them with compass directions (which would give phrases such as 'at the furthest points *to the east* are the Baktrians'); no consideration of intelligibility mandates such replacement, a point we shall return to later. In the first paragraph, however, a recent translator who preserves the wind names renders three of the directional terms and phrases literally, but inconsistently replaces the fourth with a conventional cardinal term:

> vom Punkt des Sonnenaufgangs zur Zeit des Äquinoktiums der Apeliotes, vom Punkt des Sonnenuntergangs zur Zeit des Äquinoktiums der Zephyros, vom Mittagspunkt her der Notos, *vom Nordpunkt* her der Aparktias.[32] (italics added)
>
> (from the point where the sun rises at the time of the equinox the Apeliotes, from the point where the sun sets at the time of the equinox the Zephyros, from the midday point the Notos, *from the north point* [rather than 'from the Bear'] the Aparktias.)

For greater consistency, after making *mesēmbria* 'the midday point', we might render *arktos* here as 'the bear'.

But is it right always to translate the eight words for the four cardinal points only by the four conventional words in English? Might it not be truer to the original author's intentions to use the primary sense of each of the Greek terms: bear(s) and north wind; dawn and rising; south wind and midday; evening and setting?

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[31] I use 'Libyē' rather than 'Libya' for Greek Λιβύη, as it denotes Africa as a whole.

[32] Meyer 2013, fr. 3.

Table 2 Cardinal and ordinal terms in Herodotos

		Literal meaning	Primary (animal, atmospheric, temporal)	Secondary (directional)
N	*arktos*[a]	Bear	2	5
	boreēs[b]	North wind	10	38
E	*anatolē* (6) + verb *anatellō* (4)[c]	Rising, rise	–	10
	ēōs[d]	Dawn	5	37
S	*mesambriē*	Midday	5	19
	notos	South wind	6	20
W	*dysmē*[e]	Setting	1	4
	hesperē	Evening	–	49
	zephyros	West wind	2	3

[a] Both references to *arktoi* as bears are to the animals, not the constellations. In the directional sense, Hdt. always use the singular form.

[b] Not counting 7 references to the mythological figure Boreas (all at 7. 189).

[c] Hdt. uses *hēliou anatolai* ('risings of (the) sun') 4 times, always preceded by πρὸς ἠῶ (τε) καί (*pros ēō (te) kai*, 'towards (the) dawn and'). He almost always uses *anatolē* in the plural. He also uses forms of ἀνατέλλω (*anatellō*, 'rise') with ἥλιος (*hēlios*, 'sun') 4 times.

[d] Not including the remarkable adjectival phrase τὸν ἑῷον στράτον (*ton ēōon straton*, lit. 'the army of the dawn'), to denote the Persian army (7. 157).

[e] Herodotos always uses the plural, *dysmai*. He does not use *dysis*.

5 Naming and Necessity

5.1 *'The West Yet Glimmers with Some Streaks of Day': What's in a Name?*

Proper names do not express essences, even if they have a definite etymology or are homonymous with meaningful words.[33] Trivially, when we see a mention of a person surnamed Redhead we do not for a moment suppose them to have red hair. More tellingly, a place called Newtown is not necessarily either new or a town even though, if it is not now, it probably was both of those at one time; the most we can say about its connotations is that on hearing its name we will probably assume it is a settlement. A weak application of this thesis to the present discussion would be that the four cardinal directions in English, even though their remote ancestries have been reconstructed—'north' being tentatively derived from roots meaning left or down, 'east' more confidently from dawn, 'south' from sun, and 'west' from dwelling or night[34]—cannot ever be thought to carry such connotations when used in discourse today.

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[33] See e.g. the classic lectures of Kripke 1972, republished as Kripke 1980.

[34] Etymologies claimed for 'east', 'south', and 'west' are documented by Skeat 1888, who regards the origin of 'north' as unknown, though in the revised edition of his shorter dictionary (Skeat 1901) he notes that some link it to 'left' or 'lower'. See also Onions 1933; Onions 1936. Nielsen 1945, 4, broadly concurs with Skeat.

In Greek, however, as noted earlier, all the words for cardinal directions (not forgetting the ninth term, Zephyros, the west wind)[35] have original, literal meanings and are used in both their primary and their secondary senses.[36] Table 2 illustrates Herodotos' use of the terms in question (some in their Ionic forms).[37]

In this case, therefore, the application of the 'naming and necessity' principle would involve a stronger claim: that when one of these terms is used in a directional sense—for example, when *anatolē*, 'rising', is used to mean 'the east'—it is an example of metonymy (as when we use 'the Crown' to mean 'the monarch') and carries no connotations of its original meaning. Whether a word is being used in its primary or its secondary sense can be determined on the basis of the context in which it used.

5.2 'Ce qu'a vu le vent d'ouest': Metonymy with Primary Meaning Suppressed

Among the terms listed selectively in the Appendices, the adjectives—especially in their comparative and superlative forms—are perhaps the most purely metonymic instances of these terms in use. We will never suppose that an author means to describe a people or place as 'more bearlike' than another, more 'dawnlike', or 'the one most characteristic of rising'. In his astrological work *Tetrabiblos* (3. 6. 3), Ptolemy contrasts people who are ἀπηλιωτικώτεροι (*apēliōtikōterοi*), literally 'more characteristic of the Apeliotes' (east wind), with those who are λιβικώτεροι (*libikōterοi*), literally 'more characteristic of the Lips' (south-west wind). It would be perverse not to read these words as meaning 'located further east' and 'located further south-west' and translate accordingly.

Geographical writers did not write in a separate domain from historians (and were often the same men). Numerous examples can be found in Herodotos (above) and the other major historians of cardinal terms being used purely directionally, without any hint of their original denotations being evident. We must not forget that Greek writers wishing to indicate compass directions had no other terms that they could use, so it must have been possible for them to use these words in a purely directional sense. In many passages the cardinal direction is therefore the only reasonable meaning to impute to such terms. Their use, however, is uneven: there are remarkably few such directional terms in, for example, Thucydides' *Histories*[38] and

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[35] Not a name with a meaning; possibly derived from the noun ζόφος, *zophos*, 'gloom', LSJ; cf. Nielsen 1945, 9.

[36] The same is true in Modern Greek, where derivatives from the Classical words operate similarly: for example, δύση (*dýsi*) usually means 'west' but also 'setting' or 'sinking', while ανατολή (*anatolí*) means 'east' and 'rise'.

[37] Data from Logeion, Perseus, and TLG (1 May 2020).

[38] Thucydides: no directional uses of *arktos*, *heōs*, *anatolē*, *zephyros*, or *dysis* (26 of *heōs* and 1 of *dysis* in temporal senses); (N) 5 directional expressions using *boreas*; (S) 3 cases of *pros noton*; 1

the *Hellenika* of Xenophon.[39] Let us focus on a couple of passages where the cardinal terms are used relatively often, to help determine how they should best be translated.

5.2.1 Polybios

Just over half of the 30 occasions on which the second-century BC historian Polybios uses *anatolē* are directional; he is also fond of *mesēmbria* to denote ‘south’ (29 occurrences; there are none of *notos* in a directional sense); and he prefers *dyseis* (plural; 22 uses) to other terms for ‘west’.[40] In two famous passages, he puts speeches into the mouths of protagonists in the affairs of Greece, in which in the word for a solar event is unmistakably used in a directional sense. In one, the speaker warns the king of Macedonia, Philip V, to remember ‘the scale of the war that has arisen towards the *dyseis*’, urging him ‘to look towards the *dyseis* … and pay attention to the wars that have arisen in Italia’, and to consider ‘the clouds appearing now from the *hespera*’ (Polybios 5. 104. 2, 7, and 10).[41] A later speaker is made to reuse the last metonymy, warning Philip’s enemies the Aitolians that ‘they have failed to notice that they have drawn onto themselves such a great cloud from the *hespera* that … shall subsequently be a cause of great evils for all Hellenes’ (7. 37. 10).[42] ‘Settings’ and ‘evening’ would make no sense here; the terms in these passages can only denote ‘the west’, the sphere of Roman power. In such contexts, which are ubiquitous in Greek writings, we are justified in using simple cardinal names in translation without elaborate explanation—though it would be prudent to tell the reader, especially in a book on geography, which term is being translated on each occasion (in the above examples *dyseis* or *hespera* would both be rendered as ‘west’).

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of τὰ μεσημβρινά, *ta mesēmbrina*, ‘the midday places’ (2 of *mesēmbria*, temporal); (W) 2 of *hespera* or the adjective *hesperios*, ‘western’ (3 temporal).

[39] Xenophon, *Hellenika*: no occurrences of *arktos*, *boreas*, *anatolē*, *notos*, *dysis*, *zephyros*, or cognate terms; (E) 3 of the adj. ἕῴος (*heōos*, ‘of the dawn’) for the ‘eastern’ wall of a place, 1 of *ta pros heō* for ‘the eastward parts’ of a city; (W) 4 directional uses of *hespera* (10 temporal); 1 temporal of *dysmē*.

[40] Polybios uses *anatolai* (plural) as a simple direction 16 times, *anatolē* once; qualifies the term with ‘summer’ 5 times, with ‘winter’ and ‘equidiurnal’ once each, to refer to an ordinal direction; refers 3 times to sunrise as an event, once to moonrise; twice uses the term for the source of a river. (Data from Logeion and Perseus databases, 1 May 2020.) He uses *ēōs* in a directional sense 3 times; *notos* only of the wind; words related to *hespera* 11 times in directional sense (and twice temporal).

[41] (2) τὸ μέγεθος τοῦ πρὸς ταῖς **δύσεσι** πολέμου … (7) πρὸς τὰς **δύσεις** βλέπειν … καὶ τοῖς ἐν Ἰταλίᾳ συνεστῶσι πολέμοις προσέχειν … (10) τὰ προφαίνομενα νῦν ἀπὸ τῆς **ἑσπέρας** νέφη.

[42] λελήθασιν αὑτοῖς ἐπισπασάμενοι τηλικοῦτο νέφος ἀπὸ τῆς **ἑσπέρας,** ὃ κατὰ […] τὸ συνεχὲς πᾶσιν ἔσται τοῖς Ἕλλησι μεγάλων κακῶν αἴτιον.

5.2.2 Markianos

Also telling are passages where a series of orientations are systematically enumerated in rapid succession, as when the late antique geographer Markianos, in his *Circumnavigation of the Outer Sea*, defines a series of regions in Asia by those surrounding each; the progress of his thought being perhaps too swift to allow any expectation that the reader should pick up on the original, non-directional meanings of the terms:

> ἡ Σουσιανὴ κεῖται μὲν ἐν τῷ Περσικῷ κόλπῳ· περιορίζεται δὲ ἀπὸ μὲν ἄρκτων τῇ Ἀσσυρίᾳ, ἀπὸ δὲ δύσεως τῇ προειρημένῃ Βαβυλωνίᾳ παρὰ τὸ τοῦ Τίγριδος ποταμοῦ μέρος τὸ μέχρι θαλάσσης, ἀπὸ δὲ ἀνατολῆς τῇ Περσίδι, ἀπὸ δὲ μεσημβρίας τῷ Περσικῷ κόλπῳ […]
>
> Sousiane lies in the Persian gulf. It is bounded on the north (*apo arktōn, lit. 'from the bears'*) by Assyria; on the west (*apo dyseōs, lit. 'from the settings'*) by the aforementioned Babylonia beside this part of the river Tigris as far as the sea; on the east (*apo anatolēs, lit. 'from the rising'*) by Persis; and on the south (*apo mesēmbrias, lit. 'from the midday'*) by the Persian gulf […]

The passage echoes much earlier usage, such as that of Herodotos in the fifth century BC, describing Ionia (1. 142):

> οὔτε γὰρ τὰ ἄνω αὐτῆς χωρία τὠυτὸ ποιέει τῇ ᾿Ιωνίῃ οὔτε τὰ κάτω, οὔτε τὰ πρὸς τὴν ἠῶ οὔτε τὰ πρὸς τὴν ἑσπέρην
>
> For neither do the places above it behave in the same way as Ionia, nor do those below it[43]; neither do those to the east of it (*pros tēn ēō, lit. 'towards the dawn'*) or to the west (*pros tēn hesperēn, lit. 'towards the evening'*).

Again, a rapid accumulation of orientations makes the non-cardinal connotations irrelevant, and we should translate using standard cardinal directions.

5.3 'There's a Bitter East Wind and the Fields are Swaying': Primary Meaning Present

Other passages, however, make it hard not to be aware of the original, primary sense of a term. This is particularly the case when a directional expression is a phrase composed of two or more words (other than a simple preposition-plus-noun phrase), where a syntactical relationship is created between the terms. Among these, perhaps the most telling are those that refer to the stages of the sun's daily movement, such as 'the rising sun' or 'the setting(s) of the sun', where it is hard to suppose that the author does not intend us to acknowledge the metonymy, recognizing the primary

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[43] One would normally take ἄνω (*anō*), 'up', to mean 'up-country', i.e. 'inland'; but here it is opposed to κάτω (*katō*), 'down', which cannot mean 'out at sea'. Possibly Herodotos is thinking of spatial relationships on a display map of the kind that Aristagoras of Miletos possessed (5. 49).

meaning as well as the directional. The same is true of those phrases that incorporate seasonal terms, such as ‘summer rising’ and ‘winter setting’; and finally of those expressions that incorporate astronomical references, such as ‘equidiurnal’ (i.e. equinoctial) sunrise or summer sunset, where the reader or listener is likely to perceive the connotations of sky and horizon as well as understand the ordinal direction as intended. Such phrases often occur in passages where cardinal directional terms are employed in their purely metonymic sense (e.g. *arktos* meaning north) while others, including phrases, make their connotations visible.

5.3.1 Ps.-Skylax

Some sources revealingly combine different sets of terms and point up the contrast between directional and ‘meaningful’ usage, as in this remarkable passage from the anonymous mid-fourth-century BC *Periplous* (*Circumnavigation*) known as Pseudo-Skylax (47. 3–4):

> (2) ἔστι δὲ ἡ Κρήτη μακρὰ στάδια βφʹ, στενὴ δέ, καὶ τέταται ἀπὸ ἡλίου δυσμῶν πρὸς ἡλίου ἀνατολάς
>
> (3) <ἐπὶ Κωρύκ>ω̣ ἀκρωτηρίῳ̣ ἐστὶ πρώτη πόλις πρὸς ἥλιον δυόμενον ἡ προειρημένη Φαλασάρνα καὶ λιμὴν κλειστός. Πολυρρηνία, καὶ διήκει ἀπὸ βορέου πρὸς νότον. Δικτυνναῖον Ἀρτέμιδος ἱερὸν πρὸς βορέαν ἄνεμον, τῆς χώρας Περγαμίας. πρὸς νότον δὲ Ὑρτακίνα. Κυδωνία καὶ λιμὴν κλειστὸς πρὸς βορέαν· […] πρὸς νότον δὲ Λίσσα […] πρὸς βορέαν δὲ ἄν<εμον> ἡ Ἀπτεραία χώρα. […]
>
> 4. μετὰ δὲ ταύτην ὄρος Ἴδα καὶ Ἐλεύθερναι πρὸς βορέαν. πρὸς νότον δὲ Σύβριτα καὶ λιμήν πρὸς νότον Φαιστός. πρὸς βορέαν Ὀαξὸς καὶ Κνωσσός. πρὸς δὲ νότον Γόρτυνα. […] Ἴτανος ἀκρωτήριον Κρήτης πρὸς ἥλιον ἀνίσχοντα[44]

> (2) Krete is 2,500 stades long, and narrow, and extends from the settings of the sun (*apo hēliou dysmōn*) towards the risings of the sun (*pros hēliou anatolas*).
>
> (3) <After Koryk>os promontory the first city towards the setting sun (*pros hēlion dyomenon*) is the aforementioned Phalasarna with an enclosed harbour. Then Polyrrhenia, and it extends from the north (*apo boreou*) towards the south (*pros noton*). Diktynnaion, a sanctuary of Artemis, towards the north wind (*pros borean anemon*), belonging to the Pergamia territory. Towards the south (*pros noton*) Hyrtakina. Kydonia with an enclosed harbour towards the north (*pros borean*). […] Towards the south (*pros noton*) Lissa […] Towards the north wi<nd> (*pros borean an<emon>*) the Apteraia territory. […]
>
> (4) After this Mount Ida, with Eleuthernai towards the north (*pros borean*). Towards the south (*pros noton*) Sybrita with a harbour towards the south (*pros noton*), Phaistos. Towards the north (*pros borean*) Oaxos and Knossos. Towards the south (*pros noton*) Gortyna. […] Itanos, the promontory of Crete towards the upcoming sun (*pros hēlion anischonta*).

It is likely that in this passage Pseudo-Skylax is drawing upon an earlier source specifically dedicated to Crete, for its arrangement is quite different from that of the rest of his *periplous*: the elongated island is described from west to east, the gaze swinging from the north coast to the south and back again as necessary (Fig. 2). I have translated *boreas* and *notos* above, when they occur alone, metonymically as

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[44] The Greek text is that reconstructed by Shipley 2019.

Fig. 2 Crete, showing places mentioned by Pseudo-Skylax (Shipley 2019: 130)

'north' and 'south' because the passage also twice contains the phrase *pros borean anemon* (in one case partly restored), which is translated literally as 'towards the north *wind*' (*anemos* means 'wind'), not simply 'towards the north'. If the variation in expression has any significance, the unadorned *boreas* and *notos* should be purely directional without their original connotations being present. A similar variation can be seen in Herodotos' practice: of the 20 instances in which he uses *notos* as a directional term, eight include the word *anemos*, as in *pros noton anemon*, 'towards the south wind'.[45] Translations should reflect this variation.

The phrase *apo hēliou dysmōn*, likewise, merits literal translation ('from the settings of the sun', 'from the sun's settings', or 'from the sunsets') as it has been chosen by the writer where a simpler metonymic phrase such as *apo dyseōs*, 'from the setting', could have been used; the latter, in such a context, would be translated simply 'from the west'.

5.3.2 Aristotle, *Meteorologika*

Aristotle, a contemporary of the unknown author of the *periplous* just quoted, devotes Chap. 6 of book 2 of his *Meteorologika* (the title means roughly 'aerial phenomena') to the winds, and includes one of the earliest mentions of a diagram accompanying a text (the original is, of course, lost),[46] as well as one of the earliest codifications of the 'wind rose', a version of which we have already encountered in the version quoted from the slightly later author Timosthenes. An extract from the middle of his chapter is particularly worthy of attention when we consider the denotations and connotations of wind names and directional expressions, as it combines

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[45] In one of these 8 cases the word order is varied: *pros anemon noton* (Hdt. 7. 129. 1).

[46] We have no original, or even near-contemporary, copies of Classical, Hellenistic, or Roman-period books unless they happen to have been copied onto stone or metal (which is rare); occasionally we have fragmentary copies on Egyptian papyri. Most ancient writings survive only in medieval parchment or vellum manuscripts.

metonymic uses of cardinal terms (e.g. the adjective *boreia* = 'northerly') with names of winds used literally:

> Ἔστι δὲ τῶν εἰρημένων πνευμάτων βορέας μὲν ὅ τ᾽ ἀπαρκτίας κυριώτατα, καὶ θρασκίας καὶ μέσης· ὁ δὲ καικίας κοινὸς ἀπηλιώτου καὶ βορέου· νότος δὲ ὅ τε ἰθαγενὴς ὁ ἀπὸ μεσημβρίας καὶ λίψ· ἀπηλιώτης δὲ ὅ τε ἀπ᾽ ἀνατολῆς ἰσημερινῆς καὶ ὁ εὖρος· ὁ δὲ φοινικίας κοινός· ζέφυρος δὲ ὅ τε ἰθαγενὴς καὶ ὁ ἀργέστης καλούμενος.
>
> ὅλως δὲ τὰ μὲν βόρεια τούτων καλεῖται, τὰ δὲ νότια· προστίθεται δὲ τὰ μὲν ζεφυρικὰ τῷ βορέᾳ (ψυχρότερα γὰρ διὰ τὸ ἀπὸ δυσμῶν πνεῖν), νότῳ δὲ τὰ ἀπηλιωτικά (θερμότερα γὰρ διὰ τὸ ἀπ᾽ ἀνατολῆς πνεῖν). διωρισμένων οὖν τῷ ψυχρῷ καὶ τῷ θερμῷ καὶ ἀλεεινῷ τῶν πνευμάτων οὕτως ἐκάλεσαν. θερμότερα μὲν τὰ ἀπὸ τῆς ἕω τῶν ἀπὸ δυσμῆς, ὅτι πλείω χρόνον ὑπὸ τὸν ἥλιόν ἐστι τὰ ἀπ᾽ ἀνατολῆς· τὰ δ᾽ ἀπὸ δυσμῆς ἀπολείπει τε θᾶττον καὶ πλησιάζει τῷ τόπῳ ὀψιαίτερον.

The difficulties of doing justice to the terminology, and an unwillingness to use wind names that might be unfamiliar to readers, caused the Loeb translator of 1952 to undergo contortions in order to convey what is admittedly an elliptical, and possibly not quite logical, passage:

> Of the winds thus described the truest north winds are Aparctias, Thrascias and Meses. Caecias is part east and part north. South are the winds that come from due south and Lips.[47] East are the winds that come from the equinoctial sunrise and Eurus. Phoenicias is part south, part east. West is the wind from due west and also the wind called Argestes.
>
> There is a general classification of these winds into northerly and southerly: westerly winds are counted as northerly, being colder because they blow from the sunset; easterly winds are counted as southerly, being warmer because they blow from the sunrise. Winds are thus called northerly and southerly according to this division into cold and hot or warm. Winds from the sunrise are warmer than winds from the sunset, because those from the sunrise are exposed to the sun for longer; while those from the sunset are reached by the sun later and it soon leaves them.

An alternative rendering will stay closer to the Greek:

> Among the said winds, Boreas (*i.e. the set of northerly winds*) is chiefly Aparktias, but also Thraskias and Mesēs; but the Kaikias is shared between Apeliotes and Boreas. Notos is both the direct wind from the south (*mesēmbria*), and also the Lips. Apeliotes is that from the equinoctial sunrise, and also the Euros; Phoinikias is shared. Zephyros is both the direct wind and the one called Argestes.
>
> Overall, some of these are called northerlies (*boreia*), others southerlies (*notia*). The westerlies (*zephyrika*) are assigned to Boreas, as they are colder since they blow from the west (*dysmai*). To Notos are assigned the easterlies (*apēliōtika*), as they are warmer since they blow from the east (*anatolē*). People called them by these names (*i.e. grouped them in two categories*) because they were distinguished by cold, heat, and warmth. For those from the east (*ēōs*) are hotter than those from west (*dysmē*), because they are under the sun for a longer time than are those from the east (*anatolē*); but it leaves those from the west (*dysmē*) more swiftly and approaches that location later.[48]

The Loeb translator seems unsure whether certain terms are meaningful or purely metonymic (directional). Now substituting cardinal terms for wind names (e.g., 'part east and part north' rather than 'shared between Apeliotes and Boreas'), now

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[47] This makes it appear that Lips is a directional term.

[48] The Loeb translator has reversed the order of this last phrase to improve the logic.

leaving wind names unchanged, the translation obscures more than it illuminates Aristotle's admittedly compressed expression, and leads to apparent tautology that is not present in the Greek ('south are the winds that come from due south and Lips … West is the wind that comes from the west and also the wind called Argestes'). In the second paragraph (as divided above), the Loeb translates both *heōs* and *anatolē* as 'sunrise', whereas they are purely directional terms in this passage; as are *dysmai* and *dysmē*, both unnecessarily translated 'sunset'. It would be desirable to reflect the variation between *heōs* and *anatolē*, but it is difficult without importing metonymic words ('dawn', 'rising'). Part of the solution is to to include the different transliterated Greek words in parentheses.

5.3.3 Theophrastos

Aristotle's younger contemporary Theophrastos also discusses the winds systematically in his *Weather Signs*. Although the following extract uses only wind names, it offers a salutary indication of the responsibilities of the translator. A small extract (from section 36) suffices:

> Ὑγροὶ δὲ μάλιστα ὅ τε καικίας καὶ λίψ· χαλαζώδης δ᾽ ἀπαρκτίας καὶ θρακίας καὶ ἀργέστης· νιφετώδης δὲ ὅ τε μέσης καὶ ἀπαρκτίας· καυματώδης δὲ νότος καὶ ζέφυρος καὶ εὖρος.

The Loeb translator of 1916 imagines that converting unfamiliar wind names to compass directions will make the meaning clear, but leaves the Greek far behind:

> The north-east and south-west are the wettest winds; the north<,> the north-north-east<,>[49] and the north-east bring hail; snow comes with the north-north-east and north. The south, the west, and the south-east winds bring heat.

The wind names are suppressed, but the plethora of hyphenated compass bearings arguably makes the text more resistant to reading—even though a reconstruction of Theophrastos' diagram (mentioned in the Greek text) accompanies the printed text.[50] An alternative rendering, much closer to the Greek and surely no less transparent, is:

> The Kaikias and Lips are particularly moist; the Aparktias, Thrakias,[51] and Argestes are characterized by hail; the Meses and Aparktias are snowy; Notos, Zephyros, and Euros are burning.

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[49] I have added the two commas, clearly omitted by typographic error.

[50] Though with the wind names only in Greek: Hort 1916, 414 (relevant passage of text on pp. 416–17).

[51] Same as Thraskias in other sources.

6 Conclusion: An Enriched Experience

A translator should endeavour to replicate differences in the original. To ignore variations in the Greek, and use only ‘north’, ‘east’, ‘south’, and ‘west’ whenever any of the nine simple (one-word) cardinal terms in Greek is used, might seem regrettable: it offers the reader less than one might; it could be a missed opportunity to clarify the text; it may sometimes amount to falsifying the text.

Should we then veer to the opposite extreme, and always communicate the original senses of the terms? Geographical areas might in that case be said to extend ‘from the settings to the risings’, barbarian peoples to live ‘towards the midday’ or ‘in the dawn’, one place to lie ‘towards the setting’ from another, and so on. This has something to commend it, in reminding the reader that the original texts are from a very different cultural milieu[52]; but one risks attempting to teach the reader a new vocabulary and change their understanding in a way that they may find rebarbative. A translator cannot afford to lose their audience. We might gloss each term with an insertion such as ‘(*i.e. the north*)’; but if we were to do so at every occurrence we would make many passages less legible. The more serious problem with this approach is that, on the basis of context, it is evident that Greek authors, as we have shown, very often use these eight cardinal terms metonymically, no hint of their primary meanings (e.g. ‘bear’, ‘dawn’, ‘setting’) being intended or needed. We must fall back on the regular cardinal terms in English.

Is the use of English compass bearings justified in the case of phrases denoting either cardinal or ordinal points, or in the case of wind names? Should we render the unfamiliar Thraskias as ‘north-west’ or ‘north-west wind’, the phrase ‘sun’s settings’ as ‘west’, and so on? But this, too, would impoverish the reader’s experience and, as we have seen, can make texts harder to understand as well as diverging further from the original.

As Fowler remarks of the split infinitive, the correct response to such anxieties is to ‘know and distinguish’.[53] A middle way seems best. A familiar starting-point for translators is to try to replicate for modern readers, as far as possible, the effect a text may be thought to have had upon ancient readers (or listeners),[54] rather than to follow an ephemeral modern style. (Some early Penguin Classics volumes have been said to adopt the style of a 1950s British civil servant.[55]) A suitable compromise, inevitably involving subjectivity at certain points, would be, as Raymond Dawson opined in 1993, to offer a version that while ‘as close to the original as

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[52] Cf. R. B. Rutherford, reviewing Woodman 2004, at *BMCR* 2005.07.15, on ‘defamiliarising (emphasising [a work’s] alien or remote qualities)’.

[53] Fowler 1965, 579–82, at 579: ‘The English-speaking world may be divided into (1) those who neither know nor care what a split infinitive is; (2) those who do not know, but care very much; (3) those who know and condemn; (4) those who know and approve; and (5) those who know and distinguish.’

[54] A view famously expounded by Arnold 1861.

[55] D. Nightingale, pers. comm, *c*.1978.

possible, *even if the result is sometimes a little outlandish*' (italics added), does not read 'as if it were written at the end of the twentieth century'.[56] Applying this to geographical texts is not always easy; but some of the examples above have illustrated how a pronounced departure from the Greek, for example the silent replacement of wind names (other than *boreas* and *notos* used directionally) with compass points, sells the reader short and does not necessarily make things clearer.

The case has been made above that the one-word Greek terms for cardinal directions, when there is no reason to think their primary senses are part of the author's intention, should be translated by the four English terms. Rather than repeated comments within the translation, an editorial note at the start of the translation, particularly of a geographical work, should be used to explain that cardinal terms in Greek are more numerous than in English and illustrate how they have been translated; and, if appropriate, to note the ancient author's habitual usage. Regrettably, there seems to be no way to use two alternative English terms for each cardinal point (as would be possible in, for example, French, where *midi* might very appropriately be used for *mesēmbria* and *sud* for *notos*). There are situations in which 'sunrise', 'midday', and 'sunset' might serve but, as these are not normal directional terms in English, they cannot help but force their original meanings upon the reader, unlike *anatolē*, *mesēmbria*, and *dysis* when used in this way. (The terms 'orient' and 'occident', as general directional terms, are not current English; and the former carries unwelcome ideological freight.) If these simple terms occur in proximity to the other member of their pair (e.g. *ēōs* to *anatolē*), to directional wind names, or to other multi-word direction phrases, the transliterated terms may be added in parentheses, in a form such as 'east (*ēōs*)'.

In conclusion, the following policy seems to commend itself:

> (1) Single Greek words for cardinal directions to be translated by their simple English equivalents, explaining (in an introduction or note) the translator's practice; including, when necessary to distinguish, the transliterated Greek in parenthesis. *Examples*: *arktoi* 'north'; *ēōs* 'east'—or, for clarity, 'east (*anatolē*) … east (*ēōs*)'.
>
> (2) Cardinal directions expressed by phrases of two or more words to be translated so as to preserve the syntactical relationship and grammatical number. *Examples*: *hēliou dysmai* 'settings of the sun'; *therinē anatolē* 'summer sunrise' (rather than the vague 'rising'); *boreas anemos* 'north wind'.
>
> (3) Ordinal directions (NE, SE, SW, NW) expressed by astronomical modifications to be translated as literally as possible. *Example*: *isēmerinē dysis* 'equidiurnal setting', if necessary with explanations such as '(*i.e. equinoctial*)' and '(*due west*)'.
>
> (4) Names of winds, when not used simply as under (1) above, to be retained as names, with capital initial and in roman type. *Examples*: Boreas, Aparktias.

In these ways it is hoped that translators will modify their habitual procedure in the interest of clarity and of representing the thoughts of the Greek geographers more accurately.

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[56] Dawson 1993, xvi.

Appendices

The two catalogues below are illustrative, not comprehensive. In this section of the paper, translations below are strictly literal unless prefixed by 'i.e.' Some noun phrases are converted to the nominative case. The prefix 'Ps.-' means 'Pseudo-'.[57]

Some citations are accompanied by a reference to their original context: e.g. Timosthenes fr. 3 is a quotation or paraphrase preserved in the surviving treatise of Agathemeros at 2. 6. Citations of Agatharchides are accompanied by '(Photios)' or by a citation of Diodoros because our extensive derive from long summaries in those two authors (those of Photios, though later, being generally more accurate). For approximate dates of authors, see n. 3 above.

Appendix 1: Examples of Celestial Directions

North

***ἄρκτος** (arktos), 'bear', pl. ἄρκτοι (arktoi), 'bears'*

ἀπὸ ἄρκτου (*apo arktou*), 'from (the) bear', Timosthenes fr. 3 (Agathemeros 2. 6); Ps.-Aristotle 4; ἀπὸ τῆς ἄρκτου (*apo tēs arktou*), 'from the bear', Agatharchides 10 (Photios)

ἀπὸ ἄρκτων (*apo arktōn*), 'from (the) bears', Markianos 6; ἀπὸ τῶν ἄρκτων (*apo tōn arktōn*), 'from the bears', *Airs, Waters, and Places* 3

ἐπὶ τοὺς ἄρκτους (*epi tous arktous*), 'to the bears', Markianos 6

πρὸς ἄρκτον (*pros arkton*), 'towards (the) bear', Herodotos 1. 148; Hipparchos fr. 21 (Strabo 2. 1. 27); *Hypotyposis* 53; πρὸς τὰς ἄρκτους (*pros tas arktous*), 'towards the bears', Agatharchides 43b (Diodoros 3. 19. 1)

adj. **ἀρκτικός** (*arktikos*), 'of (the) bear(s)'

τὰ ἀρκτικά (*ta arktika*), 'the (places) of the bear(s)', Dikaiarchos fr. 124 (Strabo 2. 4. 2); = Arctic circles, Eratosthenes fr. 44 (Geminus 15)

ἀρκτικὸς πόλος (*arktikos polos*), 'pole of the bear(s)', Ps.-Aristotle 2 (also ἀνταρκτικὸς πόλος, *antarktikos polos*, 'pole opposite the bears'—the unknown South Pole)

comparative: ἀρκτικώτερος (*arktikōteros*), 'more of/towards the bear(s)', i.e. 'more northerly', 'further north', Hipparchos fr. 11 (Strabo 1. 1. 12)

adj. **ἀρκτῷος** (*arktōios*), 'of (the) bear(s)'

ἀρκτῴοιο … βορέαο (*arktōioio … boreao*), 'of Boreas of the bear(s)' (Homeric dialect), Dionysios Periegetes 519

ὁ ἀρκτῷος ὠκεανὸς (*ho arktōös ōkeanos*), 'the ocean of the bear(s)', i.e. the northern or Arctic part of the Ocean, Markianos 1

adj. **προσάρκτιος** (*prosarktios*), 'by/towards (the) bear(s)', Strabo 1. 4. 5

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[57] The name 'Ps.-Skymnos' is in quotation marks because the attribution of the Hellenistic poem to the real Skymnos of Chios is not a suggestion made in any manuscript but a hypothesis of the early modern period, now disproved. The work would better be called 'Anonymous, *Iambics to King Nikomedes*', but 'Pseudo-Skymnos' has stuck.

τὰ προσάρκτια μέρη (*ta prosarktia merē*), ‘the parts towards the bears (*from these*)’, i.e. to the north of these, Timosthenes fr. 5 (Strabo 2. 1. 41)

τὴν προσάρκτιον τῆς Εὐρώπης πᾶσαν (*tēn prosarktian tēs Europēs pasan*), ‘all the part of Europe towards the bear(s)’, Polybios 34. 5. 9

East

ἀνατολή *(anatolē), ‘a rising’*

ἀπὸ (or ἀπ’) ἀνατολῆς (*apo anatolēs*), ‘from (the) rising’, Agatharchides 10 (Photios); Ps.-Aristotle 4; Markianos 6; *Hypotyposis* 1

ἐν ταῖς ἀνατολαῖς (*en tais anatolais*), ‘in the risings’, Hekataios fr. 18b (scholiast on Apollonios Rhodios, *Argonautika* 4. 284)

ἐντὸς ἀνατολῶν (*entos anatolōn*), ‘within (the) risings’, ‘Pseudo-Skymnos’ 270

πρὸς ἀνατολάς (*pros anatolas*), ‘towards (the) risings’, Theophrastos, *History of Plants* 9. 15. 2; πρὸς τὰς ἀνατολάς (*pros tas anatolas*), Polybios 2. 14. 4

with ἥλιος (*hēlios*), ‘sun’: ἀπὸ ἠλίου ἀνατολέων (*apo hēliou anatoleōn*), ‘from (the) risings of (the) sun’, Ionic, Herodotos 4. 8; πρὸς ἡλίου ἀνατολάς (*pros hēliou anatolas*), ‘towards (the) risings of (the) sun’, Ps.-Skylax 47. 2

special forms: ἀπὸ ἰσημερινῆς ἀνατολῆς (*apo isēmerinēs anatolēs*), ‘from (the) equidiurnal (*i.e. equinoctial*) rising’, i.e. from due west, Timosthenes fr. 3 (Agathemeros 2. 6) *bis*; ἀπὸ τοῦ περὶ τὰς ἰσημερινὰς (sc. ἀνατολὰς τόπου) (*apo tou peri tas isēmerinas*, sc. *anatolas topou*), ‘from the (place) around the equidiurnal (*i.e. equinoctial*) (risings), i.e. around due west, Ps.-Aristotle 4

adj. **ἀνατολικός** (*anatolikos*), ‘of (the) rising’, Hipparchos fr. 21 (Strabo 2. 1. 27)

τὸ ἀνατολικὸν (ἡμισφαίριον) (*to anatolikon*, sc. *hēmisphairion*), ‘the hemisphere of (the) rising’, Strabo 2. 3. 2

comparative: ἀνατολικώτερος (*anatolikōteros*), ‘more in/towards (the) rising(s)’, i.e. further east, Hipparchos fr. 21 (Strabo 2. 1. 27)

superlative: ἀνατολικώτατος (*anatolikōtatos*), ‘most in/towards (the) rising(s)’, i.e. furthest east, Markianos 6

ἥλιος ***ἀνατέλλων*** *(hēlios anatellōn), ‘(the) rising sun’*

τὰ πρὸς … ἥλιον ἀνατέλλοντα (*ta pros … hēlion anatellonta*), ‘the parts towards (the) rising sun’, Herodotos 4. 40

ἥλιος ***ἀνίσχων*** *(hēlios anischōn), ‘(the) sun emerging’*

πρὸς ἥλιον ἀνίσχοντα (*pros hēlion anischonta*), ‘towards (the) emerging sun’, Hanno, 3; Hekataios fr. 204 (Stephanos of Byzantion s.v. Χοιράδες); Ps.-Skylax 47. 4; Herodotos 3. 98

ἥλιος ***ἀνιών*** *(hēlios aniōn), ‘(the) ascending sun’*

πρὸς ἀνιόντα ἥλιον (*pros anionta hēlion*), ‘towards (the) ascending sun’, ‘Ps.-Skymnos’ 522–3

ἠώς *(ēōs), dawn’;* ***ἕως*** *(heōs) in Attic dialect*

ἀπὸ ἠοῦς (*apo ēous*), ‘from (the) dawn’, Herodotos 2. 8; ἀπὸ τῆς ἠοῦς (*apo tēs ēōus*), ‘from the dawn’, *Airs, Waters, and Places* 6

ἐπὶ ἕω (*epi heō*), ‘to (the) dawn’, Eratosthenes fr. 72 (Arrian, *Indike* 3. 1–5)

πρὸς ἠῶ τ’ ἠέλιόν τε (*pros ēō t’ ēelion te*), ‘towards dawn and sun’, *Iliad* 12. 239

πρὸς ἕω (*pros ēō*), ‘on the side of (the) dawn’, Eratosthenes fr. 32 (Agathemeros 1. 2), fr. 71 (Arrian, *Anabasis* 5. 6. 3); Dionysios son of Kalliphon 83

τὰ πρὸς ἠῶ (*ta pros ēō*), ‘the parts towards (the) dawn’, Herodotos 4. 40; τὰ πρὸς τὴν ἠῶ (*ta pros tēn ēō*), ‘the parts towards the dawn’, Herodotos 2. 8

adj. **ἑωθινός** (*heōthinos*), ‘of the dawn’

ἑωθινὸν ἔθνος (*heōthinon ethnos*), ‘nation of the dawn’, i.e. eastern nation, Dionysios Periegetes 697

comparative: ἑωθινώτερος (*heōthinōteros*), ‘more in/towards the dawn’, i.e. further east, Strabo 11. 2. 2; *Hypotyposis* 53

superlative: ἑωθινώτατος (*heōthinōtatos*), ‘most in/towards the dawn’, i.e. furthest east, Strabo 4. 5. 1; *Hypotyposis* 1

adj. **ἑῷος** (*heōios*), ‘of/in the dawn’

ἡ ἑῴη θάλασσα (*hē heōiē thalassa*), ‘the sea in the dawn’, Eratosthenes fr. 72 (Arrian, *Indike* 3. 1–5)

τὰ ἑῷα (*ta heōia*), ‘the parts in the dawn’, Ps.-Aristotle 4

ὁ ἑῷος ὠκεανὸς (*ho heōos ōkeanos*), ‘the ocean in the dawn’, Markianos 1

ἐξ ἑῴας (*ex heōias*) (sc. χώρας, *chōras*), ‘from (the) dawn (land)’, Aristotle, *Problemata* 946b14

πρὸς ἠοίων … ἀνθρώπων (*pros ēoiōn … anthrōpōn*), ‘from men of the dawn’, *Odyssey* 8. 29

πρὸς τῷ ἑῴῳ τείχει (*pros tōi heōiōi teichei*), ‘by the dawn wall’, Xenophon, *Hellenika* 4. 4. 9

South

μεσημβρία *(mesēmbria), ‘the midday’*

ἀπὸ μεσημβρίας (*apo mesēmbrias*), ‘from (the) midday’, Timosthenes fr. 3 (Agathemeros 2. 6); Ps.-Aristotle 4; Markianos 6; Ionic ἀπὸ μεσαμβρίης (*apo mesambriēs*), Herodotos 1. 6; ἀπὸ τῆς μεσημβρίας (*apo tēs mesēmbrias*), ‘from the midday’, Agatharchides 10 (Photios)

ἐπὶ μεσημβρίαν (*epi mesēmbrian*), ‘to (the) midday’, Eratosthenes fr. 71 (Arrian, *Anabasis*, 5. 6. 3)

πρὸς μεσημβρίαν (*pros mesēmbrian*), ‘towards (the) midday’, Eratosthenes fr. 83 (Strabo 2. 1. 26); ‘Ps.-Skymnos’ 171, 521; Dionysios son of Kalliphon 62; Ionic πρὸς μεσαμβρίην (*pros mesambriēn*), Herodotos 1. 142

πρὸς μεσημβρίης (*pros mesēmbriēs*), ‘on the midday side of’, Hekataios fr. 108 (Stephanos of Byzantion s.v. s.v. Δωδώνη)

ὑπὸ τὴν μεσημβρίαν (*hypo tēn mesēmbrian*), Artemidoros (Diodoros 3. 2. 1)

adj. **μεσημβρινός** (*mesēmbrinos*), ‘of the midday’

τὰ μεσημβρινά (*ta mesēmbrina*), ‘the parts towards the midday’, Thucydides 6. 2. 5; Strabo 2. 1. 12

κατὰ τὸ μεσημβρινόν (*kata to mesēmbrinon*), ‘towards the midday (place)’, Ps.-Aristotle 4

ὁ μεσημβρινὸς ὠκεανὸς (*ho mesēmbrinos ōkeanos*), ‘the ocean of midday’, Markianos 1

comparative: μεσημβρινώτερος (*mesēmbrinōteros*), ‘more in/towards the midday’, Geminus 14. 10

superlative: μεσημβρινώτατος (*mesēmbrinōtatos*), ‘most in/towards the midday’, Strabo 2. 5. 33

West

δύσις *(dysis), 'sinking', '(a) setting' (noun)*

ἀπὸ δύσεως (*apo dyseōs*), 'from (the) setting', Agatharchides 10 (Photios); Ps.-Aristotle 4; Markianos 6; Ionic ἀπὸ δύσιος (*apo dysios*), Hekataios fr. 217 (Strabo 12. 3. 22)

ἐπὶ δύσιν (*epi dysin*), 'to (the) setting', Markianos 6; *Hypotyposis* 1

πρὸς δύσιν (*pros dysin*), 'towards (the) setting', Hekataios fr. 102c (Strabo 6. 2. 4); Eratosthenes fr. 32 (Agathemeros 1. 2)

πρὸς δύσεις (*pros dyseis*), 'towards (the) settings', Polybios 1. 42. 5; πρὸς τὰς δύσεις βλέπειν (*pros tas dyseis blepein*), Polybios 5. 104. 7

πρὸς ἡλίου δύσιν (*pros hēliou dysin*), 'towards (the) setting of (the) sun', Thucydides 2. 96

modifications:

ἀπὸ ἰσημερινῆς δύσεως (*apo isēmerinēs dyseōs*) and ἀπὸ δύσεως ἰσημερινῆς (*apo dyseōs isēmerinēs*), 'from (the) equidiurnal setting', Timosthenes fr. 3 (Agathemeros 2. 6); cf. Ps.-Aristotle 4

ὑπ᾽ ἰσημερινῆς <θερινῆς> τε δύσεως (*hyp' isēmerinēs <therinēs> te dyseōs*), 'Ps.-Skymnos' 172; εἰς χειμερινὰς δύσεις (*eis cheimerinas dyseis*), Polybios 1. 42. 6

adj. **δυτικός** (*dytikos*), 'of/in/towards (the) setting(s)'

τὰ δυτικά (*ta dytika*), 'the parts towards (the) setting(s)', Ptolemy 2. 11. 16

comparative: δυτικώτερον (*dytikōteron*), 'more in/towards the setting(s)', Ptolemy 1. 14. 7; Markianos 6; *Hypotyposis* 1

superlative: δυτικώτατος (*dytikōtatos*), 'most in/towards the setting(s)', Ptolemy 1. 11. 1; Markianos 6; *Hypotyposis* 1

δυσμή *(dysmē), 'sinking', 'setting' (noun)*

ἀπὸ ἡλίου δυσμῶν (*apo hēliou dysmōn*), 'from (the) settings of (the) sun', Ps.-Skylax 47. 2; Ionic ἀπὸ … ἡλίου δυσμέων (*apo … hēliou dysmeōn*), Herodotos 2. 31

πρὸς δυσμαῖς (*pros dysmais*), 'towards (the) settings', 'Ps.-Skymnos' 169

πρὸς ἡλίου δυσμέων (*pros hēliou dysmeōn*), 'on the side of (the) setting sun', Herodotos 7. 115

adj. **δυσμικός** (*dysmikos*), 'of the setting(s)'

δυσμικὴ πλεύρα (*dysmikē pleura*), '(the) side towards the setting(s)', Ptolemy 2. 11. 1

ἥλιος ***δυόμενος/δύνων*** *(hēlios dyomenos/dynōn), '(the) sun setting'*

πρὸς ἥλιον δυόμενον (*pros hēlion dyomenon*), 'towards (the) sun setting', Ps.-Skylax 47. 3

πρὸς δύνοντος ἡλίου (*pros dynontos hēliou*), 'towards (the) setting sun', Aeschylus, *Supplices* 255]

ἑσπέρα *(hespera), 'evening'*

ἀπ᾽ ἑσπέρης (*ap' hesperēs*), 'from (the) evening', i.e. west, Eratosthenes fr. 72 (Arrian, *Indike,* 3. 1–5)

ἀπὸ ἑσπέρης δυσμέων (*apo hesperēs dysmeōn*), 'from (the) settings of (the) evening', i.e. west, Herodotos 2. 31 (Ionic)

ἐπὶ τῆς ἑσπέρης (*epi tēs hesperēs*), (winds) 'at the evening (point)', i.e. from the west, *Airs, Waters, and Places* 6 (if correct)

πρὸς ἑσπέραν (*pros hesperan*), 'towards (the) evening', i.e. the west, Hekataios fr. 102b (Strabo 7. 5. 8; Hanno, 3; 'Ps.-Skymnos' 519; Ionic πρὸς ἑσπέρην (*pros hesperēn*), Herodotos 2. 8

ὡς πρὸς ἑσπέραν (*ta pros hesperan*), ‘roughly towards (the) evening’, i.e. the west, Eratosthenes fr. 71 (Arrian, *Anabasis*, 5. 6. 3)

τὰ πρός ἑσπέραν (*hōs pros hesperan*), ‘the parts towards (the) evening’, i.e. the west, Thucydides 6. 2. 3

adj. **ἑσπέριος** (*hesperios*), ‘of evening’

ἑσπέριος (κόλπος) (*hesperios*, sc. *kolpos*), ‘of the evening’, here meaning the more westerly of two (gulfs)

τὰ ἑσπέρια (*ta hesperia*), ‘the parts in/of the evening’, i.e. west, Thucydides 6. 2. 5; Dikaiarchos fr. 124 (Strabo 2. 4. 2); Ps.-Aristotle 4

τὸ ἑσπέριον (ἡμισφαίριον) (*to hesperion*, sc. *hēmisphairon*), ‘the evening hemisphere’, Strabo 2. 3. 2

τὴν ἑσπέριον θάλασσαν (*tēn hesperion thalassan*), ‘the evening sea’, Timosthenes fr. 7 (Stephanos of Byzantion, s.v. Ἀπία)

ὁ ἑσπέριος ὠκεανὸς (*ho hesperios ōkeanos*), ‘the evening ocean’, Markianos 1

πρὸς … ἑσπερίων ἀνθρώπων (*pros hesperiōn anthrōpōn*), ‘from evening men’, i.e. men in the west, *Odyssey* 8. 29

Ordinals with Seasonal Qualifiers

Strictly speaking these directions, defined in terms of solstitial sunrise and sunset, are not the same as modern ordinals (NE, SE, SW, NW) which have azimuths of 45°, 135°, 225°, and 315° (taking north as zero), but are at around 60°, 120°, 240°, and 300° at the latitude of Athens. See n. 27 above.

North-East

ἀπὸ θερινῶν ἀνατολῶν (*apo therinōn anatolōn*), ‘from (the) summer risings’, Timosthenes fr. 4 (Strabo 1. 2. 21)

ἀπὸ τροπῆς θερινῆς (*apo tropēs therinēs*), ‘from (the) summer turning’, i.e. sunrise at the solstice, Timosthenes fr. 3 (Agathemeros 2. 6)

μεταξὺ θερινῶν ἀνατολῶν καὶ χειμερινῶν (*metaxy therinōn anatolōn kai cheimerinōn*), ‘between (the) summer risings and (the) winter (ones)’, ‘Ps.-Skymnos’ 170–1

ἀπὸ τοῦ περὶ τὰς θερινὰς ἀνατολὰς τόπου (*apo tou peri tas therinas anatolas topou*), ‘from the place around the summer risings’, Ps.-Aristotle 4

South-East

ἀπὸ χειμερινῆς ἀνατολῆς (*apo cheimerinēs anatolēs*), ‘from (the) winter rising’, Timosthenes fr. 3 (Agathemeros 2. 6)

πρὸς χειμερινὴν ἀνατολὴν (*pros cherimerinēn anatolēn*), Eratosthenes fr. 83 (Strabo 2. 1. 26)

μεταξὺ θερινῶν ἀνατολῶν καὶ χειμερινῶν (*metaxy therinōn anatolōn kai cheimerinōn*), ‘between (the) summer risings and (the) winter (ones)’, ‘Ps.-Skymnos’ 170–1

ἀπὸ τοῦ περὶ τὰς χειμερινὰς (ἀνατολὰς τόπου) (*apo to peri tas cheimerinas*, sc. *anatolas topou*), Ps.-Aristotle 4

South-West

ἀπὸ δύσεως χειμερινῆς (*apo dyseōs cheimerinēs*), 'from (the) winter setting', Timosthenes fr. 3 (Agathemeros 2. 6); cf. Ps.-Aristotle 4; pl. ἀπὸ δύσεων χειμερινῶν (*apo dyseōn cheimerinōn*), 'from (the) winter settings', Timosthenes fr. 4 (Strabo 1. 2. 21)

North-West

ἀπὸ δύσεως θερινῆς (*apo dyseōs therinēs*), 'from (the) summer setting', Timosthenes fr. 3 (Agathemeros 2. 6); ἀπὸ τῆς θερινῆς δύσεως (*apo tēs therinēs dyseōs*), 'from the summer setting', Ps.-Aristotle 4; pl. ἀπὸ δύσεων θερινῶν (*apo dyseōn therinōn*), 'from (the) summer settings', Timosthenes fr. 4 (Strabo 1. 2. 21)

μέχρι δυσμῶν θερινῶν (*mechri dysmōn therinōn*), 'as far as (the) summer settings', 'Ps.-Skymnos' 173

ὑπ' ἰσημερινῆς <θερινῆς> τε δύσεως (*hyp' isēmerinēs <therinēs> te dyseōs*), 'under (the) equidiurnal (*i.e. equinoctial*) and <summer> setting', 'Ps.-Skymnos' 172

Appendix 2: Examples of Wind Directions

North Winds

***ἀπαρκτίας** (aparktias), '(wind) from the bear(s)'*

κατὰ ἀπαρκτίαν (*kata aparktian*), 'by (the) Aparktias', Timosthenes fr. 3 (Agathemeros 2. 7)

***βορέας** (boreas) or βορρᾶς (borrhas), 'Boreas' or 'north wind'*

εἰς βορρᾶν (*eis borrhan*), 'to (the) north wind', Eratosthenes fr. 32 (Agathemeros 1. 2); Artemidoros (Agathemeros 18)

πρὸς βορρᾶν (*pros borrhan*), 'towards (the) north wind', Eratosthenes fr. 71 (Arrian, *Anabasis*, 5. 6. 3); 'Ps.-Skymnos' 174

adj. **βόρειος** (*boreios*), 'of/towards Boreas', Eratosthenes fr. 44 (Geminus 15); Hipparchos fr. 21 (Strabo 2. 1. 27)

βόρειον ἡμισφαίριον (*boreion hēmisphairion*), 'hemisphere towards Boreas', Strabo 2. 3. 2

βόρειον κλίμα (*boreion klima*), 'zone of latitude towards Boreas', Ps.-Aristotle 2

East Wind

***ἀπηλιώτης** (apēliōtēs), '(wind) from the sun'*

κατ' ἀπηλιώτην (*kat' apēliōtēn*), 'by (the) Apeliotes', Timosthenes fr. 3 (Agathemeros 2. 7) (but SE at Timosthenes fr. 4 (Strabo 1. 2. 21))

πρὸς ἀπηλιώτην ἄνεμον (*pros apēliōtēn anemon*), 'towards (the) Apeliotes wind' or 'towards (the) wind from the sun', Herodotos 4. 22; Eratosthenes fr. 71 (Arrian, *Anabasis*, 5. 6. 3

adj. **ἀπηλιωτικός** (*apēliōtikos*), 'of the (wind) from the sun'

comparative: ἀπηλιωτικώτερος, 'more of/towards the wind from the sun', Ptolemy 2. 1. 4

South Wind

νότος, *Notos*

ἀπὸ νότου (*apo notou*), ‘from (the) south wind’, Eratosthenes fr. 32 (Agathemeros 1. 2)

ὡς ἐπὶ νότον (*hōs epi noton*), ‘generally to (the) south wind’, Eratosthenes fr. 71 (Arrian, *Anabasis*, 5. 6. 2)

κατὰ νότον (*kata noton*), ‘in the direction of (the) south wind’, Timosthenes fr. 3 (Agathemeros 2. 7)

πρὸς νότον (*pros noton*), ‘towards (the) south wind’, Artemidoros (Strabo 4. 1. 1)

adj. **νότιος** (*notios*), ‘of Notos’ or ‘of the south wind’; also ‘moist’, ‘rainy’

νότιον κλίμα (*notion klima*), ‘zone of latitude towards the south wind’, Ps.-Aristotle 2

τὸ νότιον ἡμισφαίριον (*to notion hēmisphairion*), ‘hemisphere towards the south wind’, Strabo 2. 3. 2

comparative: νοτιώτερος (*notiōteros*), ‘more towards the south wind’, Hipparchos fr. 11 (Strabo 1. 1. 12), fr. 21 (Strabo 2. 1. 27)

West Wind

ζέφυρος, *Zephyros*

ἀπὸ ζεφύρου (*apo zephyrou*), ‘from (the) Zephyros’, ‘Ps.-Skymnos’ 173

κατὰ ζέφυρον (*kata zephyron*), ‘in the direction of (the) Zephyros’, Timosthenes fr. 3 (Agathemeros 2. 7)

πρὸς ζέφυρον (*pros zephyron*), ‘towards (the) Zephyros’, ‘Ps.-Skymnos’ 519, Herakleides Kritikos 9B

adj. **ζεφύριος** (*zephyrios*), ‘of the Zephyr’

ζεφύριον τοῖχος (*zephyrion toichos*), ‘(the) wall towards the Zephyr’, i.e. western wall, *Inscr. Délos* 290 (C3 BC), lines 166-7 [τῶι δεῖνι ἐργολα]βήσαντι τοῦ νεὼ τῆς Δήμητρος τὸν τοῖχον τὸν ζεφύριον οἰκοδομῆσαι καὶ τοῦ πρὸς ἕω τὰ ὑπὲ | [ἀποπεπτωκότ?]α κτλ.

οἴκημα ζεφύριον (*oikēma zephyrion*), ‘(the) house towards the Zephyr’, probable reading in *IG* xii. 5. 126 (Paros, C2 BC), lines 2–3 [ἐν τῶι οἰκή|ματι τῶι] ζεφυρίωι (?) μὴ καίειν πῦρ, ‘not to kindle fire [in the] zephyric [house?]’

Ordinals

See note on ‘Ordinals with seasonal qualifiers’ in Appendix 1.

καικίας, Kaikias (approx. NE)

κατὰ καικίαν (*kata kaikian*), ‘in the direction of (the) Kaikias’, Timosthenes fr. 3 (Agathemeros 2. 7)

εὖρος, Euros (approx. SE)

κατ’ εὖρον (*kat’ euron*), ‘in the direction of (the) Euros’, Timosthenes fr. 3 (Agathemeros 2. 7) [but NE at Timosthenes fr. 3 (Strabo 1. 2. 21)]

πρὸς εὖρον (*pros euron*), ‘towards (the) Euros’, Eratosthenes fr. 32 (Agathemeros 1. 2)

λίψ, Lips (approx. SW)

κατὰ λίβα (*kata liba*), ‘in the direction of (the) Lips’, Timosthenes fr. 3 (Agathemeros 2. 7)

ἀργέστης, Argestēs; ἰᾶπυξ, Iapyx (approx. NW)
κατὰ ἀργέστην (*kata argestēn*), 'in the direction of (the) Argestes', Timosthenes fr. 3 (Agathemeros 2. 7)
ὡς πρὸς … ἄνεμον ἰάπυγα (*hōs pros … anemon iapyga*), 'generally towards (the) Iapyx wind', Eratosthenes fr. 71 (Arrian, *Anabasis*, 5. 6. 3)

Intermediate Winds

βορέας/βορρᾶς, Boreas or Borrhas (approx. NNE)
κατὰ βορρᾶν (*kata borrhan*), 'in the direction of (the) north-north-easterly wind', Timosthenes fr. 3 (Agathemeros 2. 7)
Boreas/Borrhas also means generally a northerly, or approx. north, wind.

φοῖνιξ, Phoinix (approx. SSE)
κατὰ φοίνικα (*kata phoinika*), 'in the direction of (the) Phoinix', Timosthenes fr. 3 (Agathemeros 2. 7)

λευκόνοτος, Leukonotos (approx. SSW)
κατὰ λευκόνοτον (*kata leukonoton*), 'in the direction of (the) Leukonotos', Timosthenes fr. 3 (Agathemeros 2. 7)

θρασκίας, Thraskias (approx. NNW)
κατὰ θρασκίαν (*kata thraskian*), 'in the direction of the Thraskias', Timosthenes fr. 3 (Agathemeros 2. 7)

Not noted here:
λιβόνοτος (*libonotos*), Timosthenes fr. 3 (Agathemeros 2. 7) (approx. SSW).
ὀλυμπίας (*olympias*), Timosthenes fr. 3 (Agathemeros 2. 7) (approx. NW).
κιρκίας (*kirkias*), Ps.-Aristotle 4 (approx. NNW).

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Part II
Case Studies

Although differing widely in cultural focus and astronomical details, these case studies apply the general approaches developed by Ruggles and others to a wide range of evidence, both archaeological and textual, from different parts of the world.

The first two case studies, Prendergast's island-scale study of Irish passage tombs and related cairns and Gonzalez-Garcia's examination of a ritual landscape in northern Spain, echo the earliest phase of Ruggles' work—and the earliest era studied by archaeoastronomers—the investigation of prehistoric stone monuments. Prendergast employs a method of scanning the local horizon as seen from his sites, a method pioneered in Ruggles' (1984) investigation of western Scottish sites, to establish whether passage tombs preferentially faced restricted, intermediate, or distant horizons. He found a noticeable preference for distant horizons centred in the northerly direction. Drawing on cultural analogues from cultures known to respect the direction north, he advances the hypothesis that the liminal northern horizon indicated by the Irish sites represented to the tomb builders the direction of the abode of their ancestors.

González-García expressly acknowledges the inspiration of Ruggles' earlier work on the Island of Mull, where he consciously shifted the focus of research from individual sites to a "wider 'ritual landscape'" (Martlew & Ruggles, 1993: 63). González-Garcías's focus on the landscape near the passage grave of Chabola de la Hechicera (the Sorceress' Shack) identifies a group of neighbouring sites which share similar orientations and from most of which a significant mountain, Lapoblación, which marks the summer solstice from Hechicera, is visible. Despite the importance of this mountain, he dismisses folklore associating Hechicera with the summer solstice as too recent to be associated with the builders of these sites. More secure placing of this group is found by cluster analyses of azimuths, which places this group in a distinct transitional place among similar Spanish regional groups.

With Boutsikas' examination of the orientation of Greek temples, we enter the world where archaeoastronomical studies are complemented by the existence of written sources, which give access to Greek astronomical concepts. One of these is the concept of the equinox, the utility of which Ruggles questioned in a classic paper (1997), yet which recurs frequently in this volume. The Greeks defined the equinox either geometrically, in terms of the intersection of the equator and the ecliptic, or temporally, in terms of the equality of day and night. Boutsikas complements this textual evidence with measured data of the orientation of 131 Greek temples, which leads her to the cautious conclusion that "If any general astronomical concerns were responsible for the placement of Greek temples, the equinoxes seem to be the most likely candidate." Looking more closely at the possible equinoctial data, she sees indications of a displacement toward the time when day and night was of equal length, possibly reflecting the cosmological importance of the equality of day and night in Greek religion.

Hannah provides another perspective on Greek astronomy. His discussion of stars and constellations addresses the broader historical question of "why did the Babylonians and Greeks … populate the sky with these particular figures?" Drawing on a wide range of textual material from these cultures, he contrasts the Greek constellations, in which adjacent constellations were actors in mythological stories, with the Babylonian ones, which lacked such mythological connections. He then sketches out the usefulness of such connected groups of constellations for navigation, agriculture, and ritual. He sees the need to establish a calendar to synchronize nature and agriculturally focussed religious rituals as a possible driving force in the development of star calendars. A brief, preliminary, study of Euctemon's Fifth Century BCE parapegma suggests that by that time the relation of the constellations could be established by calculation, not merely by observation.

Adjacent constellations and Greek mythology take a surprisingly new role in Norris and Norris's study of the Pleiades and Orion. They find very similar accounts of the Pleiades as seven girls being chased by a man associated with the constellation Orion in both Greek mythology and Australian Aboriginal folklore. If these stories have a common origin, it must date back some 100,000 years to the emigration of the ancestors of the Greek and Aboriginal Australian cultures from Africa. This has astronomical consequences; due to proper motion of the component stars, the Pleiades looked slightly different 100,000 years ago. In particular, at that time there were seven perceptible stars. Since a lost seventh sister is present in many cultures' stories of the Pleiades, the authors suggest this theme reflects the great historical depth of this mythological tradition.

The final case study considers the mathematically focused astronomies of Mesoamerica. Iwaniszewski examines the relation between Maya lunar concepts expressed in the eclipse table of the Dresden Codex and the lunar series recorded in monumental inscriptions. He takes as a reference an inscribed record of a possible solar eclipse dated 9.17.19.13.16 5 Kib 14 Ch'en (July 790) that was recorded on Stela 3 at Santa Elena Poco Uinic. Analysis of these written records revealed the similar, but subtly different concepts used in these approaches. The Eclipse Tables incorporated a well-defined body of knowledge, including a regular lunar period of 5 or 6 lunar months, while the inscriptions recording a Lunar Series reflected locally defined concepts for establishing the current age of the moon, the number of days in the current month, and the place of that month in a 6 month "bundle" of lunar months.

As Iwaniszewski concludes, "Concepts regarding the lunar cycle … represent a particular point of view that is embedded in social networks and relationships with the surrounding world, rather than in a fixed body of current knowledge." If we draw an overarching theme from the case studies discussed here, it is that a culture's astronomy reflects the diverse ways people interact with the heavens.

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The North Sky and the Otherworld: Journeys of the Dead in the Neolithic Considered

Frank Prendergast

1 Introduction

There is a curious but relevant similarity in the endeavours of early nineteenth century surveyors in Ireland and the builders of Neolithic passage tombs long before them. Albeit of very different chronologies and purpose, both constructed cairns on the summits of hills and mountains making each prominent on the skyline and with views of the distant horizon.

In 1826, one of the 39 survey stations used for the principal triangulation of Ireland was constructed on the summit of Slieve Donard, Co. Down. This is the highest peak in the Mourne Mountains (elevation 853 m above mean sea level) and affords great vantage over the surrounding landscape, Irish Sea and south-west Scotland (Fig. 1). Triangulation involved angle and distance measurement to dimensionally scale the network of these sparse control points, a critical reference frame for the new maps of the island published at the then unprecedented scale of 6 in. to 1 mile. The task for the surveyors on Slieve Donard involved laying a square stone 'megalith' measuring 3.5 ft. × 3.5 ft., marked with a bored hole in the centre. Next, the 'Great Theodolite' was positioned to enable observation of the angles to outlying similar stations. On completion, a vertical timber pole mounded by a dedicated cairn of loose stones was built over the slab to enhance its long range visibility (Clarke & James, 1858: 35). Height and associated intervisibility with other primary control stations on distant peaks were the principal attributes of this scientific infrastructure. Unluckily, Slieve Donard was also the location for a pair of Neolithic cairns set 237 m apart, one of which was delimited by contiguous transversely-set kerbstones making it a likely passage tomb. These were the highest such extant

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F. Prendergast (✉)
College of Engineering and Built Environment, Technological University Dublin,
Dublin, Ireland
e-mail: frank.prendergast@tudublin.ie

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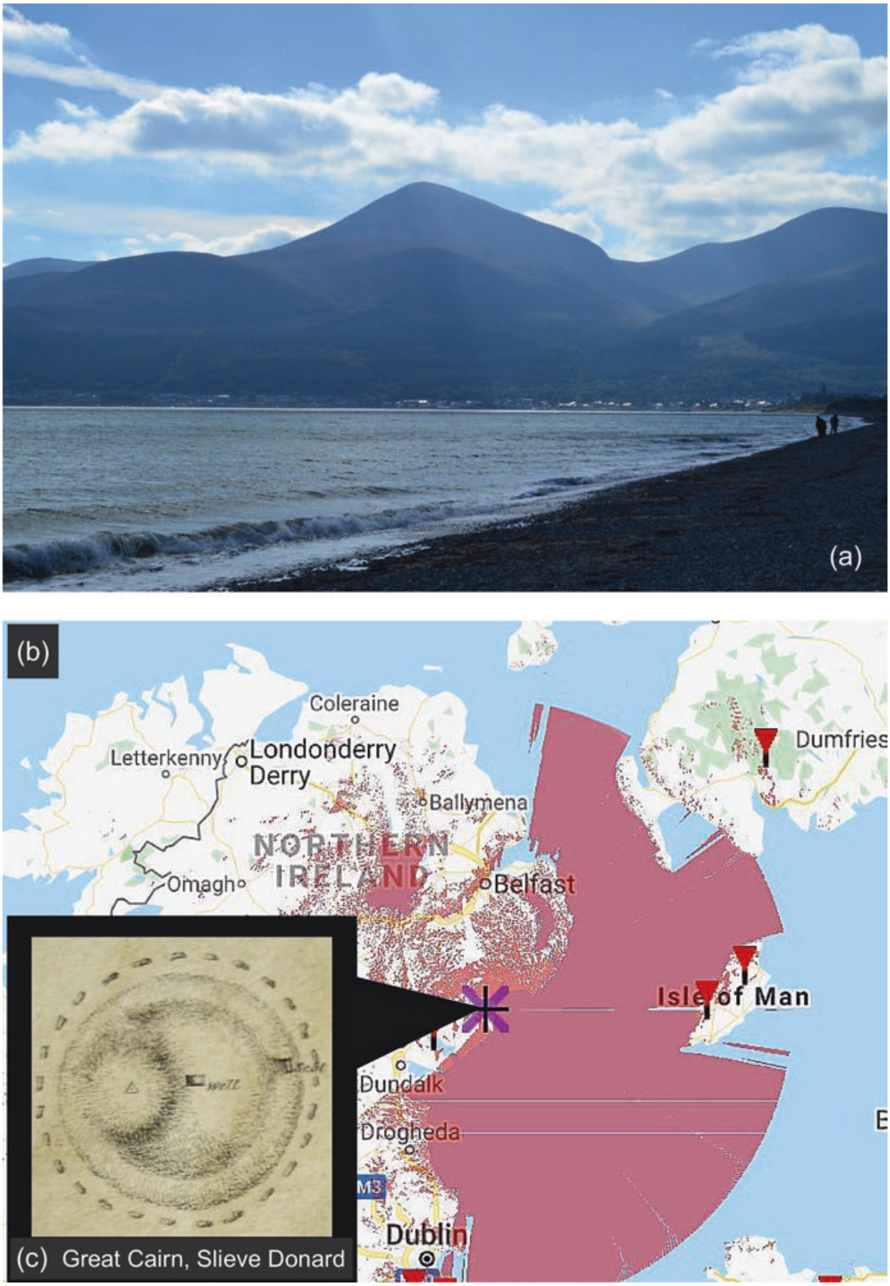


Fig. 1 (**a**) Slieve Donard, Co. Down looking west (photo: F Prendergast); (**b**) viewshed from summit of Slieve Donard (HeyWhatsThat.com); (**c**) plan of The Great Cairn, Slieve Donard (courtesy: National Archives Dublin Ref. OS Fair Plan 105; Sam Moore is credited with the discovery of this drawing)

prehistoric structures in Ireland and northwest Europe at that time but their location conflicted with the task of the survey.

The larger of the prehistoric structures, known as the 'The Great Cairn', had a basal diameter of 24.4 m. The apex offered a conveniently elevated platform on which to situate the stone slab described above. The relative locations of the survey station and added 'survey cairn' are illustrated in Fig. 1c. It is documented that Lt. Col. Thomas Colby, who directed the triangulation survey and had a professed indifference to antiquity, ordered the destruction of this ancient monument (Andrews, 2001: 96, 163). The logical deduction is that Colby would have first destroyed and infilled the burial chamber cavity to stabilise the ground prior to laying the heavy stone slab which marked the survey point. During a subsequent triangulation campaign to geodetically connect the survey networks of Ireland and Great Britain in 1841, a theodolite located in Scotland was mistakenly trained upon the extant adjacent 'Lesser Cairn' on Slieve Donard. When this error was detected during the calculation phase, that monument was similarly pulled asunder prior to a re-observation of the angles. These accounts document how two of the island's passage tombs were destroyed by human agency—a fate that undoubtedly befell others in the millennia following the Neolithic. The recorded monuments considered in this chapter, the two hundred and thirty passage tombs and 36 related unclassified hilltop cairns, are the surviving *corpus* (Fig. 2a). Many of the latter, although unexcavated or ruined, are considered by archaeologists to be likely passage tombs, *inter alia*, because of their landscape siting, proximity to known tombs, and round form (O'Sullivan & Downey, 2011).

Topographical maps, print and digital, were an essential aid during the data collection phase of the archaeoastronomical investigation of the tombs undertaken by the author. These are modern products and the legacy of the trigonometrical survey of the 1820s, enabling 'the translation of a geography into a graphic image' (Robinson, 1990: 1). In the prehistoric past, however, 'maps' would have been a memorised intangible and cultural information system of local and distant landscapes, horizons with varying range, built monuments, and skyscape (described later) imprinted not onto paper but in the mind and memory. This chapter will explore how those landscapes, liminal horizons and skies may have been imagined and culturally imbued by the passage tomb builders, primarily constructed in the Middle Neolithic *c*. 3600–3000 BC.

Research on Irish passage tombs published elsewhere by the author has analysed their axial orientation, alignment, intervisibility, and height characteristics (Prendergast, 2016, 2018, 2020). However, any consideration of symbolism being embedded in horizon range related to orientation at these sites has remained unpublished until now. Accordingly, the first analysis of this type of spatial data will seek answers to several research questions. Were Irish passage tombs intentionally situated to have vistas characterised by preference for a particular horizon range—restricted, intermediate or distant? Might any preferred range category be delimited by an easily perceived and notable sector of the horizon associated with astronomically interesting and symbolically meaningful orientation? If detected, might such emerging evidence provide insights related to cosmological symbolism linked to

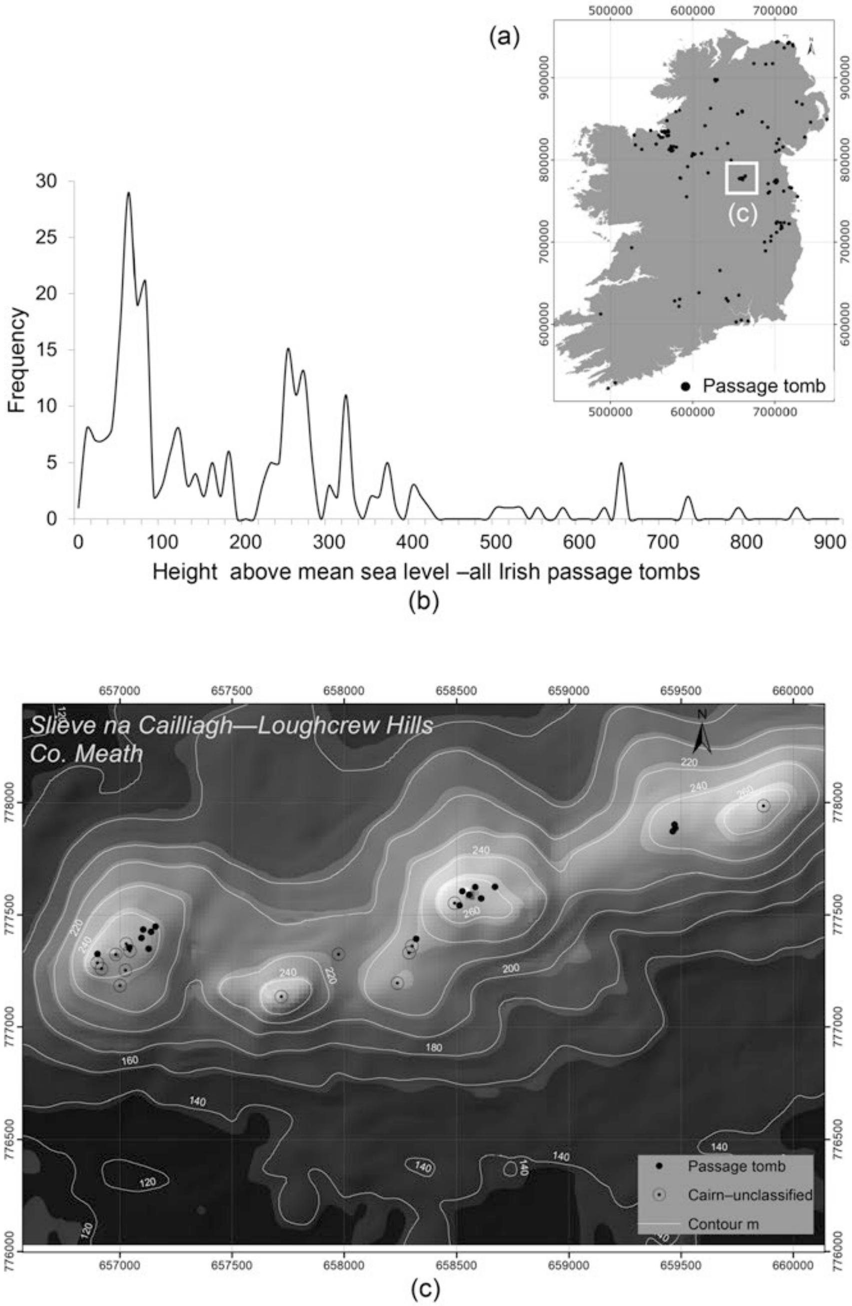


Fig. 2 (**a**) Distribution of Irish passage tombs; (**b**) histogram of Irish passage tomb heights; (**c**) distribution of passage tombs, Loughcrew Hills or *Slieve na Cailliagh*, Co. Meath

burial strategies and imagined journeys of the spirits of dead to an afterlife and otherworld?

2 Landscape, Skyscape, Monuments and Perception

Theoretical considerations of landscape and space, and how these may have been comprehended in the prehistoric past, are of fundamental importance in Irish and wider archaeological studies (e.g. Cooney, 2000; Tilley, 1991). Then, people lived in places 'that were imbued with meaning', 'derived from a pre-existing world' and 'materialised through monuments and by association with elements of the natural landscape' (O'Brien, 2002: 156). More broadly, recent discourses on the crucial importance and role of the sky have now rightly corrected the omission of its role in archaeological narratives and brought human engagement with the celestial dome central to archaeological thought (Henty & Brown, 2019; Prendergast, 2013; Silva & Campion, 2015). Skyscape as a concept, but here linked to perceptions of the horizon, captures this universal human awareness of the heavenly portion of the total environmental domain. Fabio Silva (2017: 4), for example, defines this comparatively new term as 'indigenous conceptual frameworks that constitute a society's understanding of "the heavens and the celestial bodies and how they relate back down to human beliefs and practices", to their notions of time and place, to their structures and material remains' (Silva, 2015: 3). The importance of understanding past perceptions of the landscape, especially if connected with the sky, introduces wider contexts critical to understanding the interrelated meaning and symbolism of both. Also by the presence/absence of writing and our knowledge of religious beliefs and mythology, attempts at imagining, interpreting or re-experiencing how humans engaged with their landscape and skyscape in the distant past are inevitably constrained by our own temporal separation and cultural differences. Advisedly then, any enquiry must be carefully approached and shaped using the widest range of perspectives ideally supported by spatial data analysis, mindful that (and with applicability to the meaning of skyscape) 'it is important not to forget that the contemporary term "landscape" is highly ideological' (Tilley, 1994: 24).

In viewing space, modern regard for landscape and skyscape as an aesthetic source of human interest and pleasure is likely to be in sharp contrast to what this meant to societies in prehistory. Cycles of birth and death, identity and memory would have been intertwined with complex strategies for survival that had little in common with contemporary notions of aesthetics and perceptions of cosmos and landscape. Furthermore, myths and legends pertinent to the Neolithic, but clearly lost to us, also 'have an immediate interest to archaeology in trying to unravel the nature and meaning of ancient events and traditions' (Darvill, 2002: 278). On the true nature of myth, the anthropologist Levi-Strauss notes how some claimants suggest that human societies express fundamental feelings through their mythology and use myths to 'try to provide some kind of explanations for phenomena which they cannot otherwise understand—astronomical, meteorological, and the like.'

(Lévi-Strauss, 1968: 207). Lewis-Williams also points out how Neolithic people almost certainly rationalised their world view of a perceived tiered cosmos by narrating myths which likely described and regarded the cosmos 'as a framework for the origins, events, journeys, transformations and beings' described in those myths'(Lewis-Williams & Pearce, 2005: 149). Drawing on these ideas, if the analysis of horizons encountered at Neolithic passage tombs and cairns can reveal hidden or previously unknown aspects of a cosmology, especially relating to how journeys of the dead and afterlife were perceived, such evidence might potentially bring insights on the myths themselves.

With the focus on naked-eye viewing of the sky in the prehistoric past, cyclical positions of the celestial elements of the cosmos would not have perceptibly changed in a timescale lasting several hundreds of years. The temporality of passage tomb building in this context has three phases—Early Neolithic (3800–3600 BC), Middle Neolithic (3600–3000 BC) and Late Neolithic (3000–2400 BC). From what is now reliably known, Stefan Bergh and Hensey (2013) supplies 25 ^{14}C dates obtained from pin fragments at the Carrowmore passage tomb complex, Co. Sligo in western Ireland. These span the period from 3775–3520 cal BC to 3304–2950 cal BC (all 95% probability), indicating deposition mostly in the Middle Neolithic. In the east of the island, Muiris O'Sullivan et al. (2013: 32–34) provides ten radiocarbon determinations obtained from the passage tomb known as the Mound of the Hostages at Tara, Co. Meath, dating from 3370–2930 cal BC to 2870–2470 cal BC (all 95% probability). At the nearby Knowth complex of twenty passage tombs in the Boyne Valley, George Eogan and Kerri Cleary (2017: 378) provides 60 AMS ^{14}C determinations on cremated and non-burnt human bone obtained from nine of the tombs. The main phase of funerary activity at Knowth is considered to have begun in 3169–3045 cal BC and ended in 3020–2920 cal BC (all 95% probability), a duration of 100–220 years. The known date for the construction of the nearby Newgrange passage tomb similarly fits a Middle Neolithic timeframe. A programme of radiocarbon dating on human bone and cereal grains at a multi-phase passage tomb in Baltinglass, Co. Wicklow in eastern Ireland shows an unusually long and atypical history spanning at least six centuries, 3700–2900 cal BC (Schulting, McClatchie, Sheridan, McLaughlin, & Whitehouse, 2017). Synthesising then, Bergh and Hensey (2013) suggests passage tombs 'were not static entities but were the locale for complex multi-layered and mostly poorly understood ritual practices, which evolved over time'. Based on the available evidence, Bergh further asserts the tombs were 'multi-phase sites, often demonstrating extensive activity both prior to, and following, the megalithic construction'. He highlights another diagnostic difference to culturally differentiate the passage tomb tradition from the Neolithic court and portal tomb traditions—the widespread recurrence of a distinctive pin fashioned from deer antler or animal bone, often accompanying cremated bones found within the monuments. This corroborates the observation by Michael Herity (1974) that passage tombs contained a distinctive assemblage of artefacts and grave goods, had a unique shape of burial chamber (cruciform) in many cases, and used embellished structural stones unlike anything discovered in the other tomb types. Quartz spreads are another well-known decorative feature. Additionally, and where spatial overlap occurs, passage tombs are always located at elevations higher than court and portal tombs. This finding advocates that height, and relative height, was symbolic and hierarchical to the passage tombs builders (Prendergast, 2011). Additional support for a shared belief system across the passage tomb tradition in Ireland is added here using the example of polished stone axes. Some were made from porcellanite, a high-value fine-grained stone found on Rathlin Island off the north coast of Co. Antrim yet discovered across Ireland and Britain (Cooney, 1992). Axe production, though not exclusive to the Neolithic, greatly increased in this period. A range of usages have been ascribed including depositions in hoards, in sacred places, and to mark particular events. A number arrived here from Britain and Europe, some made of precious jadeite, further suggesting such artefacts were imbued with symbolism and had ceremonial contexts. Their wide geographical spread across the island, far beyond the source of their production, could support the thesis that axe distribution was symbiotic to the diffusion of religious customs and ideas specific to the passage tomb tradition. The above timelines, broadly *c*. 4000–2500 cal BC, next move the discussion to a consideration of the palaeoenvironmental record, and how this may have impacted on horizon range and associated views surrounding the tombs.

In the millennia since the Neolithic, the effects of precession and obliquity on the earth's axis of rotation have altered the apparent positions of observable celestial bodies. Modern planetarium tools combined with digital models of the terrain allow exact reconstruction of those ancient skies and scenes. Landscapes, by comparison, evolve unpredictably over short and long timescales due to climatic and anthropogenic factors. This has a major bearing on the scenic analysis of present day views if these are used to infer that similar conditions prevailed in the prehistoric past. Modelling the impact of farming on woodland dynamics during the Neolithic is one approach to addressing such uncertainties using studies of spatial and temporal changes in settlement patterns and demographics in the Neolithic (McLaughlin et al., 2016). Relatedly, their analysis of radiocarbon-dated pollen shows that for localised regions, in Ireland at least, deforestation can be linked to intensive phases of farming activity. O'Connell, Molloy, and Jennings (2020) present new evidence of such landscape change at a Neolithic settlement in north Co. Mayo, western Ireland. The site is more widely known as the Céide Fields, an extensive stone-wall field system now covered by blanket bog. That study provides unambiguous evidence for substantial farming beginning *c*. 3800 BC, including widespread woodland clearance. A distinct lull in farming lasting several centuries followed, with a resumption detected from *c*. 2700 BC onwards. These data show how human activity was a determining factor in the complex cycles of forestation and deforestation. O'Connell also stresses the well-recognised importance of the Céide Fields for understanding farming impact on landscape during the Neolithic, not just in western Ireland, but in Atlantic Europe, generally. If the findings for the Céide Fields region can be legitimately extrapolated to other parts of the island, the safest conclusion for this discussion is that landscapes fluctuated from complete forestation to more open vistas across the chronological period of tomb building. As a consequence, height and proximity of the tree canopy surrounding specific burial sites cannot be reliably modelled and this requires an examination of their landscape setting.

Spatial analysis of the topographical locations of passage tombs and related cairns demonstrates their pronounced preference for vantage in the majority of cases. Survey fieldwork by the author at every such site on the island can validate this claim. This attribute makes them prominent on the skyline with an associated high degree of intervisibility (Bergh, 1995, Cooney & Grogan, 1999: 55–71, Prendergast, 2020). Based on their measured elevations, Fig. 2b also reveals a bi-modal distribution in tomb elevations. Although the majority (70%) are located at more moderate elevations (0–150 m), the remainder (30%) are predominantly located in upland topography above the 150 m contour with a number located on very high summits such as Slieve Donard (see Fig. 1). Virtually all sites have views of the distant horizon in varying directions of the compass with a view of the northern horizon and northern sky being especially evident. Such siting and view characteristics are not encountered in Neolithic court and portal tombs, even where these have spatial adjacency with the passage tombs. The observed bi-modality in elevation could additionally reflect a possible religious stratification of the landscape for burial purposes related, perhaps, to a partitioned world-view. In terms of chronology and funerary traditions, court tombs broadly date to 3700–3200 BC and have trapezoidal-shaped chambers set in a long cairn used to contain inhumed and cremated human remains. Portal tombs date to 3800–3200 BC and had repeated episodes of inhumed burials. The burial chambers of passage tombs were generally placed at the end of the access passage set within a round covering cairn delimited by kerbstones, often richly embellished with megalithic art. The predominant burial rite was cremation although unburnt bone (including from children) and the skulls and long bones of adults are evident. A striking feature of passage tomb orientation is the discovery of wide-scale deliberate alignment of the entrance to face another elevationally higher tomb or a related cairn (Prendergast, 2016). This finding suggests that view, and directed view from within the burial chamber, were an elemental part of passage tomb cosmology.

Moving the discussion towards symbolism of the total environmental domain, Robert Hertz (1907–1960: 96) is, perhaps, the earliest anthropologist to articulate ideas of a tiered cosmos and cultural significance being attached to the horizon. Hertz draws on ethnographic studies by Tregear (1904) which recorded cultural traditions in New Zealand's *Maori* society. Tregear discovered how the skyline was an elemental part of the *Maori* belief system and world view. Relevantly, their *Kumara* crop could only be dug when the bright star *Vega* was above the horizon. To the *Maori*, the visible likeness of a deified ancestor sometimes announced itself as a rising star identified as '*Venus* flashing along the horizon' (Tregear, 1904: 91, 403). Culturally, this provides an example of the symbolism and liminality of the intangible horizon. On liminality, the architectural theorist Pierre von Meiss (1989: 155) wrote 'The horizon is a limit even if this limit is in reality intangible, because the more we advance, the more the horizon is replaced by new horizons'.

In Ireland, commanding views of horizon are an obvious and notable feature associated with the elevated siting of numerous passage tombs. Interestingly, investigation by Vicky Cummings of the landscape setting of prehistoric megalithic chambered monuments in nearby north-west Wales reveals very few exhibit intervisibility. The chronology of those particular monuments is poorly understood, being related to their structural diversity and the lack of any agreed typology. Furthermore, while three-quarters of the Welsh tombs investigated are located within view of the sea, virtually all have a restricted view of the horizon in one direction related to their locations being on the sides of hills or mountains as distinct from hilltop summits (Cummings & Whittle, 2004: 41–55). Those findings suggest a binary relationship between burial location and view—of a restricted horizon on land and of the distant horizon at sea. Typological certainty does attach to Bryn Celli Ddu, one of only two developed passage tombs in that region. The differentiated chamber and passage are astronomically aligned on sunrise at summer solstice (Burrow, 2010). Excavation of the tomb revealed evidence of pre-cairn activity and fragments of cremated and unburnt adult human bone. Burrow indicates the tomb was built between 3074 and 2956 cal BC, was 'deliberately imbued with "secret knowledge" which would have required a level of initiation before it could be understood', and to being 'textured with meaning' from when construction commenced.

Thinking more broadly on cemetery and settlement locations having linkage to perceptions of the horizon and sky, Hannon (1983: 264) notes the strong cultural tendency to place cemeteries on hilltops so as to be generally remote from farmland, to have good drainage and, critically, be elevationally closer to the perceived abode of deities and the spirits of the dead. In an analysis of settlement processes throughout prehistoric Europe, Hamond (1981) concludes there were at least three interacting factors to be considered: the locational strategy pursued, the influence of the local environment, and past experience. It is suggested here that deciding where to dwell *versus* where to place the remains of the dead are a dualism guided by pragmatic and spiritual principles, and an architectural design determinant linked to the settlement process. More deeply, tradition and culture dictate the form and location of a tomb to reflect the spiritual and cosmological principles of the community. Beyond the immediacy of the morphology of the burial structure and tomb location, view and any associated visual impact on the surrounding landscape may be more potent than the symbolic power and function of the monument itself. Relatedly, Cooney (2000: 147–148) advocates the term 'complex' should replace 'cemetery' to describe any cluster of distinctively located tombs. In the case of passage tombs, this is because of their frequent siting on elevated ground, prominence in the landscape and having entrances which often face larger centrally-placed tombs. Prendergast (2016) provides backing for these ideas having additionally discovered, at an island scale, that where a tomb entrance faces another tomb or related cairn, the targeted 'focal' tomb is always at a higher elevation. This suggests an embedded hierarchy in tomb location linked with symbolism in height difference. The eminent folklorist Dáithí Ó hÓgáin (1999: 20) combines the evidence from archaeology and folklore to argue that the tendency to situate passage tombs on eminences and hilltops 'in itself reflects a desire to stress the social, and probably also the spiritual, importance attributed to them'. These ideas reinforce Cooney's thesis that the term 'complex', as opposed to 'cemetery', highlights the greater range of ceremonial purposes attaching to these groups of monuments in particular. Figure 2c illustrates a prime example of how passage tombs cluster on hilltops. Applied more broadly, hill and mountain summits used as locations for tombs provide decidedly enhanced views of the distant horizon and skyline. This is the intangible zone where most celestial bodies appear to rise and set, the interface between the natural and supernatural worlds.

Writing on the symbolism of the horizon, Krupp (1997: 2) draws on ethnographic evidence related to the Pueblo Indians of Chaco Canyon in northwest New Mexico. In that culture, circular form signified their horizon, the rim of their world where the earth made contact with the sky. According to Krupp, the world's key cardinal directions are also found there, contain power, provide a template for terrestrial order and are widely incorporated into everything from sand paintings to ceramics and architecture. The architect Ian Ritchie also observes 'The skyline can be seen as the traditional domain of power, whether secular or religious', adding 'Skylines can themselves be monuments and monumental', and how we may read 'the economic, political and religious geography, and history' from the skyline (Ritchie, 2004: 10–11).

Moving next towards a quantitative analysis, the horizon at any location is easily profiled using estimated measures of range and orientation determined by a stationary observer viewing the surrounding space. Methodologically, this is termed 'visibility analysis' *i.e*. the determination of those portions of the landscape that can be seen, the quantitative categorisation of its content, and the qualitative assessment of the findings (Fellerman, 1986: 48). Visibility analysis is a sub-component of the broader process termed 'scenic analysis', a visual language with the potential to reveal perceptions, in this case of the horizon, possibly encoded in its character. These ideas are examined in the following section.

3 Scenic Analysis of the Horizon at Irish Passage Tombs

An historical description of the Irish landscape by the botanist Robert Lloyd Praeger (1937: 3) alludes to the unusual character of the island's topography being the result of 'ancient crumplings of the Earth's crust' resulting in the formation of mountain ranges in the coastal regions and a broad lowland plain in the centre. He also noted how this had profoundly influenced early human settlement patterns, 'tending to push pre-existing cultures not into an inaccessible centre, as in most islands, but into the mountain-fringe'. This is borne out in the observed distribution of *c*. 1800 Neolithic tombs (all classes) which largely avoid the interior lowland plain. The small number that do are exclusively passage tombs, occupying hilltops as, for example, at Loughcrew, Co. Meath. Figure 2c illustrates the complex of 18 passage tombs and 13 unclassified cairns dramatically clustered on the summits of the Loughcrew Hills *c*. 150 m above the surrounding lowland. There, views of the horizon are profound, varying in range according to the direction faced by the observer.

Variation in all horizon ranges is easily classified into distance zones for the purpose of quantitative and qualitative analysis. In the 1970s, the Forest Service of the U. S. Department of Agriculture included ‘Distance Zones’, divisions of the particular landscape being viewed and evaluated for their scenic and resource content (Forest Service, 1974: 5, 7, 44). Three zonation categories were used:

- Foreground—limited to a quarter to half-a-mile from the observer;
- Middleground—extending from Foreground to 3–5 miles;
- Background—extending from Middleground to Infinity.

Scenic analysis for archaeological purposes was first developed by the archaeologist David Fraser (1983: 371–379) to examine the horizons surrounding 76 Neolithic cairns on Orkney, Scotland. The aim there was to understand the relationships between the builders of chambered cairns and the land in which they lived. That study correlated the variation in horizon range surrounding each cairn with orientation, and used three categories (of range) to do so—Restricted (<500 m), Intermediate (500 m–5 km) and Distant (>5 km). Fraser further divided each horizon surrounding a cairn into 10° sectors on the compass and noted the bearings of junctions where distance category changed. It was found that:

- Cairns were not located in places with extensive sectors of restricted visibility;
- Cairns were located in places affording extensive sectors of intermediate visibility;
- There was a very high probability that cairns were intentionally located to ensure visibility of the distant horizon;
- Distant visibility was predominantly towards two points of the compass—between east and south, and towards the west.

Fraser also queried the need for the tomb builders of Orkney to have views with distant visibility and in particular directions—south-east and west. At the latitude of Orkney (+59°), winter solstice sunrise in the Neolithic would have occurred on a horizon of angular altitude 0° at azimuth *c*. 140° i.e. south-east. In the west, the sun would have set in a position spatially midway between its directional limits on the horizon at the winter and summer solstices. Overall, his conclusions were that the cairn builders were likely aware of the cyclical movements of the brightest bodies in the sky but, given the precision limitations of the data, astronomical hypotheses could neither be accepted or refuted without further work (Fraser, 1988: 335).

This type of horizon scan was also used by the archaeoastronomer Clive Ruggles in the study of 300 western Scottish sites with upright or leaning standing stones. That interdisciplinary project primarily investigated the axial azimuths and derived astronomical declinations of those monuments. Horizon ranges at selected sites were additionally recorded, allowing the following preliminary conclusions: some of the sites had ‘local horizons’ nearer than 1 km in particular directions; there was a lack of evidence in the data to conclude that more distant horizons were preferred by the builders; many sites indicated a local horizon in the south that could fall ‘within the limiting lunar range’ (Ruggles, 1984a: 281, 285). Data subsequently collected by Ruggles at other archaeological sites would see a more comprehensive treatment of such horizon scan data with more meaningful results.

In the early 1980s, 97 recumbent stone circles (RSC) in Aberdeenshire, Scotland were examined for their orientations, astronomical declinations and the character of the skyline as indicated by horizon scans (Ruggles, 1984b). Except for two, the landscape settings are either on flat ground, hill tops, or south to south-east facing slopes. Four horizon range categories were used by Ruggles (Fraser used three) to evaluate skyline distances surrounding each RSC. Azimuths of the junctions between each distance category were recorded to the nearest degree. A graph of that data shows the x-axis as azimuth and the y-axis as a percentage of horizons by category (Ruggles, 1984b, Fig. 1). The obvious and general trend in that data indicates a distinct preference for avoidance of horizons categorised as 'near' towards the south. Ruggles also found 'no convincing evidence that there existed a preference for very distant, as opposed to moderately distant, horizons in any particular direction'.

The horizon was similarly investigated in two studies of Bronze Age rock art sites undertaken by the archaeologist Richard Bradley. The first, of petroglyphs in Northumberland, England, found that the inscribed panels were carefully located at viewpoints overlooking important prehistoric routes (Bradley, Harding, Rippon, & Mathews, 1993). In each case, the extent of visibility was recorded in three distance bands delimited by compass bearings—Restricted (<500 m), Intermediate (500 m–5 km) and Distant (>5 km). Bradley applied the same method to analyse vistas surrounding rock art panels in Galloway, south-west Scotland (Bradley, Harding, & Mathews, 1993) with statistically supported correlations between topography, aspect and preference/avoidance of horizons in particular distance bands as categorised above.

Turning now to the Irish passage tombs, Fraser's methodology is adopted here to investigate the horizon surrounding each of these monuments at an island scale. The aim is to test the data for evidence of orientated visibility of the horizon being correlated with a specific distance band (Restricted, Intermediate and Distant) and to interpret the findings.

4 Horizon Scans at Irish Passage Tombs

The majority of Irish passage tombs occur mostly in the northern half of the island. The distribution pattern is irregular, strongly characterised by dense or dispersed clustering, and with a discernible preference for elevated siting as earlier described. The inclusion of 36 unclassified hilltop cairns in the analysis is justified because of their proximity to passage tombs in some cases or because these structures, if isolated, are often found to be targeted in an alignment sense by the passage and entrance of a passage tomb facing a cairn (Prendergast, 2016).

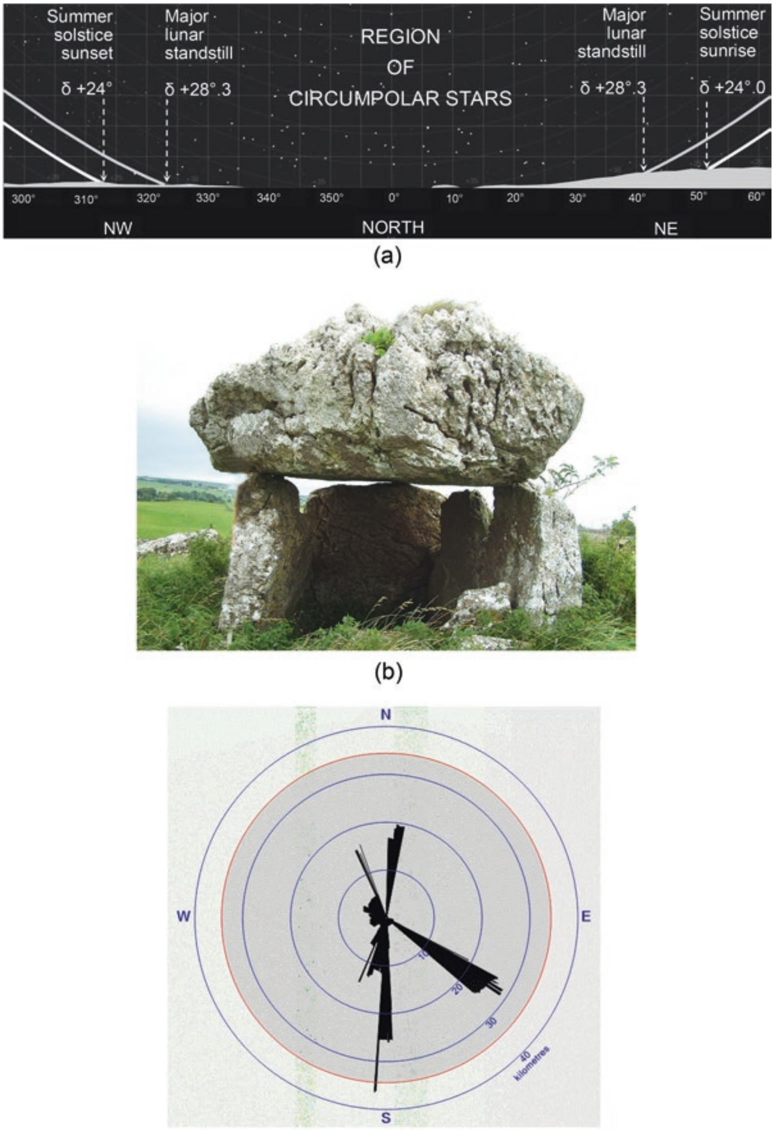
Methodologically, horizon scans to measure notable changes in distance category by orientation were recorded at the sites shown in Fig. 2a. The technique described below was used because of its speed and simplicity while simultaneously undertaking archaeoastronomical surveys at the tombs. Horizon scans can be digitally created using height terrain data remotely captured by airborne methods—photogrammetric or LiDAR. Since 2000, open-source space-based radar height data, termed SRTM (Shuttle Radar Topographic Mission) by the National Aeronautics and Space Administration of the United States (NASA) are available with near-global coverage at a resolution on the ground of 90 m (*c*. three arc seconds) globally and 30 m (*c*. one arc second). The latter was released in 2015 (NASA Jet Propulsion Laboratory, 2014) and is suitable for generating horizon profiles and panoramic views at user-specified locations (e.g., HeyWhatsThat Panorama Viewer, 2019, and see Fig. 1b). 'Horizon' is another GIS tool used by archaeoastronomers investigating the alignment of built structures (Smith, 2020). This is open-source software which generates horizon profiles and scans as shown in Fig. 3 using Scragg passage tomb, Co. Roscommon in north-west Ireland as an example. Figure 3a shows a north-west to north-east section of the horizon at Scragg cut from a full horizon scan using NASA's one arc second SRTM height data. The paths of the sun at summer solstice and the moon at major standstill are additionally shown. The scene is valid for 3000 BC July 18 in the Julian calendar system, the date of summer solstice at that time (NASA Jet Propulsion Laboratory, 2015). Figure 3c illustrates a polar plot of the maximum horizon distance *versus* azimuth surrounding Scragg tomb with Horizon's default distance bands of 10 km–40 km.

If the cursor is placed inside the Horizon Distance Window of the 'Horizon' programme, the display will interactively show azimuth and maximum horizon distance in that direction—an example of distance category by orientation. On a cautionary note, unless high-resolution LiDAR data is used, such digital tools will not give an accurate horizon scan where the range is Restricted (<500 m). This makes it necessary to use site-based naked-eye observations in such cases as next described.

Horizon scans were recorded at the Irish passage tombs using the method described by Fraser (1983: 371). The magnetic bearings of junction points where landscape distances changed from Restricted to Intermediate or Distant were observed with a hand-held compass (Silva Sight Master graduated to 1°). These were later corrected to azimuths using the magnetic declination of date (NOAA National Centers for Environmental Information, 2015). For analysis, the horizon was next conceptually divided into 36 sectors of 10° and the observed visibility data compiled with a spreadsheet. Table 1 explains the method with an example: columns one and two show hypothetical field data, columns three and four show the generalised equivalent.

Figure 4 shows the percentage frequency of occurrence of the three horizon categories or groups (Distant, Intermediate and Restricted) obtained at 266 sites, compiled in Microsoft Excel using 9576 discrete values of azimuth variables in a 36 column × 266 row matrix.

The Two-Sample Kolmogorov-Smirnov test (also known as K-S2) at the 0.05 level of significance determines if each of the three horizon categorical groups come from the same distribution (Table 2). The results show that the three horizon categories are from different distributions and the null hypothesis is rejected.



(a)

(b)

(c)

Fig. 3 (**a**) Horizon profile and sky looking north from Scregg passage tomb (SMR: RO042-090----) computed using Horizon v. 0.13a (Smith, 2020), valid for *c.* 3000 BC with additions by the author; (**b**) Scregg passage tomb looking north (photo. F Prendergast). The cairn is denuded but kerbstones are extant. Sides formed of single limestone slab and roof of single large stone. The plan shape of chamber is undifferentiated (rectangular). It has an isolated setting on the crest of hill with commanding views including of the distant north horizon. The passage axis has an indicative azimuth of 146° and an astronomical declination −28°; (**c**) horizon distances surrounding Scregg computed using Horizon v. 0.13a with NASA SRTM one arc second resolution terrain height data. The viewshed is scaled in 10 km distance bands

Table 1 Orientation of horizon visibility (sample data to outline method)

Field data		Field data generalised for analysis		
Azimuth	Distance band	Azimuth	Distance band	Sector count (36)
0°–189°	Restricted	0°–190°	Restricted	19
189°–274°	Distant	190°–270°	Distant	8
274°–360°/0°	Intermediate	270°–360°/0°	Intermediate	9

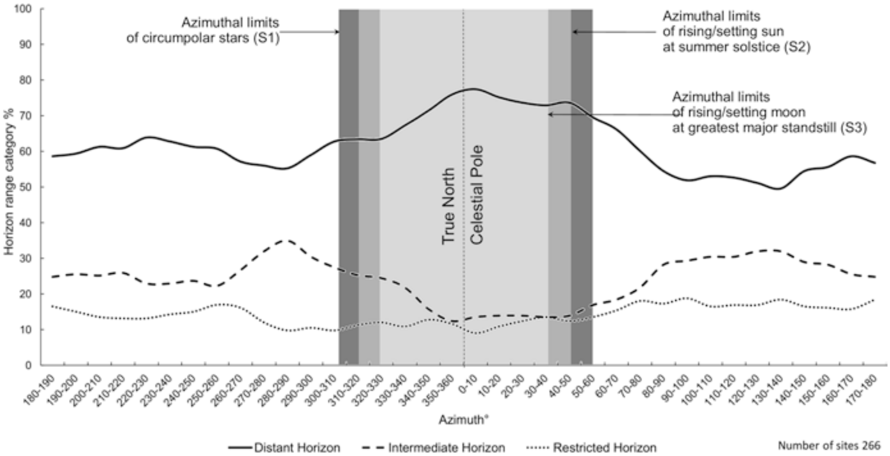


Fig. 4 Horizon range by azimuth orientation for Irish passage tombs and related hilltop cairns

Table 2 Statistical comparison of horizon range groups

Group comparison	D-stat	D-crit	*p*-value (0.05)	Null hypothesis
Distant *versus* Intermediate	0.095	0.033	<0.001	Reject H_0
Distant *versus* Restricted	0.103	0.041	<0.001	Reject H_0
Intermediate *versus* Restricted	0.073	0.046	<0.001	Reject H_0

The one-way ANOVA (analysis of variance) test further examines if a statistically significant difference exists between the group means. The assumptions for this test require that the dependent variables are normally distributed and their variances homogenous. The recorded measurements do not fully satisfy the requirements of this test. Nonetheless, it is useful to present the groups means and their variances to indicate the considerable differences in the three distributions (Table 3) and how this reveals the Distant Horizon category (D) as being the preferred range at the majority of sites. The Fit Distribution Tool of MATLAB (an interactive system for numerical computation) was also used to analyse D, this being the most distinctive of the three classes of horizon range with culturally meaningful potential. That test failed to find any distribution, including the normal distribution, fitting the data.

Observationally, the data in Fig. 4 show a discernible, though not statistically supported, rise in the frequency of the orientation of visibility in the Distant horizon

Table 3 Summary statistics of group means: Distant, Intermediate and Restricted horizon range

Group	Count	Mean frequency	Variance
Distant horizon	36	164.6	418.8
Intermediate horizon	36	63.6	278.5
Restricted horizon	36	37.8	54.7

Table 4 Azimuthal limits of circumpolar sector (S1); azimuthal limits and astronomical declinations for northerly limits of the rising/setting sun (S2) and moon sector (S3)

	Circumpolar star limit at west elongation	Circumpolar star limit at east elongation	Setting sun at summer solstice	Rising sun at summer solstice	Northerly limit of setting moon at major standstill	Northerly limit of rising moon at major standstill
	S1	S1	S2	S2	S3	S3
Azimuth	305°–308°.5	51°.5–55°	314°	46°	324°	36°
Astronomical declination	–	–	+24°	+24°	+28°	+28°

Table valid for the latitude range of Ireland *c*. 51°.5 N–55° N, *c*. 3000 BC

distribution being symmetrically centred about true or geographical north (0° azimuth). Interpretatively, this pattern of increase broadly coincides with three astronomically distinctive regions in the northern sky. Each are closely correlated in terms of their angular width and direction and would be obvious to any observer with an interest or purpose in naked-eye watching of the cyclical movements of prominent celestial bodies on or above the horizon, now or in prehistory. These are termed sectors S1, S2 and S3 in Fig. 4:

- Sector S1: zone bounded by the azimuthal limit of circumpolar stars;
- Sector S2: zone lying north of the azimuthal limits of the rising/setting sun at summer solstice;
- Sector S3: zone lying north of the azimuthal limits of the rising/setting moon at major standstill.

Table 4 shows the azimuths and astronomical declinations associated with S1, S2 and S3.

The horizon scan data presented here could suggest human societies in the prehistoric past, apart from having a conceptual framework of their world, might also have held special regard for the northern sky broadly identified by the sector arc limits and the distant horizon as shown in Fig. 4. This region is in diametric opposition to the southerly sky and horizon which embraces the life-giving and light-giving qualities of the sun and moon. Could this bi-partite division of the whole horizon suggest a religious or ritual concern with the northern sky being the perceived and reserved realm of the dead? Such a proposition associates death with religious beliefs, the most common feature of which is ‘a belief in non-physical beings’ (Cooney, 2000: 87). Cooney also claims that the ‘dead are everywhere’—

true if referring to the deposited corporeal remains of the living in burial tombs. Here, the enquiry has more to do with the perceived journey and abode of the spirits of the dead in an imagined afterlife and prompts asking—what might have been so distinctive about the northern sky and the distant horizon in the minds of Neolithic people?

5 The Northern Sky Considered

The region of sky defined by circumpolar stars (S1 in Fig. 4 and Table 4) has azimuthal limits of *c*. 53° east and west of the north celestial pole (NCP) for the mean latitude range of Ireland. The NCP is a specific but conspicuous point in the heavens which, if it were demarcated by a star, would appear to be stationary. In the northern hemisphere, it is the intersection point of the rotation axis of the earth with the celestial sphere. Any star whose angular distance from the NCP is less than the latitude of the observer is circumpolar. These stars appear to revolve in a counterclockwise manner about the NCP due to the rotation of the earth. An observer facing the NCP will also be looking due north, the opposite of due south where the sun culminates in the sky at local noon. Significantly, circumpolar stars remain visible for the whole of every night throughout every year. On this, Krupp (1997: 19) states ‘As the hub of the most fundamental movement in the sky, the sky’s north pole confers significance to one direction, the direction in which it resides’. Bernadette Brady (2015) writing on naked-eye astronomy related to the Old Kingdom Pyramid Texts of Egypt, and drawing on Bradshaw (1990) and Davis (1977), describes ‘the holiness that the Egyptians attributed to the northern part of the sky’ and how ‘their entire universe hung from the northern pole’. Brady further states that ‘Upon their death, the divine kings, not only had the right to re-join these stars but were required to do so for the cosmic health of the nation’. This ancient textual evidence, although from another culture, points to religious concern and symbolic importance being attributed to circumpolar stars and the north sky.

The second region, S2 in Fig. 4 and Table 4, is bounded by the northerly rising and setting limits of the sun on the horizon. This has an angular width of *c*. 46° east and west of the NCP. The sun will never rise or set in S2. The third region, S3 in Fig. 4 and Table 4, is bounded by the northerly rising and setting limits of the moon. This has an angular with of *c*. 36° east and west of the NCP. Similarly, the moon will never rise or set in this zone. Astronomically, the maximum value of the moon’s declination will vary over the period of a complete cycle of the nodes which lasts *c*. 18.6 years (Hatfield, 1969: 4). Expressed differently, the maximum northerly azimuthal limits of lunar rise and set for the latitude range of Ireland, though infrequent, occur only in years of greatest annual lunar standstill.

Regions S1, S2 and S3 each define a horizontal field of vision centred about true north, each being *c*. 106° wide (the region of circumpolar stars), *c*. 92° wide (the region beyond the northerly limits of sunrise and sunset) and *c*. 72° wide (the region beyond the greatest northerly limits of moonrise and moonset) respectively. For low-precision naked-eye viewing purposes, as would have been the case for sky watchers in the prehistoric past, these zones are advisedly merged into one entity termed simply here as the Arc of the Northern Sky.

The belief systems and ritual practices of communities who erected the passage tombs in Ireland and beyond are clearly unknowable. There is, as described earlier, general acceptance by archaeologists that Neolithic tomb builders choose locations for topographical vantage, intervisibility and proximity to an otherworld—conceived as the abode or realm of the deities, perhaps. The hypothesis argued here, and backed by spatial data, is that a view of the distant horizon was important and preferred above intermediate and restricted horizon ranges at the majority of passage tombs. The horizon scan data is also hinting at human interest in a distinctive and culturally meaningful sector—the northern horizon. This lies explicitly and discernibly beyond the northerly rising and setting limits of the moon and sun and is bounded/delimited by stars which can never set. This is easily determined by mere observation with the unaided eye. Significantly, if the sky and horizon line are viewed in any planetarium software, the apparent motions of the sun and moon looking due south are strikingly perceived as being clockwise or right-handed. In the opposite direction, looking due north, the apparent motion of all circumpolar stars is demonstrably anti-clockwise or left-handed. This simple and obvious natural opposition is a duality which makes for a compelling argument/hypothesis—that the spirits of the dead released by the fires of cremation travelled into the north sky, rising above the distant horizon in that direction to join with the immortal ancestral spirits in an imagined otherworld.

In summary, scenic analysis has revealed that visibility of the distant horizon surrounding most Irish passage tombs was strongly preferred. Moreover, the greatest frequency of such views coincides with a specific sector of the horizon, firstly, lying beyond the northerly rising and setting limits of the sun and moon and, secondly, framed by the region of circumpolar stars. Might such an orientated view of the heavens point to a new element in the cosmology of the Neolithic? If ever such existed, might this reflect underlying principles that are culturally meaningful, linked to funerary and mortuary processing of the dead and the perceived journey of their spirits to join with the ancestors in the realm of the northern sky? Inferentially, was the northern sky a domain considered to be the ancestral world?

6 Death, North and the Otherworld

The passage tomb tradition in Ireland began after the beginning of the fourth millennium BC and 'is synonymous with the emergence of novel subsistence and settlement patterns but also with the contemporaneous appearance of new ritual and mortuary traditions, part of which was specially constructed tombs with an accessible chamber' (Eogan & Cleary, 2017: 739). Construction, especially of the three mega-tombs at Newgrange, Knowth and Dowth in the Boyne Valley Co. Meath, was a complex feat of engineering achievement involving the local community over an extended period lasting for at least a generation perhaps. These monuments share many common features including hilltop clustering, emphasised entrance facades, decorated structural stones, communal burial of adults and children, and deposition of grave goods. The orientation and alignment of the chambers and passages is now more fully documented and understood; some have solstitial astronomical alignment of the virtual axis while many more are found to face elevationally higher focal tombs and related cairns.

Not far from the Boyne Valley lie Fourknocks I and II passage tombs, also in Co. Meath. Cooney and Condit (2005) contend that the elaborate cruciform architecture of tomb I, the incised megalithic art and the elevated setting and commanding views of the landscape, suggest people in the Neolithic ordered their world, related to a ‘complex and fluid set of religious meanings’. Interestingly, and perhaps significantly, Fourknocks I, having an azimuth 7° and astronomical declination +36°, has a distinctly northerly orientation, well beyond the limits of the lunar-solar arc of the horizon. The field of vision from the burial chamber frames the prominent Cooley Mountains in the same direction. Surveys of the island’s tombs by the author also show that *c*. 20% of the sites with extant chambers and passages have their axial orientations similarly facing the northern sky delimited by sectors the S1, S2 and S3 in Fig. 4. The null hypothesis is that the observed data are sampled from a population with the expected frequencies. A simple two-tailed chi-squared test of the relative frequencies of this phenomenon suggests ($c^2 = 9.9$, $p = 0.04$) that the data are not from the same distribution and the null hypothesis is rejected. A focussed discussion of any significance attaching to the horizon and sky beyond the lunar-solar arc is thus warranted, referencing culturally different ethnographic and archaeological sources which post-date the Neolithic. This strategy is backed by Jung (1964: 58) who, writing on the manifestations of symbolic images perceived by the senses (archetypes) in humans everywhere, agues these to be ‘without known origin’ and, more relevant to this discussion, ‘reproduce themselves in any time or in any part of the world—even where transmission by direct descent or “cross fertilization” though migration must be ruled out’.

Early twentieth century ethnographic studies of the many societies inhabiting Indonesia reveal that the ghosts of the dead, released by the smoke of cremation, travelled in the direction from which the ancestors were believed to have come. Locally, for the Tobada of Central Celebes, that direction was north, the land of the dead (Perry, 1915: 145). A description of celestially-related orientation of the dead in northern Italy documents how the body of an Etruscan ruler was laid to rest to face the gods believed to live in the north (Rose, 1922: 135). Amongst the indigenous peoples of North America, the smoke from the fires of cremation were widely thought to be a means by which the spirit was transported to join with the ancestors in the sky and thus secure immortality (James, 1928). Similarly in North America, the Omaha people had deep cultural ties to the sky and earth (Ridington, 1988). In that culture, beliefs were emphatically symbolised in the architectural layout of their dwelling structures. The *Huthuga*, a circular layout of their tribal villages, reflected the Omaha belief system with the entrance to the complex facing east, the direction of the rising sun. Adult males were categorised as Earth People and Sky people. The latter, responsible for the spiritual needs of the community, lived exclusively in the north-half of the layout, the direction symbolically linked with the sky.

Elsewhere, the Maya civilisation of Mesoamerica identified north by using the zenith position of the sun. North represented the realm of deceased god-kings, identified by the region of the pole star. This cosmology was further conceptually realised by their platform temples being aligned south-north toward the abode of the god-kings (Wightman, 2007: 908). Regionally closer to home, Andreas Nordberg (2009) describes how in Old Norse mythology, 'death was a cosmic drama, altering human existence in the most dramatic way' and, after a liminal period, the spirit was united with the ancestors in the Other World situated in the north. He also found evidence of religious symbolism in two round stone settings at a grave-field at Sylta, near Stockholm, Sweden. These structures date to *c*. 500 AD, were built of perfectly round stone packing covered by gravel, and contained cremated human remains. What is important here is Nordberg's finding by excavation of infilling of the grave with stones laid in a counter-clockwise direction, interpreted as showing an opposition to the sun's movement. He argues this pattern of deposition had symbolic meaning, connected to death, and that 'the World of the Dead was reverse, upside-down and opposite to its counterparts in the world of the living'.

Each of the above examples demonstrate how the horizon and sky in the northern direction symbolised journeys of the dead to the afterlife, contrasting with the life and light giving properties of the sun and moon symbolised by the inverse sector of the horizon and sky in which these celestial bodies rose, culminated and set. Such ethnographic accounts also reveal the variability of mortuary and funerary practices which accompanied the rituals associated with death. Can these ideas be validly retro-applied to the more distant prehistoric past, the period predating the Early Medieval in Ireland and Britain (*c*. AD 400)? Can such enquiry inform our understanding of the beliefs and traditions related to life, death and the afterlife in the Neolithic?

Pushing back in time then, a link between the north direction and death is claimed in the archaeological re-examination of human remains discovered during excavations of an Iron Age hillfort in Broxmouth, East Lothian, in Scotland. The site had three distinct entities and zones: a formal cemetery outside the hillfort, isolated graves within the ramparts and scattered disarticulated bones. The cemetery, located on the extreme north side of the hill as far from the entrance to the complex as was possible, is thought to reflect an association with darkness and death (Armit et al., 2013).

Archaeoastronomical investigation of the Bronze Age recumbent stone circle in Tomnaverie, Scotland by Liz Henty (2014) argues how solar, lunar and stellar movements in the winter sky were likely sacred to the builders and monumentally enshrined. Henty hypothesises that Bronze Age ideas about death were 'mirrored in the sky' and, drawing on an interview with the archaeologist Richard Bradley, reports that Bradley now considers 'circles as being related to the sky and to light; and since they face the dark part of the sky where light decreases, this is how they are linked to the dead and the idea of going down into the underworld'.

Of greatest interest here is whether reverence for the sky was shaped by perceptions of the local topography, especially an orientated regard for the liminal horizon where celestial bodies seemingly travelled out of, and into, the imagined underworld. If such was ever the case, did such veneration identify with the sector of sky characterised by the region of imperishable circumpolar stars lying beyond the lunar-solar arc of the horizon where stars can neither rise nor set? Furthermore, was there a sacred belief that the spirits of the dead joined with the ancestors in this perpetually darkest region of the sky? In considering spatial order and cosmology in Phase 1 and 2 at Stonehenge, Pollard and Ruggles (2001) argue that 'a multiplicity of meanings and symbolic references were embodied in attendant depositional practices' at that monument. Referencing other scholars, they consider the symbolism of body directions at the site and how these relate back to ideas of sidedness, left and right. In that model, 'Left' is associated with darkness and evil, the cardinal directions west or north equate to the world of the profane, weakness and death. Whether the north sky was ever explicitly regarded as the abode of the ancestral spirits is not specifically considered.

7 Broader Contexts: New Horizons

Archaeological and anthropological thought on prehistoric ritual and religion are crucial to broadening our understanding of the belief systems and traditions of preliterate societies. Such enquiry takes us on a journey, in search of the unknowable, in a sense. Unlike the security of ethnographic evidence or the tangibility of material culture retrieved by archaeological excavation, enquiry into the intangible nature of lost traditions and belief systems is a perilous journey into the unknown. The formulation of ideas and theory imposes a burden of rigorous duty of care—in the methodological procurement of data and in the derivation of culturally contextualised interpretations. As scholars, we are fortunate to have a relevant body of developed literature providing a framework for different research approaches and consensus drawn from peer thinking. This provides a reliable platform to explore the distant past and the inhabitants of these islands (e.g. Bell, 1997; Gibson & Simpson, 1998; Insoll, 2011; Lewis-Williams, 2010).

Passage tombs are one of several distinctly different prehistoric traditions in Ireland, representing the surviving expressions of our earliest religious architecture. Typologically, they are regarded as the monumental pinnacle of the megalithic tomb building tradition. Such claims are justified given their elaborate architectural form in many cases and the prevalence of developed inscribed and incised megalithic art on the structural stones; over 80% of all such art in Western Europe is found here. Attributes such as landscape setting, elevation separateness from other types, entrances facing other tombs and related cairns located at higher elevations in every case, and the solstitial alignment of some burial chambers and passages are a striking characteristic. Their marginally later chronology than the court and portal tombs, taken in conjunction with these attributes, could suggest the emergence of a new and different cosmology. The hypothesis put forward here could lend support to that thesis. The central idea is that the starry elements of the celestial dome were not only regarded and revered but that the northern sector of the distant horizon, and the northern sky, may have played a key role in the funerary function of the tombs and the belief system of the tomb builders.

Archaeological opinion has moved demonstrably towards acceptance of the idea that skyscape and culture are inseparable. Indeed, writing on monumentality in the Neolithic, Chris Scarre states ‘The symbolism of monuments draws not only on forms and materials taken from the landscape but also on the movements of the sun, moon, stars, potent elements in the mythological and cosmological understanding of Western and non-Western societies alike. Such relationships enhance the potency of monuments’ (Scarre, 2011: 18–19). In this chapter, the idea is advanced that passage tombs and related cairns drew religious inspiration from the summits of locally high terrain, enshrined meaning from the liminal distant horizon to the north, and imbued the darkest region of that sky with the symbolism of death linked to a belief that the spirits of those interred within the burial chambers journeyed to the afterlife in that direction, the abode of the ancestors.

In his *Opus Magnum* ‘Astronomy in Prehistoric Britain and Ireland’, Clive Ruggles advocates how ‘there is a pressing need to examine further evidence on the location and design of monuments in relation to the contemporary landscape, but in a systematic way. This will enable us to question, and ultimately improve, a range of ideas about the ways in which symbolic relationships between monuments and the surrounding terrain and sky reflected contemporary world-views’ (Ruggles, 1999: 156). The data, hypothesis and discussion presented in this chapter is a response to Clive’s aim in that regard.

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Diachrony and the Big Picture: Chabola de la Hechicera, a Peculiar Orientation and a Sacred Landscape

A. César González-García

1 Introduction

Megalithic monuments abound in the northern part of the Iberian Peninsula. They appear in the local late Neolithic as the result of a complex process of crystallization of this period's social dynamics on the landscape. In general, most of the megalithic chambers appear as more or less elaborate passage graves under a conspicuous earth mound. Their location has been investigated in the last decades in search of patterns within the framework of Landscape Archaeology. This has allowed us to understand their connection with mountain passes, fords, or possible prehistoric routes (Alday Ruiz et al. *El Neolítico en la Península Ibérica y su Contexto Europeo*. Cátedra, Madrid, 2012, pp. 291–332). Archaeoastronomy has also highlighted the coherence of Megalithic monument orientation throughout large regions, perhaps pointing at the presence of common traits within larger areas than can be indicated by other material remains found at or near the burial grounds themselves (González-García and Belmonte, J History Astronomy, 41: 225–238, 2010).

Chabola de la Hechicera (Sorceress' Shack) forms part of a small cluster of passage graves in the vicinity of the river Ebro and the Sierra de Cantabria, in the Rioja Alavesa wine region. Michael Hoskin measured the orientation of most of these graves in the late 90s (Hoskin, *Tombs, temples and their orientations. A new perspective on mediterranean prehistory*. Ocarina Books, Bognor Regis, 2001) showing that, contrary to the general custom across most of Iberia and particularly in this area of north-central Spain, the corridors opened towards the south or south-southeast. Also, when inspecting the panoramic view and some images of the site, a particularly interesting topographic feature catches our attention. At the north-eastern extreme of the Sierra de Cantabria, the chain of mountains that constrains

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A. C. González-García (✉)
Institute of Heritage Science, Incipit—CSIC, Santiago de Compostela, Spain
e-mail: a.cesar.gonzalez-garcia@incipit.csic.es

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the Ebro valley to the north of this area, the Castillo de Lapoblación (1.243 m.; hereafter Lapoblación but also called León Dormido), appeared particularly prominent from the location of Hechicera.

Thus, inspired by Clive Ruggles' work on the island of Mull (Ruggles and Martlew, Archaoastronomy, 17: S1–S13, 1992; see also, Ruggles, *Astronomy in prehistoric Britain and Ireland*. Yale University Press, Yale, 1999, pp. 112–124). We explore in this paper why Chabola de la Hechicera has that peculiar orientation and whether its location can be connected to the sighting of that mountain. In particular, we will explore if this prominent spot could be related to astronomical features providing a connection with a sacred landscape for the people who built this megalithic burial chamber.

2 Hechicera in Context

Chabola de la Hechicera is located near the small village of Elvillar, in the vicinity of Laguardia, the capital of the wine region of Rioja Alta, to the south of Alava province (Basque Country) and at a short distance, as the crow flies, to the Ebro river (c. 6 km).

Discovered in 1935, the corridor and part of the chamber were excavated in the following year (1936; Barandiarán, 1957), the same year when the Spanish Civil War started. A new excavation took place in in 1947 and a larger excavation was carried out in the mid 70s when some major restoration work was undertaken (Apellániz & Fernández, 1978). Finally, the last intervention took place in 2010, which cleaned up the structure and delimited the tumulus (Martínez-Torres, Fernández-Eraso, Mujika-Alustiza, Rodríguez-Miranda, & Valle-Melón, 2014; Pérez Vidiella, Miranda, & Valle Melón, 2012).

Chabola is a passage grave formed by a polygonal chamber with 7–9 orthostats (Fig. 1). The uncertainty in the number of orthostats in the chamber is due to the presence of two large orthostats between the chamber and the corridor, which are larger than those inside the corridor, but slightly smaller than those in the chamber (Narvarte Sanz, 2005: 88–99). At present, a covering stone is placed on top of the rear part of the chamber, but it was probably broken at some point in the past. Three pairs of orthostats form the corridor. This is nearly 5 m long and slightly less than 1 m wide. It is apparently segmented in two parts by a closing stone. The 30s and 70s excavations recovered a number of severely damaged human remains together with stone tools, ceramics and beads from both the chamber and the corridor. In the upper layers there were also some metallic elements and decorated ceramics perhaps indicating the long use of the chamber (from 3800 BC to 1100 BC in several phases and stages, see below). In fact, several closing layers, i.e. deposits that are interpreted as being meant to seal and close the burial in several phases, have been indicated from the late Neolithic until the early Bronze Age (Narvarte Sanz, 2005: 88–99).

Fig. 1 Chabola de la Hechicera megalithic site. (**a**) General view of the monument where the upper layers of the stone crust that covers the tumulus can be appreciated together with the megalithic chamber. (**b**) Close up view of the entrance corridor and the chamber. It is also noticeable the Sierra de Cantabria mountains to the background of the monument, towards north. (**c**) Zenithal image of the passage grave and tumulus during the last restoration works. The dotted arrow indicates the orientation of the corridor. The dashed arrow indicates the direction towards the Lapoblacion Mountain. (**d**) View towards the Lapoblacion Mountain from Hechicera. This direction is nearly perpendicular to that of the corridor. Images: A. César González-García

A tumulus of nearly 26 m in diameter covered the structure but did not completely hide the chamber and the corridor. The first excavators reported that the tumulus was composed of two layers. The lower covered the larger part and, on top of it, a second layer was built with a nearly 14 m diameter and a total height of 4 m. An intricate crust of middle size stones covered the upper part. The tumulus is truncated next to the entrance of the passage grave by a paved atrium with flat slabs. It is also delimited on the east side by a stone wall which is not symmetric to the western side (Fig. 1; Martínez-Torres et al., 2014).

The excavations uncovered a Bell Beaker burial in the eastern part of the tumulus. A general attempt to destroy or to render useless the monument at some point in pre-History has also been proposed (Narvarte Sanz, 2005: 88–99).

Most of the human remains were recovered in the mid 70s excavations. These are composed of 39 individuals: 30 adults and 9 infants. They were buried together with a number of goods, including a palette bone idol, a fragmented geometric stone, an arrow flint, as well as Bell Beaker ceramics and some metal goods. According to the most recent dating, the megalithic monument was built in the early fourth millennium (3800 cal BC). The bone idol could correspond to this date. Then, a number of dates correspond mostly to the late Neolithic and Chalcolithic period

(3600–2900 cal BC), while the Bell Beaker phase could correspond to the last set of dating during the Bronze Age (1600–1100 cal BC; Arenal & de la Rúa, 1988; Fernández-Eraso & Mujika-Alustiza, 2013). These data indicate a long history of construction, and use by local communities. The history appears to be discontinuous with variable intensity in the occupation and several possible moments of closing and reuse.

3 Orientation

According to Michael Hoskin (Hoskin, 2001: 236; see also Table 1), the orientation of the passage grave is 143°, and the altitude of the horizon in that direction is 0.75° rendering a declination of −35.8° (see Table 1).[1] Such a declination is way far from the solar range.

The width of the corridor allows for a window of visibility ranging from azimuths of 131°–166°. The northern extreme of this opening, with a declination of −29°, would allow the marginal visibility of the lunar southern extreme. However, any astronomical intentionality connected to the sun or the moon in the horizon of the orientation of the corridor based on this premises seems a bit far-fetched. In fact, Hoskin indicated that Hechicera faced the 'sun long after it had risen and was climbing in the sky, and so we have here a custom that was strictly Sun Climbing' (Hoskin, 2001: 117).

This declination, though, could coincide with the declination of the Pointers (α and β Centauri) and the Southern Cross at the moment of building and use of the passage grave.

Another interesting fact is that the corridor of Chabola is almost perpendicular to the direction where we can see the Lapoblacion Mountain, a prominent feature of the local landscape (Fig. 2a, c). The corridor seems to be facing the most distant horizon as seen from this spot, facing the Sierra de Iregua to the SE, and the slopes towards the river Ebro valley (Fig. 2d). Finally, it might also be relevant to note that the prevailing wind in this area runs from east to west, also nearly perpendicular to the entrance corridor, and the orientation could avoid those winds perhaps providing shelter to the human remains inside.

Interestingly, the ethnography of the name of this megalith might provide further relevant information. Most megalithic sites in the Basque country bear names from the area where they are located after their discovery. However, a few of them where

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[1] Most of the data was obtained by Michael Hoskin and his collaborators in the 90s (see e.g. Hoskin, 2001). The data was obtained with an off-shore compass (Hoskin, 2001: 12). The new data presented in this contribution was obtained with a Suunto 360 professional tandem, with a compass and clinometer with ¼° accuracy in azimuth and altitude. The new measurements in Table 1 are the mean of a set of at least five measurements, and while the state of preservation of some of the dolmens would set a stringent limit on the accuracy of the orientation, we have opted to provide the figures to the error level of the instruments employed.

Table 1 Orientation data for the several sites in the vicinity of Chabola de la Hechicera

						Lapoblación			Dating
Site	φ (°/’)	λ (°/’)	a (°)	h (°)	δ (°)	a(°)	h(°)	δ(°)	(cal. BC)
Layaza	42/35	2/39	147	0.7	−37.9	Not visible			2800–2000
Sotillo	42/34	2/37	180	1.6	−46.1	74	2	13	3000–1900(1300)
Montecillo	42/33	2/40	182	1.6	−46.1	70	2	15.8	2500–2300
Chabola de la Hechicera	42/34	2/33	143	0.75	−35.8	58	3	25	3500–2900(1750)
S. Martín	42/34	2/36	172	1.0	−46.1	64	2.8	20.7	3600–
Alto de la Huesera	42/34	2/34	140	0.75	−34.1	63	3	21.5	3000–2900
El Encinal	42/34	2/32	142	0.8	−35.2	54	4	28.5	–––––
Los Llanos	42/36	2/32	142	0.8	−35.2	74	4.5	14.7	(4300)3700–
La Cascaja	42/35	2/44	177	1.1	−46.6	Not visible			–––––
Longar	42/35	2/24	179	1	−46.9	300	3.7	24.1	3100–2900

The columns provide the name of the megalithc site, location (latitude and longitude) the orientation of the corridor, altitude of the horizon and declination. Then we include the alignment towards the Lapoblación mountain. Finally, we provide the dating for the several sites as given by Fernández-Eraso and Mujika-Alustiza (2013)

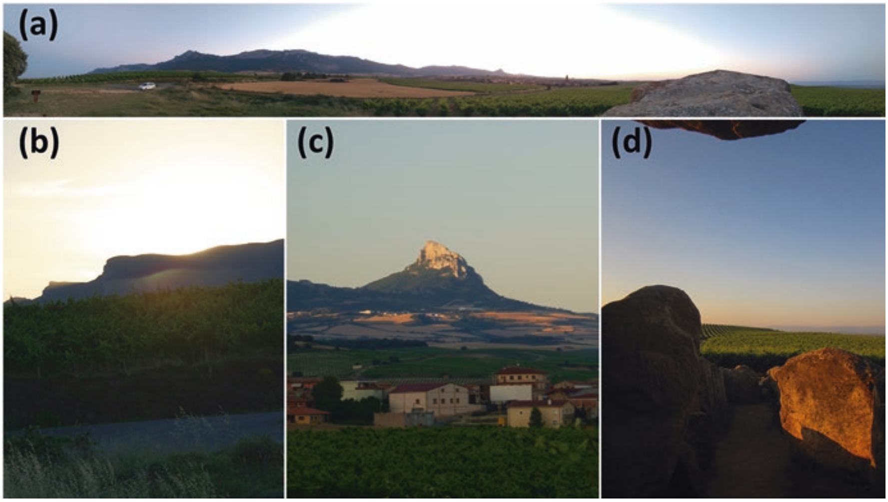

Fig. 2 The landscape surrounding Chabola de la Hechicera. (**a**) General panorama centred in the northern horizon. The northern part of the horizon is dominated by the imposing view of Sierra de Cantabria mountain range. The picture was taken from a position close to the megalithic chamber. The capstone can be observed in the lower right. (**b**) The summer solstice sunset as seen from Hechicera's location happens on the NW extreme of the Sierra (at a position close to that of the car in the upper image). At this moment, the last part of the surrounding landscape to be still lit by sunlight is the peak of the Lapoblación mountain (**c**), seen on the NE extreme of the Sierra. (**d**) The chamber and corridor open towards SE, facing the gentle slopes going towards the Ebro valley. The river is not directly observable from this site. Images: A. César González-García

known since long ago, and had their own proper name usually connected with Basque mythological figures. The name of the site, Chabola de la Hechicera (Sorginaren Txabola in Basque) or Sorceress' Shack, connects this site to a commonplace in Basque folklore, the Sorceress (Gordón Peral, 2008; Vegas Aramburu, 1991). In particular, the legend of Hechicera, which could be traced back at least to the beginning of the nineteenth century (Vegas Aramburu, 1991), says that this was the shack of a Sorceress who at night on Saint John's day (June 24th) turned into stone anybody that came along her way.

As indicated above, the orientation of the main axis of Hechicera is far from any solar orientation looking out from the interior of the structure. The reverse orientation, looking from the outer extreme of the corridor towards the chamber, faces the high parts of the Sierra de Cantabria to the north (see Fig. 2a) and is thus also far from the summer solstice sunset.

However, the northern horizon is extremely interesting, as in the northeast appears the shape of the Lapoblación Mountain with a prominent figure. The peak of this mountain has an azimuth of 58° and declination near +25° and thus is nearly perpendicular to the corridor entrance, as mentioned above. Interestingly, the summer solstice sunrise would be visible on the slopes of this prominent peak as seen from Hechicera.

Fig. 3 Summer solstice sunrise as seen today from Chabola de la Hechicera on June 19, 2017. The sun rises from the slope of the Pico del León Mountain. At the time of use of the megalith, the sun rose further up in the slope. This is indicated by the empty circles in the image. Image, A. César González-García

Interestingly, at summer solstice, the sun sets on the western most slopes of the Sierra and the last rays illuminate Lapoblación (Fig. 2b, c), while the rest of the landscape is already in shadows. The next morning the sun rises from the slopes of such peak in a stunning way (Fig. 3).

This observation could render support to the importance of Saint John's day in the story and perhaps to the summer solstice: the actual orientation of the corridor is not directly connected with this astronomical event, but the location of Hechicera could be, so that it is on the spot where the sunrise and set of such day happen with a peculiar phenomenology in the local landscape. However, we do not know if the builders and users of Hechicera also noticed this fact in prehistoric times. In spite of this, and as it was mentioned earlier, Hechicera forms part of a small cluster of megalithic monuments. A set of 8 further monuments can be identified in the close vicinity, which share several characteristics.

4 A Regional Pattern?

These eight monuments include seven passage graves and a simple dolmen, although this last monument might be a further passage grave whose passage is missing today (Fernández-Eraso & Mujika-Alustiza, 2013; Narvarte Sanz, 2005). In general, the eight monuments present similar characteristics to those of Chabola. They are megalithic chambers with six (Huesera) to ten (San Martín) orthostats and polygonal shapes. The archaeological findings include human remains plus the material record composed of lithic material, ceramics and beads (Narvarte Sanz, 2005). It is interesting that in several cases there are some figurines in bone, identified as idols (notably in San Martín; Fernández-Eraso, Mujika-Alustiza, & Fernández-Crespo, 2015) by the archaeologists who excavated the different sites.

The dating of the human remains from sites indicate that the construction of these megaliths started at the end of the local Middle Neolithic or early late Neolithic (i.e. end of the V and mid IV millennium cal BC; Fernández-Eraso & Mujika-Alustiza, 2013). They seem to be contemporaneous to other megalithic monuments in nearby regions such as the north of Burgos or the Basque Country to the north (Fernández-Eraso, 2007–2008). It must be noted that, in general, two phases of use have been identified. The first one would be from mid-fourth millennium cal BC, during the late Neolithic and Chalcolithic, and the second at the end of the third millennium BC, during the fist Bronze Age. It is interesting that some of the megalithic sepulchres continued to be used until the end of the second millennium BC (e.g. El Sotillo; Fernández-Eraso & Mujika-Alustiza, 2013).

The orientation of all these monuments is towards the southern part of the horizon, with clearly two main directions (see Table 1; Fig. 4). One seems to be quite similar to that of Hechicera, with declination −36°, while the second is very close to due south, and declination −47° (see Fig. 4). The consistency of the orientation

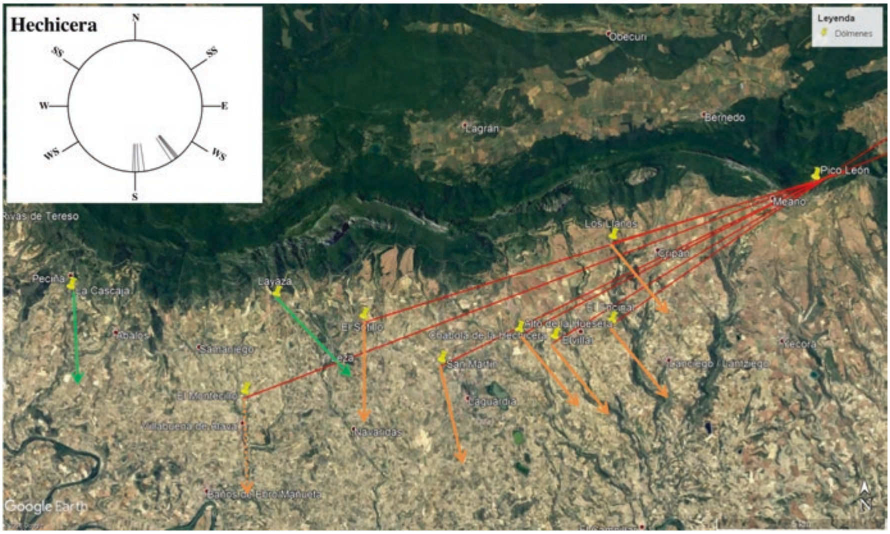

Fig. 4 The nine megalithic chambers in the vicinity of Chabola de la Hechicera. A yellow pin marks the locations of the passage graves. The arrows indicate the orientation of each chamber and corridor, the orange color indicates that Lapoblación Mountain (Pico León in the figure) is visible from the site of the megalithic chamber. If this mountain is not visible it is indicated in Green. The red line connects each site with the mountain. Top left inset: orientation diagram for the megalithc chambers in the Rioja Alavesa. They all appear to cluster in two narrow directions. The first is similar to the orientation of Hechicera. The second scatters slightly from due south. Image by the author from a photograph courtesy of GoogleEarth

indicates that the coherence of the group is not only present at the typological architectural features, meaning the shape of the structure, but also at a more formal one that includes how the monument is placed and located in the local environment.

Although the monuments appear in close vicinity, the mean distance to the nearest neighbour grave is 2.5 km (De Carlos Izquierdo, 1988) and, although some of them present intervisibility relations, not all are visible to each other. Spatial studies of this megalithic group indicate that the monuments seem to be in general on the middle ground between the river Ebro and the Sierra and that the monuments were built on a potentially important economic route running east to west (Alday Ruiz et al., 2012; De Carlos Izquierdo, 1988).

It is important to note that the river Ebro is not directly visible from any of the nine megaliths (including here Hechicera; see Fig. 2d). However, it is clear that the corridors open to the south, facing the furthest horizon seen from their location. In particular, Sierra de Iregua (c. 35 km away) can be seen in that direction on clear days. The orientation of the corridors is not facing towards the closest neighbouring grave. The horizon towards north is high and at close proximity due to the Sierra de Cantabria Mountains just a few km away. In fact, we have checked also the direction looking from the outside in, instead of the customary inside out. Taking into account the height of the horizon we can notice two main facts. The first is that the monuments point always to the Sierra, but each points to different parts. The second is that if we consider the declination, i.e. the part of the sky that such directions might be pointing at, the spread of the data is larger than in the opposite direction. While to the south the declinations for the eight monuments cluster on just two values, towards north they spread at several different values. An astronomical intention towards north then seems more speculative than to the southern skies.

The wind could be a driving factor in the orientation of the corridors, as indicated above. The prevailing winds in the area today are running east west due to the configuration of the local orography, and one might argue that the same winds could have been important in the past. The orientation towards the south could thus avoid those winds, but this still does not answer why all structures seem to be directed so narrowly towards two particular spots and not spread around the perpendicular of the wind direction, as one might expect if this were the only explanation.

Given the interesting visibility relation between Hechicera and Lapoblación Mountain, we took the chance to verify if the peak was visible from all monuments and then measure the direction towards its summit (see Table 1 and Fig. 4). We must remember that the corridors are not facing this mountain, but it appears as a prominent spot on the local horizon. The peak is visible from seven megalithic chambers (including Hechicera). In all cases, it appears to the northeast, ranging from declinations +13° to +28.5°. We could speculate that the visibility of this mountain could have been related to the sighting of a 'summer' sunrise from the end of April to mid August. It might be noticeable that in most cases this peak appears to be roughly perpendicular to the direction of the corridor.

In the close vicinity of this megalithic cluster there is a number of burials in rock shelters in the Sierra de Cantabria (Fernández-Eraso & Mujika-Alustiza, 2013). Recent results suggest that there was a cultural difference between the people buried in these shelters and those placed inside the megaliths (Fernández-Crespo et al., 2020). Also to the south there is a contemporaneous collective burial site (called San Juan ante Portam Latinam; Vegas et al., 1999), where 289 individuals of both sexes and including infants and adults were buried. A large fraction of the individuals presented evidence of violence. This shelter opens to the southwest, similarly to the ones in the Sierra and also in broad similarity with the orientation of the corridors of the megalithic monuments.

A singular megalithic monument some 13 km to the west of Hechicera is Longar (Narvarte Sanz, 2005: 272–277; Armendáriz & Irigaray, 1995; Table 1). This is a collective burial site on a horseshoe shaped chamber excavated in the bedrock, filled with dry stone masonry and covered by two sandstone boulders. The chamber is elongated and opens in a perforated stone, and towards a *dromos* or open corridor. Inside the tomb the archaeologists discovered the remains of at least 114 individuals of both sexes. Some of the bodies showed evidence of the cause of death being due to warfare, such as arrow flints attached on bones. Interestingly, the chamber included a few ceramics deposited as grave goods. The dating of the site is 2500–2400 cal BC according to the ^{14}C of the bones (Alday et al., 2016). This is contemporaneous to Hechicera, during the transition to the Chalcolithic.

The orientation of Longar is due south. Longar is in full view of Lapoblación, and interestingly this mountain displays a completely different profile from here, but the direction towards this mountain would coincide with summer solstice sunset as seen from Longar (Table 1).

The dating of the several megalithic monuments in the Hechicera station could perhaps help us interpret all the results exposed above (Fernández-Eraso & Mujika-Alustiza, 2013); Table 1). Most are deduced from the human remains recovered during the successive excavations. In the following lines, we will consider that the earliest dates are mostly contemporaneous with the first use and thus erection of the megalithic structure. We are aware of the strong assumption this entails, and to this, we must add the scarcity of the data.

Figure 5 left compares the declination of each corridor with that earliest date. We do not see any systematic trend. However, it is interesting to note that all monuments with declinations close to −36° seem to be built prior to 3100 cal BC, while most of the monuments with declinations closer to −46° (due south) appear systematically later than those of the first group. The exception to this is San Martín dolmen where there is a dating from a very early stage.

Figure 5 right compares the declination of the Lapoblación Mountain as seen from each of the sites where we have a dating. There seems to be a general trend of declinations from values close or above 24° at the earliest stages towards declination c. 14° later on°. Now the exception is the Los Llanos dolmen, which is the closest dolmen to this mountain peak and has a very early dating with a declination towards the peak of 14°.

These figures suggest that the earliest dolmens tend to have an orientation of c. −36°, and are located in a spot where Lapoblación Mountain is seen at a declination c. 22°.

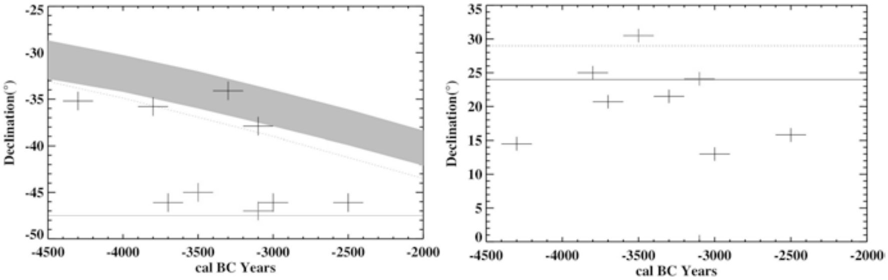

Fig. 5 (**a**) Comparison of the declinations of the corridors (left) and that of the Lapoblación Mountain (right) with the earliest dating obtained from the Hechicera cluster. The Longar and San Juan burial sites are also included as red crosses. The grey band in the left panel indicates the declination range covered by the Southern Cross during the period indicated in the x-axis. The dotted line indicates the declination of α Cen. The solid line indicates the declination south and a flat horizon at the latitude of Hechicera. The Solid line in (**b**) indicates the declination of summer solstice while the dotted line stands for the northern lunar extreme

To summarize, the megaliths in this area south of Sierra de Cantabria, a boundary region between the Ebro valley, the Basque Country and the Duero plateau to the west, appear as a coherent group with the orientation of most burial sites towards south. The prevailing winds and the local orography do not seem to fully explain the coherence of these orientations. We could perhaps suspect that the local topography together with some astronomical features could provide clues to interpret the area as a particularly sacred region for the local population. But, how does this compare to other neighbouring and contemporary areas?

5 In Context of the Other Megaliths in the Area

If we compare the orientation of the megalithic monuments in this group with others in the neighbourhood, we can verify that the norm in most areas next to the Rioja Alavesa is to be facing towards the east or southeast, and certainly, in most cases they can be related to Hoskin's sunrise customs.

The closest group to Hechicera would be the few passage graves to the other side of the Ebro valley, on the slopes of Sierra de Cameros that serves as a natural communication route between the Ebro and Duero valleys. Their date is almost contemporaneous to the Hechicera group with possible re-occupations during the Bell Beaker phase (Pérez Arrondo, 1983; see Fig. 6).

Other groups include those to the other side of the Sierra de Cantabria to the north, in the province of Alava; those to the north of the Burgos province, in the Sedano area, also in the Ebro valley. To the east, we could mention those in the southern parts of the pre-mountains of Navarra and Huesca, which are closer to the Ebro valley than other megalithic monuments of those provinces in the Pyrenees (Fig. 6; most data was obtained from Hoskin, 2001. A few new measurements are included in Table 2).

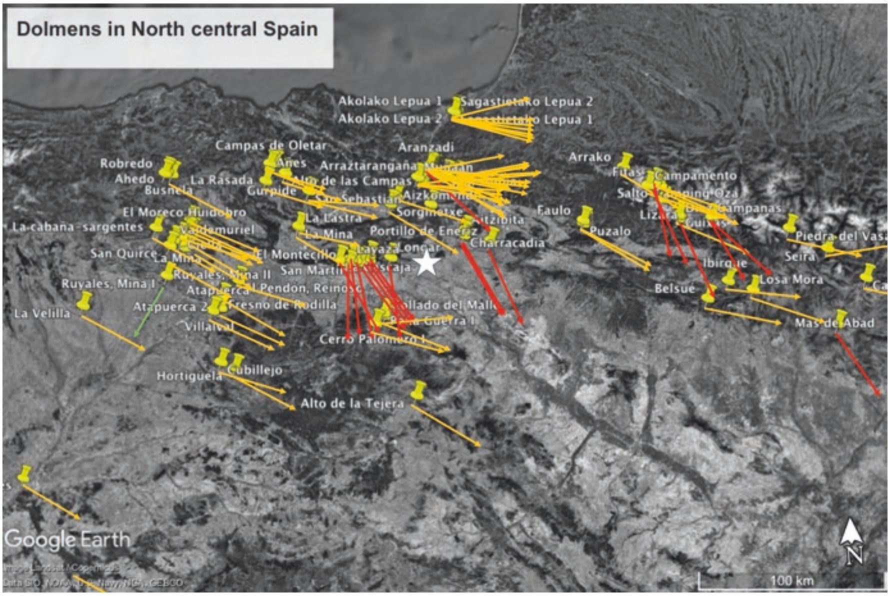

Fig. 6 Map of the megalithic chambers in north-central Spain. A yellow pin indicates each site. The arrows indicate the orientation—azimuth—of the megalith. In dark yellow are those whose orientation is compatible with sunrise. In red are those with orientations far from the solar range. Ruyales I and II (green arrow) are included here for comparison. They where measured by Hoskin (2001: 214) but they are not considered today as megaliths. Image by the autor from a photograph courtesy of GoogleEarth

The Rioja group presents orientations towards the east and southeast, in contrast to those found in the Hechicera group. A similar situation appears in the Alava province, and mostly in the Sedano area, where the orientations are predominantly towards southeast. None of these groups presents a similarity with the Hechicera group.

The closest parallel to the Hechicera station appears in the dolmens located on the hills closer to the Ebro valley, in Navarra and Huesca. Especially in Navarra, we find those of Artajona and Chacarradía, Faulo and Puzalo and in Huesca we have those in the Pyrenee valleys and Mas de Abad.

There are two passage graves in Artajona, and both contain a chamber with nine orthostats and a corridor that ends at a perforated stone (Narvarte Sanz, 2005: 269–271, 277–280). This entrance is in close resemblance to the Longar hypogeum. Typologically, and due to the presence of the perforated entrance, they are normally thought to be a late representative of the megalithic buildings in the area. Chacarradía (Narvarte Sanz, 2005: 266–269) is a passage grave with a chamber composed of eight orthostats. Several human remains were recovered from the chamber. The archaeological reports indicate that the orientation of the corridor is towards the east (see, e.g. Narvarte Sanz, 2005: 266), but we could measure an orientation of 164°, which closely resembles those of the Hechicera group.

Table 2 Orientation data for the new measurements in several regions

#	Site	φ (°/')	λ (°/')	a (°)	h (°)	δ (°)
La Rioja						
1	Collado del Mallo	42/18	2/27	85	−0.5	2.9
2	Cerro Palomero I	42/16	2/31	110	2.5	−13.1
3	Peña Guerra I	42/19	2/28	116	9	−12.5
Álava						
5	Campas de Oletar	43/3	3/7	122.5	1.75	−22.1
6	Añes	43/3	3/9	113	10	−9.4
7	Alto de las Campas	43/0	3/3	118	1.5	−19.2
8	La Lastra	42/44	2/58	103	4.7	−6.4
Navarra						
10	Faulo	42/41	1/9	135	2.4	−29.6
11	Puzalo	42/41	1/9	132	6.5	−24.4
12	Aranzadi	42/56	1/57	125	0	−25.2
13	Arzábal	42/56	1/58	95	0.2	−3.9
14	Aitzibita	42/41	1/54	127	0.5	−26.2
15	Artekosaro	42/49	2/7	96	3	−2.5
16	Charracadia	42/40	1/55	164.75	1.25	−44.3
Huesca						
17	Losa Mora	42/18	0/5	110	4.8	−11.4
18	Belsué	42/17	0/23	98	7.9	−0.6

The columns provide the name of the megalithc site, location (latitude and longitude) the orientation of the corridor, altitude of the horizon and declination

Faulo and Puzalo are two chambers near the village of Bigüezal. The first has a tumulus of 12 m in diameter composed of dry stone, with a small chamber formed by five orthostats in a rectangular plan (Narvarte Sanz, 2005: 228–230). Puzalo is very similar to Faulo, with a tumulus of dry stone of 14 m in diameter with a rectangular chamber comprised of four stones (Narvarte Sanz, 2005: 231–232). These two have an orientation towards the southeast, slightly outside the solar range, although they could be facing the lunar extremes (see Table 2).

Interestingly, all of these structures present orientations towards the southeast, in close resemblance to those of Hechicera group. Finally, we should mention the Mas de Abad dolmen, which is very close to Catalonia and offers another example of a dolmen with a southern orientation. Thus, the similarity appears throughout the Ebro valley.

If we open the scope of our inspection to regions further to the north, east and west (there is a clear megalithic void to the south), we find a similar trend again when we move towards east.

To the west, most dolmens in the Duero plateau, including those closer to the Portuguese border in Salamanca, appear to present mostly orientations between nearly due east and winter solstice sunrise. The ones in the northern parts of the

Basque Country or Navarra also tend to systematically present orientations towards the east (see Fig. 6).

Finally, the dolmens in the Pyrenees are a cumbersome group. Those in Huesca (Spanish Central Pyrenees) present mostly orientations within the solar range, although there are a number of examples that have orientations to azimuths far to the south, given their locations within the Pyrenees' valleys, the altitude of the horizon renders the declinations perfectly compatible with the luni-solar range (Belmonte & González-García, 2012). A similar situation is present in the Cerdagna valleys, of the Catalonian Pyrenees (Hoskin, 2001). We have to move to the Catalonian coast to find several groups with orientations similar to those found in Hechicera or the Ebro valley, well outside the solar range.

In order to ascertain this general impression, we have performed a cluster analysis of these several groups, similar to that in González-García and Belmonte (2010). In that paper, the Hechicera group was included together with several others in a group called north central Spain. The results indicated that, according to their orientation trends, these groups could be somehow related to the Catalonian coastal groups, although they were then considered as interlopers.

We have preformed a new and refined analysis with the new orientations. The number of groups considered is 13, and are given in Table 3. For each group we consider the mean azimuth, the median, the standard deviation, the maximum and minimum azimuths, and the two largest concentrations obtained from a curvigram representation of the azimuths in each group with a bandpass of twice the uncertainty in the azimuth determination. We have thus performed a cluster analysis based on our IDL algorithms to calculate the distances among groups by a nearest

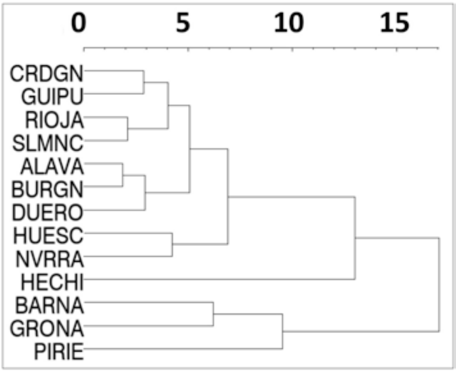

Fig. 7 Dendrogram of the groups in Table 3. The figure plots the distance between the several groups of megaliths considered. Such distance is measured in the space that considers the orientation distribution for each group. For each group, such distribution is characterized by the mean, median and standard deviation, the minimum and maximum azimuth and by the two largest concentrations. These values are given in Table 3. The dendrogram then provides a visual tool to grasp the distance between groups. Hechicera group (HECHI) is located between the Eastern clusters of megalithic monuments, with orientations mostly towards sunrise, and those in the Catalonian coast (BARNA Barcelona; GRONA Girona and PIRIE, East Pyrenees)

Table 3 Input data for the cluster analysis

Cluster	Acronym	Mean(a)	Med(a)	σ(a)	Max(a)	Min(a)	a_{max1}	a_{max2}
Alava	ALAVA	113.1	113	12.8	131	94	104.3	128.0
Barcelona	BARNA	154.8	140	54.9	270	91	120.8	221.0
Burgos North	BURGN	118.5	118	8.6	137	105	115.3	128.0
Cerdagna	CRDGN	118.0	121	25.3	161	73	119.3	85.0
Duero plateau	DUERO	119.0	120	9.7	135	102	118.4	102.0
Girona	GRNA	144.0	148	48.5	244	55	140.4	185.0
Guipuzcoa	GUIPU	104.7	102	20.9	157	77	104.9	80.0
Hechicera	HECHI	160.3	172	18.9	182	140	144.8	178.0
Huesca	HUESC	122.1 124.0	116.5 116.5	28.2 28.6	173 173	71 71	109.8 110.6	159.0 162.0
Navarra	NVRRA	115.2 96.6	101 95	30.6 15.1	169 125	80 80	93.1 94.7	85.0 85.0
East Pynenees	PIRIE	175.6	168	47.2	304	48	165.3	149.0
Rioja	RIOJA	103.7	110	16.4	116	85	107.7	80.0
Salamanca	SLMNC	111.0	112	12.2	133	84	112.9	87.0
Ebro valley	EBRO	149.2	147	26.0	182	93	165.2	135.0

The table presentes the cluster name, the acronym, the corresponding statistical data for every group. For the first analysis we considered provincial groups so, there was no Ebro valley group. In the second analysis we did include such group by detaching those passage graves closer to the valley from the ones in Navarra and Huesca. The second file in these entries provides such data. For details, see text

neighbour procedure (González-García & Belmonte, 2010). The results appear in Fig. 7. The groups considered are numbers 1–13 in Table 3.

We can see that there are two main groups based on this analysis. The largest one includes most of the monuments to the west and north of Hechicera. These have orientations mostly towards east and within the solar range. The second group includes those in the Catalonian coast.

We have rearranged slightly the groupings to have all monuments close to the Ebro valley in one group, including Hechicera, plus all the passage graves in Huesca and Navarra close to the Ebro (see Table 3, the entries here change for these three groups, while for the others are the same as before). We find that the regional grouping still appears (see Fig. 8). There is one cluster with the monuments of the Duero plateau, those of Alava and the north of Burgos and very close to it there is a second cluster which includes the monuments in La Rioja, Salamanca and Navarra. Then we have a third group with the monuments of Guipuzcoa and Cerdagna. According to this classification scheme, all these three clusters form a big family of orientations. At the other extreme there are the Catalonian coast groups. The dolmens in Huesca and those in the Ebro valley appear as a group between these other two broad regional groups.

This seems to indicate that Hechicera is in a transitional position between two large families. The two large families appear to indicate two orientation traditions that apparently were maintained over large regions and epochs. The first one is the

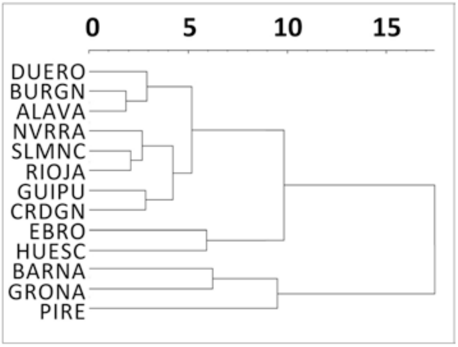

Fig. 8 Dendrogram of the groups in Table 3 now including a group for the Ebro valley that includes Hechicera group

one that would correspond to Hoskin's 'sunrise custom'. This appears mostly in the western part of the region of our study, in the Duero plateau, the mountains to the north, the Basque Country and the Pyrenees valleys. The second family presents orientations mostly to the south, from southeast to southwest, and appears mostly in the Catalonian coast, but also in the interior along the Ebro basin. The two traditions meet very close to the Hechicera group that would appear then as the last example of this family as we move from east to west.

At this point, it might be interesting to have a look at the burial places of the previous epoch both on the Catalonian coast and in the Ebro valley.

6 Previous Epochs

The first evidence of Neolithic activity in the northeast of the Iberian Peninsula appeared in the Mediterranean coasts in the mid-sixth millennium BC (Zapata, Peña-Chocarro, Pérez-Jordá, & Stika, 2004). These areas were previously occupied by Mesolithic communities. However, little evidence of funerary practices has been recovered prior to the fifth millennium BC. The middle Neolithic (end of fifth millennium cal BC) is characterised in Catalonia by the appearance and development of the 'pit burial culture'. This includes individual, occasionally double, burials in pits or stone boxes. Similar depositions have been documented in other parts of Europe, notably in Swizerland ("Cortaillod"), and France ("Chasséen"). It has been argued that this funerary custom may have spread through the trade networks existing at the time serving the exchange of honey flint from the Alps, variscite from the Gavà mine (Barcelona), obsidian from Sardinia and ceramics and other goods to the Mediterranean shores. Morell Rovira et al. (2018) suggest that the burials in France and Switzerland appeared before those in Catalonia. According to these authors, this cultural stage lasted in Catalonia until the start of the fourth millennium (Morell Rovira et al., 2018) and has been traditionally considered the phase before the collective inhumations in megalithic monuments (Balaguer, García, Tenza, &

Antequera, 2013; Tarrús, 2002). Apparently, this stage ended when the trade networks collapsed (Morell Rovira et al., 2018).

Interestingly for our purpose, although most of the necropoles tend to be rather small (4–5 graves), large numbers of remains (>650 bodies) have been recovered from a number of sites in the Catalonian coast, for the orientation of which we have qualitative information (Morell Rovira et al., 2018). The largest of these sites is Bòbila-Madurell (Plasencia Figueroa, 2016). This is the largest necropolis of this period in Catalonia to date. In several areas the excavators have recovered the remains of more than 150 individuals, always buried in a flexed lateral position. The remains have been dated from 4100 to 3660 cal BC, and therefore immediately predate the appearance of the megalithic chambers.

The communities in the Pyrenees valleys, according to their material culture, seem to be of the same cultural phase. The burials in this area consist of stone boxes, instead of pits, formed by slabs defining a rectangular space often buried under a tenuous tumulus (see e.g. Morell Rovira et al., 2018; Remolins et al., 2018). These stone boxes started to be built slightly after the start of the pits culture, but lasted for almost the same period, and they contained similar types and kinds of deposited artefacts, suggesting that this period formed the first phase of occupation in these areas by a Neolithic culture.

The bodies normally lay on their left side; the head is always placed towards the NE with their feet towards the SW (Plasencia Figueroa, 2016). However, in the few reports found for the stone boxes we can deduce that the situation was much more varied, with orientations towards the N-S or SE-NW (Remolins et al., 2018). We do not have direct and precise measurements based on Archaeoastronomical survey standards, but these general indications may suffice for our current purposes.

Closer to the Hechicera area (c. 35 km to the east), we find the Los Cascajos funerary area (indicated with a white star in Fig. 6). This is located near the Los Arcos community in Navarra. It is one of the first places where the Neolithic is clearly identified in this area (phase I, 4435–3700 cal BC) lasting possibly until the mid-fourth millennium BC (García Gazólaz et al., 2011).

The archaeologists recovered traces of a settlement plus a number of burials in nearly circular pits. Possibly an expansion of the pit burial culture to the Ebro valley, it presents 32 individuals, together with several grave goods and material remains (e.g. sickle flint, decorated ceramics, a small bottle and a necklace; García Gazólaz & Sesma-Sesma 2007). The recovered bodies appeared mostly flexed over their left side with the head towards the SE or SW (García Gazólaz & Sesma-Sesma 2007; García Gazólaz et al., 2011; see also Rojo Guerra et al., 2016). Interestingly, the general orientation (broadly N-S) is the same as in the coast, but here the head is placed opposite to the Catalonian pits.

We could therefore argue that together with the material custom, the burial practice included not only the pits and grave goods, but also the general way the bodies were laid down and this also pertained on how they were oriented. Such orientation, curiously enough is qualitatively the same in the orientations of the megalithic chambers of the posterior phase, and the bodies found inside, are also deposited with the head towards the inner parts of the chamber and the feet towards the entrance, acquiring therefore a general N-S orientation.

7 Discussion

The peculiar orientation of Hechicera and other members of its group does not seem to be easily explained by an orientation to avoid the prevailing winds. Neither a general orientation towards the further part of the horizon, with the Sierra on its back, seems to account for the pattern explained above. Also the local topology does not seem to be so systematically oriented towards the two narrow directions indicated above. In the following section, we discuss then their possible astronomical orientation.

The direct orientation of the corridors does not seem to be related neither to the sun or the moon. We could investigate if the orientation was perhaps related to the Pointers (α and β Cen) and the Southern Cross, and the location, was perhaps related to summer solstice sunrise. This could explain the orientations of the entire dataset. In other words, are there any significant stellar-solar events for this period of time?

If the sun is the element related to the mountain, then it is possible that a summer time occurrence was important. In this case the stars of the Southern Cross and the Pointers would be seen rising in the direction of the corridor after sunset (acronychal rising) around the time of the Spring Equinox. However, when the sun has declination +14° (i.e., starts to be seen rising from the Mountain from any of the megalithic sites in Hechicera group), the stars are already in their southern culmination at sunset (i.e. their rising would not be visible anymore at this time of the year). In addition, by the summer solstice, we would see the last visibility of the stars (i.e. they would be seen setting, not rising) a few minutes after sunset.

The answer to the question posed above is then, apparently not. Neither the heliacal rising nor the acronychal rising of these stars occur at moments when both (stellar and solar) orientations could be coordinated. Indeed, this result seems to weaken the possibility of a synchronic effect that may give us a hint for a particular time, but does not rule out the possibility of a stellar orientation having been adopted for the corridor, while the topographical alignment towards the conspicuous mountain could explain the actual location of the sites.

If we take the moon as the element to be linked to the mountain, the situation is somewhat reversed. The first visibility of the stars in relation to the general orientation of the corridor would coincide with the autumn equinox, while for the winter months, when we could see the full moon rising close or on top of the mountain, the stars would rise above the horizon by midnight. This line of reasoning then could perhaps favour a lunar-stellar alignment.

From the comparison with the contemporary monuments in central and NE Iberia, we could then argue that the orientation of Hechicera and the other monuments in the Ebro basin seem to share a number of interesting characteristics, notably the interest and importance of the south or SE horizon, in contrast to other orientations (like due east and Winter Solstice) more prominent in the regions found to the north and west of the Hechicera group.

In González-García and Belmonte (2010) and Belmonte and González-García (2012) we proposed and argued that there were different orientation families within Iberia. These seemed to suggest that the orientation customs appeared in certain areas that were later adopted by neighbouring ones. The above result indicates that the S-SE family observed in Hechicera, the Ebro valley and the Catalonian Coast do form such a family.

It is interesting that the megalithic monuments in the Catalonian NE have provided some of the earliest dates in north Iberia. In addition, we have observed how the general trend of human remain deposition with a broad N-S orientation appeared in the Iberian Peninsula for the first time in this Catalonian NE, and moved subsequently towards the Pyrenees valleys and the Ebro basin, reaching as far as Los Cascajos, 35 km east of the Hechicera group.

We could therefore investigate if the orientation we found in Hechicera is a relic of the previous epoch when the general N-S orientation of the bodies was introduced from central Europe. Indeed, further studies, perhaps focused on a detailed analysis of the orientation of the bodies or the pits of this period is needed. If the interpretation suggested here was indeed the case, it is intriguing that such an orientation was maintained in the area of the Ebro valley for such long period of time. It would be interesting to further investigate if this orientation custom was maintained in later periods and in newly discovered sites. One such study could be carried out at Tres Montes (Andrés Rupérez, García, & Sesma, 2001), where a burial area with the remains of nearly 100 bodies has been dated to the Bronze Age.

Finally, it should be noted that this general orientation was maintained in the central Mediterranean for a long time. We have argued elsewhere that this is a characteristic of megalithic monuments in the central Mediterranean (González-García & Belmonte, 2014; González-García, Zedda, & Belmonte, 2014).

8 Conclusion

La Chabola de la Hechicera is a passage grave in northern Spain where an in depth study of the landscape helps shedding new light towards its understanding. The study demonstrates a connection with the monument in a way that was first proposed by Clive Ruggles in his study of the standing stones of the Island of Mull (Ruggles & Martlew, 1992; Ruggles, 1999: 112–124).

Hechicera and the monuments in its vicinity share coherent orientation patterns, which are not connected to sunrise or sunset. Their orientation could be related to the Southern Cross and the Pointers. However, it is intriguing that from these locations the remarkable peak of Lapoblación is prominently visible towards NE. We could argue that the orientation of the corridor was dictated by the orientation of the bodies deposited in the interior of the structure, but the location fulfilled a number of criteria. One could be being close to trade routes, or at a mid distance from the river and the mountains. At the same time, they had to be at points where the conspicuous peak of Lapoblación was seen in such a way that it possibly marked important times within the community. In this sense, we could perhaps borrow Clive's terminology for the Mull study and propose that this area, with the visibility towards this mountain was, or formed, a sacred landscape for that community.

Interestingly, it has been argued that this is a transitional area between herders, moving their flocks towards the nearby mountains, and between agricultural communities that tended to occupy the lowlands closer to the river Ebro. The times indicated by sunrise on the peak, from the end of April to mid-August are the busiest times in the year for both groups, as they delimit the seasons of harvest for most crops, particularly wheat and barley. But this time could also mark the season of moving to the summer grounds for pastoral communities. Therefore, the sighting of sunrise behind Lapoblación Mountain could have served as a relevant time marker for such communities. We do not find any relevant time in the heliacal or the acronychal risings the Southern Cross that can be linked with these activities. Another possibility is a lunar-stellar association. This would point towards the importance of 'winter' months. Finally, we could consider that the southern orientation, and thus its possible association with the Southern Cross, had a ritual function connected only with the visibility of such stars rising on the horizon.

The folklore connects Chabola de la Hechicera with summer solstice. Interestingly, the sun rises and sets at particularly interesting spots of the horizon at this time of the year as seen from the megalith. In view of this, the association of the passage grave with sorceress and their meetings the night of Saint John, the shortest night of the year, a moment commonly associated in this land with fire and magic could be natural given the astronomical phenomena. However, any link of such folklore with the builders of these sites is clearly farfetched. The association is most probably occurring at historic times possibly then appearing as a second time in history when Hechicera was linked to astronomical events.

In conclusion, the peculiar orientation of this group could be the relic of previous orientation customs maintained through time. At the same time, the positioning of these monuments in the landscape help us understand the social time of the communities that built and used them several millennia ago.

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An Investigation of the Role of Architectural Orders in Greek Temple Orientation

Efrosyni Boutsikas

1 Introduction

The principles behind Greek temple orientations have troubled scholars for more than a century, in relation to broader archaeoastronomical investigations on the positioning of ancient religious sites across the globe. The idea behind such endeavours originates in the notion that astronomical knowledge and observations may have played a role in, or even determined, the placement of religious structures.

Between 2002–2010, Clive Ruggles and I explored the idea that astronomical principles governed the positioning of ancient Greek temples (e.g. Boutsikas, 2009; Boutsikas & Ruggles, 2011). During this time, I was most privileged to receive the supervision, training, support and unceasing enthusiasm for research of the person whose prolific career and inspirational work has led to his recognition as a leading authority in all things archaeoastronomical. Our endeavours resonated from the aim to understand the function of temples in relation to astronomy and the environment (land- and skyscape) within which they are situated. This research indicated that, although certain general patterns may be present, it is not possible to establish one general governing principle in relation to the rising and setting of the sun or the moon that may have been responsible for determining temple orientations in ancient Greece. The current paper revisits this question in order to account for one aspect not previously investigated: whether a temple's architectural order may have determined its orientation.

Orienting structures in relation to astronomical bodies and meteorological phenomena seems a familiar concept in ancient Greek thought. To our knowledge, these concepts appear with Anaximander (sixth century BCE), who first introduces the

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E. Boutsikas (✉)
Departement of Classical and Archaeological Studies, Cornwallis NW, University of Kent, Canterbury, UK
e-mail: e.boutsikas@kent.ac.uk

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notions of geometry in the city and the universe (Vernant, 1983: 180–181, 186), but it is likely that the origins of this idea date to an earlier period. This earlier period coincides also with the beginnings of monumental religious architecture in Greece. Monumental architecture, does not become widespread in the Greek space though until the seventh to sixth centuries BCE. By the time of Kleisthenes of Athens and his numerologically based political reforms at the end of the sixth century BCE though, ancient written sources suggest that cities reflect what happens in the heavens, so that the microcosm of the city participates in the macrocosm of the universe (Shipley, 2005; Vernant, 1983: 224). This idea becomes rather prominent in the Roman period, where we have explicit references to the importance of astronomy and cardinal orientations both in city planning and in the layout of religious structures (Vitruvius, *de Architectura,* 1.1.3, 1.6, 4.5.1, 4.9.1; González-García, Rodríguez-Antón, & Belmonte, 2014; Peterson, 2007).

The Doric[1] was the first of the three Greek architectural orders to emerge around 650–600 BCE, shortly followed by the Ionic,[2] which appeared in eastern Greece (the Aegean islands and Asia Minor). The earliest archaeological date for the Corinthian order is the fifth century BCE, when it is first attested in the singular interior column of the temple of Apollo at Bassae (Jenkins, 2006: 14–20). The choice of one architectural order over another is not necessarily related to the date of a structure. In a number of cases, it seems to have been linked to tradition and preference. Certain geographical areas display distinct partiality between the two older orders. We observe for example, that Doric is preferred in the Saronic islands, the Peloponnese, Southern Italy and Sicily. Some locations display use of both Ionic and Doric, such as Delos, Kos and Samothrace, whereas in Asia Minor and some Aegean islands such as Naxos, the Ionic is more widespread. The distinction in the use of the two orders becomes more prominent in the Greek colonies, but this relates to influences from the mother cities and to local traditions. The Greek Sicilian and South Italian colonies make extensive use of the Doric, whereas the Ionic order is indisputably favoured in the Greek sanctuaries of Asia Minor. In some cases, we observe that the oldest cults are housed in Doric temples, as seen for example in Delphi, Delos and Olympia. In a number of these sanctuaries, the Ionic order is also present concurrently with the Doric, as attested for example, in the Athenian Acropolis and the Acropolis of Pergamon. In these cases, the choice of architectural order does not seem to be determined by the date of construction, but rather by regional preferences. For instance, the Archaic *Oikos* of the Naxians in Delos is

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[1] The Doric order is characterised by the absence of decorative elements in the treatment of the columns, the absence of a column base and the overall stocky and thicker appearance of the building. The frieze of the Doric order is divided to *triglyphs* and *metopes*. Examples of this order are the temple of Apollo in Delphi, the temple of Hephaistos in the Athenian Agora and the exterior of the temple of Zeus in Nemea.

[2] The Ionic order has more slender columns (compared to the Doric), supported by a base and distinctive volute shaped capitals. It also differs in the treatment of the frieze, which forms a continuous band adorned with sculptural decoration. Examples of Ionic order are the Erechtheion and the temple of Nike on the Athenian Acropolis.

Ionic, whereas the Classical temple of the Athenians and the *Poros* temple of Apollo built only a few meters away, in the same sacred space, were Doric.

From the fifth century BCE, we witness the marrying together of more than one orders within the same structure. This is more commonly manifested in the combination of Doric and Ionic elements, with the earliest examples encountered in some of the Classical temples on the Athenian Acropolis. Less than four decades later emerges the earliest extant combination of all three orders in one structure, in the Temple of Apollo at Bassae, reputedly constructed by the Parthenon's architect: Doric exterior, Ionic interior and a sole Corinthian column prominently placed in the temple's *sekos*. Within less than a century, the combination of the Doric and the Ionic is explored fully, as seen in *Andron* B at the Sanctuary of Zeus at Labraunda (in Asia Minor), which unorthodoxly combined the two orders in the building's façade: Doric frieze carried by Ionic columns (Karlsson, 2013). The plasticity and playfulness of Hellenistic art finds it hard to maintain the austerity and heaviness of the Doric order. This results in the gradual abandonment of the Doric, eventually replaced by the Ionic and Corinthian orders, although use of the latter does not spread widely in Greece before the Roman period.

It is clear, that the choice of architectural orders was determined by a number of factors, relating to aesthetics, fashion, function and visitor experience. Such striking examples, are the temples of Apollo in Bassae and Didyma. The former, copies to a large extent its Archaic predecessor, maintaining the austere Doric exterior, but as mentioned, employs all three architectural orders along with a number of other unique architectural features, in order to enhance visitor experience (Boutsikas, 2020). The latter, plays with perception: it is an Ionic unroofed shell of colossal proportions, visible from a great distance and particularly imposing once approached. The actual entrance to this structure though, of much more modest size, was in the shape of two extremely narrow passages leading to an interior grove, which encompassed a small-scale Ionic temple. This small prostyle structure was the actual temple of Apollo and the seat of his oracle. Since it is possible that the orientation of a temple was influenced by the intention to enhance visitor experience by its architecture, it may be possible to trace a preference towards specific orientations employed by each architectural order. An indication that his may have been the case could be the Greek Sicilian temples, all of which are Doric and oriented towards the east. In the following sections, we will test the idea of architectural orders favouring specific orientations by examining a sample of 131 Greek temple orientations.

2 Survey Methods

The data included here comprise structural orientation measurements taken using a magnetic compass and clinometer, which offer a level of accuracy considered sufficient for the purpose of this study. Accuracy higher than one degree of arc would exceed what the ancient Greeks were able to achieve. It was not until after the time of Hipparchos (190–120 BCE) that improved *dioptra* were made. For his astronomical observations (and the composition of the first comprehensive star catalogue) Hipparchos may have used an armillary sphere (Lloyd, 1984: 344–345), which, similarly, would not be more precise than the error of the magnetic compass.[3] This margin of error becomes more evident if we consider the discrepancies found between ancient star measurements. For example, Plutarch's claim of his star coordinates deriving from measurements he made using an armillary sphere has been challenged by a number of modern studies as untrue (Duke, 2002: 36; Graßhoff, 1990; Rawlins, 1982: 359–373). Similarly, it has been noted that the discrepancies in the measurements of the position of stars between Hipparchos' *Commentary to Aratus* and Ptolemy's *Almagest* are too large and statistically correlated (systematic) to be accidental. Instead, it has been argued that perhaps Hipparchos created a catalogue of star positions by taking measurements in equatorial coordinates and that these were subsequently converted to ecliptical coordinates using analog computation (Duke, 2002). A discussion on the importance of precision in ancient Greek astronomical calculations is superfluous here, but it is important to note that pursuing a higher degree of precision than the ancient Greeks would have been capable of, is unnecessary and could introduce a meaningless and false sense of extreme accuracy.

For all but one of the sites included in this study, no magnetic anomalies and no systematic instrument error were detected. The only exception is the temple of Isis at Dion (Greece), where a metal bridge has been constructed to give access to the site, as a result of the rising water table. Since a magnetic compass is almost useless in this environment, the orientation of this temple was deduced based on Google Earth, using the compass readings only as a general guideline.[4]

Magnetic readings were corrected to true azimuths by applying the relevant magnetic correction computed for the date and place of each survey.[5] The readings were taken along the surviving walls of the structures and as close to the foundations as possible. In order to minimise erroneous orientation measurements, multiple readings were taken for each structure (e.g., on either side of a wall and along more than one wall). As a means of verifying the accuracy of each measurement, a minimum of three readings (where there was agreement between readings) and maximum of five (until there was agreement between more than two readings) were recorded for each structure.

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[3] See for example the slightly later, first century BCE Taichu calendar in China, which seems to have been created using an armillary sphere, but its measurements are one degree off from complete accuracy (Xiaochun & Kistemaker, 1997: 64). For a discussion on difficulties in obtaining accurate measurements of stars using an armillary sphere consult Duke, 2002: 37–38.

[4] In those cases where metal poles are used to rope off the temples (as for example at the Erechtheion and the Parthenon in Athens), the survey permits granted entry to the structures, thus allowing sufficient distance between these objects and the points from where the orientation measurements were taken. The multiple readings taken from several points in these structures, and their cross referencing with Google Earth, confirmed the accuracy of the measurements.

[5] Magnetic corrections were calculated using the online Magnetic Field Calculator of the National Centres for Environmental Information (https://www.ngdc.noaa.gov).

Temple orientations were subsequently converted to (astronomical) declinations (the angular distance between a celestial object and the celestial equator, an exact point in the celestial sphere (or horizon)), in order to allow for direct comparison with the rising and setting points of stars.[6]

3 Analysis

The data presented here comprise 131 orientations of Doric and Ionic temples, belonging to some 121 temples. The discrepancy between the number of surveyed structures and the actual orientations is due to the side entrances featured in a number of temples. In some cases as many as three entrances are present in one structure (e.g. Telesterion in Eleusis). Table 1 lists the temples included in the dataset, indicating also the side entrance measurements where appropriate. The collected orientations were divided to two groups: Doric and Ionic. A number of temples employing more than one order are included in the data set. These are located in mainland Greece. For instance, the Parthenon combines two orders: Doric exterior with Ionic interior. Three temples located in extra-urban sanctuaries in the Peloponnese employ all three architectural orders: the temple of Apollo at Bassae; the temple of Zeus in Nemea (Doric exterior with a Corinthian interior topped by a second story in Ionic order); and the temple of Athena Alea in Tegea (Doric exterior with a Corinthian interior topped by an upper Ionic story). The Bassae and Tegea temples are situated in Arkadia and both have a main and a side entrance. The temple at Bassae has a northern main orientation with an eastern side entrance and that in Tegea an eastern main orientation with a north side entrance. It is possible that these features were the result of local tradition and preference, paired with a very talented architect (Jost, 1985: 94–95). Similarly, the Classical temple of Zeus at Nemea employs all three architectural orders, but has the same orientation as its Doric Archaic predecessor, indicating once more that this architectural pluralism was the result of fashion, preference and intention to impact on spatial perception. It is noteworthy though, that all temples combining multiple architectural orders have a Doric exterior. For these reasons, these three temples and the Parthenon have been included in the Doric temple sample, as the order employed in a temple's exterior is considered the dominant order. The Doric sample is almost three times as large as the Ionic.

Figures 1 and 2 show that the data are divided in three data clusters: an east/west in the centre, a southern (from ca. –35° to −55°) and a northern (from ca. +34° to +65°). These match the clusters detected in a larger sample of 237 temple orientations, which combines all architectural orders and religious structures with forms

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[6] Declinations have been calculated using the software GETDEC created by Clive Ruggles. GETDEC is purpose-designed for use by archaeoastronomers in that it adjusts its astronomical computations to account for empirical experience with refraction and other kinds of real-world atmospheric conditions to which naked-eye observations of sunrise and sunset phenomena are actually subject.

Table 1 Raw data set (western orientations highlighted in grey)

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
1.	Aegina	Sanctuary of Aphaia	Temple of Aphaia	Archaic	Aphaia	Doric	37° 45′ 19″	23° 32′ 2″	+18° 39′
2.	Agrigento	Valley of temples	Temple of Hera (D)	Classical	Hera	Doric	37° 17′ 19″	13° 36′ 01″	+05° 57′
3.	Agrigento	Valley of temples	Temple of Concordia (F)	Classical	Concordia	Doric	37° 17′ 23″	13° 35′ 32″	+01° 30′
4.	Agrigento	Valley of temples	Temple of Herakles (A)	Archaic	Herakles	Doric	37° 17′ 25″	13° 35′ 11″	+01° 30′
5.	Agrigento	Valley of temples	Temple of Olympian Zeus (B)	Classical	Zeus	Doric	37° 17′ 27″	13° 35′ 4″	+11° 41′
6.	Agrigento	Sanctuary of Chthonic deities	Temple of Dioskouroi (I)	Classical	Dioskouroi	Doric	37° 17′ 29″	13° 34′ 53″	+07° 52′
7.	Agrigento	Sanctuary of Chthonic deities	Temple L	Classical	Demeter?	Doric	37° 17′ 57″	13° 36′ 12″	+11° 22′
8.	Argos	Heraion	Old Temple	Geometric	Hera	Doric	37° 42′ 00″	22° 46′ 56″	−19° 12′
9.	Argos	Heraion	New Temple	Classical	Hera	Doric	37° 41′ 58″	22° 46′ 52″	−19° 56′
10.	Athens	Acropolis	Archaios Naos	Archaic	Athena	Doric	37° 58′ 18″	23° 43′ 33″	+10° 13′
11.	Athens	Acropolis	Parthenon	Classical	Athena	Doric/Ionic	37° 58′ 21″	23° 43′ 40″	+11° 13′
12.	Athens	Acropolis	Temple Athena Polias	Classical	Athena	Ionic	37° 58′ 23″	23° 43′ 38″	+5° 48′
13.	Athens	Acropolis	Erechtheion	Classical	Erechtheus	Ionic	37°58′24″	23°43′37″	+54° 15′
14.	Athens	Agora	Temple Apollo Patroos	Classical	Apollo	Ionic	37° 58′ 36″	23° 43′ 22″	−5° 19′
15.	Athens	Agora	Temple Zeus & Athena Phratria	Classical	Zeus & Athena	Doric	37° 58′ 36″	23° 43′ 22″	−4° 33′
16.	Athens	Agora	Hephaisteion	Classical	Hephaistos	Doric	37° 58′ 36″	23° 43′ 20″	−8° 6′
17.	Athens	South slope	Old temple of Dionysos	Archaic	Dionysos	Doric	37° 58′ 16″	23° 43′ 42″	+13° 25′

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
18.	Athens	South slope	New temple of Dionysos	Classical	Dionysos	Doric	37° 58′ 15″	23° 43′ 42″	+14° 28′
19.	Athens	Agora	Metroon	Hellenistic	Mother of Gods	Doric	37° 58′ 34″	23° 43′ 22″	−6° 43′
20.	Bassae	Sanctuary of Apollo	Temple of Apollo Epikourios	Classical	Apollo	Doric/Ionic/Corinthian	37° 25′ 47″	21° 54′ 01″	+66° 20′
21.	Bassae	Sanctuary of Apollo	Temple of Apollo (side entrance)	Classical	Apollo	Doric/Ionic/Corinthian	37° 25′ 47″	21° 54′ 01″	−2° 37′
22.	Delos	Sanctuary of Apollo	Stoa (portico) of Antigonos	Hellenistic	Apollo	Doric/Ionic	37° 24′ 08″	25° 16′ 03″	−51° 30′
23.	Delos	Sanctuary of Apollo	Artemision	Hellenistic	Artemis	Ionic	37° 24′ 07″	25° 16′ 01″	−12° 37′
24.	Delos	Sanctuary of Apollo	Oikos of Naxians	Archaic	Apollo	Ionic	37°24′01″	25°16′00″	−8° 57′
25.	Delos	Sanctuary of Apollo	*Oikos* of Naxians (back entrance)	Archaic	Apollo	Ionic	37° 24′ 01″	25° 16′ 00″	+10° 00′
26.	Delos	Sanctuary of Apollo	*Oikos* of Naxians (side entrance)	Archaic	Apollo	Ionic	37° 24′ 01″	25° 16′ 00″	+52° 53′
27.	Delos	Sanctuary of Apollo	Poros temple of Apollo	Archaic	Apollo	Doric	37° 24′ 06″	25° 16′ 03″	−4° 12′
28.	Delos	Sanctuary of Apollo	Temple of Athenians of Apollo	Classical	Apollo	Doric	37° 24′ 06″	25° 16′ 03″	−5° 23′
29.	Delos	Sanctuary of Apollo	Great temple of Apollo	Classical	Apollo	Doric	37° 24′ 05″	25° 16′ 03″	−4° 59′
30.	Delos	Sanctuary of Mt. Kynthnos	Temple Zeus Hypsistos	Hellenistic	Zeus	Ionic	37° 23′ 45″	25° 16′ 28″	+12° 27′

(continued)

Table 1 (continued)

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
31.	Delos	Sanctuary of foreign gods	Heraion	Archaic	Hera	Doric	37° 23′ 53″	25° 16′ 18″	−45° 8′
32.	Delos	Sanctuary of foreign gods	Temple of Isis	Hellenistic	Isis	Doric	37° 23′ 54″	25° 16′ 07″	−1° 47′
33.	Delos	Sanctuary of foreign gods	Samothrakeion	Classical–Hellenistic	Kabeiroi (assoc. Dioskouroi)	Ionic	37° 23′ 55″	25° 16′ 12″	−0° 43′
34.	Delos	Sanctuary of foreign gods	Monument of Mithridates	Hellenistic	Mithridates	Ionic	37° 23″ 54″	25° 16′ 12″	−42° 06′
35.	Delos	Sanctuary of Apollo	Monument of the Bulls	Hellenistic	Apollo	Doric	37° 24′ 04″	25° 16′ 05″	−49° 45′
36.	Delos	Sanctuary of Apollo	Monument of the Bulls	Hellenistic	Apollo	Doric	37°24′ 04″	25° 16′ 05″	+01° 25′
37.	Delos	Sanctuary of Apollo	Monument of the Bulls	Hellenistic	Apollo	Doric	37°24′ 04″	25° 16′ 05″	+02° 09′
38.	Delos	Sanctuary of Apollo	Dodekatheon	Hellenistic	12 Olympians	Doric	37° 24′ 08″	25° 15′ 57″	−3° 42′
39.	Delphi	Sanctuary of Athena Pronaia	New temple of Athena Pronaia	Classical	Athena	Doric	38° 28′ 52″	22° 30′ 30″	−46° 59′
40.	Delphi	Sanctuary of Athena Pronaia	Old Temple of Athena Pronaia	Archaic	Athena	Doric	38° 28′ 52″	22° 30′ 33″	−45° 7′
41.	Delphi	Sanctuary of Apollo	Temple of Apollo	Archaic	Apollo	Doric	38° 28′ 56″	22° 30′ 03″	+47° 38′
42.	Delphi	Sanctuary of Apollo	Temple of Apollo	Classical	Apollo	Doric	38° 28′ 56″	22° 30′ 03″	+47° 38′
43.	Didyma	Oracle of Apollo	Temple of Apollo	Archaic	Apollo	Ionic	37° 23′ 05″	27° 15′ 22″	+32° 56′
44.	Didyma	Oracle of Apollo	Temple of Apollo	Hellenistic	Apollo	Ionic	37° 23′ 06′	27° 15′ 24″	+32° 27′
45.	Dion	Sanctuary of Isis	Temple of Isis	Roman	Isis	Ionic	40° 10′ 38″	22° 29′ 45″	+16° 6′

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
46.	Dodona	Oracle of Zeus	Temple of Themis (Z)	Hellenistic	Themis	Ionic	39° 32′ 53″	20° 47′ 25″	−23° 51′
47.	Dodona	Oracle of Zeus	Temple of Herakles	Hellenistic	Herakles	Doric	39° 32′ 54″	20° 47′ 27″	−42° 35′
48.	Eleusis	Sanctuary Demeter & Kore	Telestirion-Peisistratid	Archaic	Demeter & Kore	Doric	38° 2′ 31″	23° 32′ 21″	−18° 06′
49.	Eleusis	Sanctuary Demeter & Kore	Telestirion-Periklean	Classical	Demeter & Kore	Doric	38° 2′ 31″	23° 32′ 21″	−17° 38′
50.	Eleusis	Sanctuary Demeter & Kore	Telesterion (side entrance)	Classical	Demeter & Kore	Doric	38° 2′ 31″	23° 32′ 21″	+49° 19′
51.	Eleusis	Sanctuary Demeter & Kore	Telesterion (side entrance)	Classical	Demeter & Kore	Doric	38° 2′ 31″	23° 32′ 21″	−44° 28′
52.	Eleusis	Sanctuary Demeter & Kore	Ploutoneion	Archaic	Hades	Doric	38° 2′ 33″	23° 32′ 21″	−9° 18′
53.	Ephesos	Sanctuary of Artemis	Temple of Artemis	Archaic	Artemis	Ionic	37° 56′ 59″	27° 21′ 50″	+12° 10′
54.	Ephesos	Sanctuary of Artemis	Temple of Artemis	Hellenistic	Artemis	Ionic	37° 56′ 59″	27° 21′ 50″	+12° 10′
55.	Himera	Sanctuary of Athena	Temple of Victory	Classical	Victory	Doric	37° 58′ 26″	13° 49′ 26″	+15° 38′
56.	Isthmia	Sanctuary of Poseidon	Old temple of Poseidon	Archaic	Poseidon	Doric	37° 55′ 0″	22° 59′ 61″	−6° 35′
57.	Isthmia	Sanctuary of Poseidon	New temple of Poseidon	Classical	Poseidon	Doric	37° 55′ 0″	22° 59′ 61″	−5° 49′
58.	Kalydon	Ancient Kalydon	Temple of Apollo	Archaic	Apollo	Doric	38° 22′ 22″	21° 31′ 50″	−29° 4′
59.	Kalydon	Ancient Kalydon	Heroon of Leon of Kalydon	Hellenistic	Leon (hero)	Doric	38° 22′ 25″	21° 32′ 02″	−51° 36′

(continued)

Table 1 (continued)

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
60.	Kalydon	Ancient Kalydon	Temple of Artemis	Classical	Artemis	Doric	38° 22 ′23″	21° 31′ 50″	−22° 34′
61.	Klaros	Oracle of Apollo	Temple of Apollo	Hellenistic	Apollo	Doric	38° 00′ 18″	27° 11′ 35″	−04° 27′
62.	Korinth	Agora	Temple of Apollo	Archaic	Apollo	Doric	37° 54′ 44″	22° 52′ 82″	+12° 25′
63.	Kos	Asklepieion	Large Doric temple of Asklepios	Hellenistic	Asklepios	Doric	36° 52′ 35″	27° 15′ 26″	+46° 47′
64.	Kos	Asklepieion	Prostyle Ionic temple of Asklepios	Hellenistic	Asklepios	Ionic	36° 52′ 36″	27° 15′ 27″	−18° 13′
65.	Kos	Agora-Limenas	Temple of Pandemos Potnia Aphrodite	Hellenistic	Aphrodite	Ionic	36° 53′ 41″	27° 17′ 28″	+50° 45′
66.	Lebadeia	Sanctuary of Zeus Basileus	Temple of Zeus Basileus	Hellenistic	Zeus	Doric	38° 25′ 54″	22° 51′ 52″	+19° 42′
67.	Lemnos	Kabeirion	Hellenistic Telesterion	Hellenistic	Kabeiroi	Ionic	39° 58′ 45″	25° 20′ 30″	−36° 24′
68.	Lykosoura	Sanctuary of Despoina	Temple of Despoina	Hellenistic	Despoina	Doric	37° 23′ 23″	22° 01′ 52″	−0° 21′
69.	Lykosoura	Sanctuary of Despoina	Temple of Despoina (side entrance)	Hellenistic	Despoina	Doric	37° 23′ 23″	22° 01′ 52″	−21° 37′
70.	Magnesia	Sanctuary of Zeus	Temple of Zeus Sosipolis	Hellenistic	Zeus	Ionic	37° 51′ 10″	27° 31′ 36″	+01° 56′
71.	Magnesia	Temple of Artemis	Temple of Artemis Leukophryne	Hellenistic	Artemis	Ionic	37° 51′ 12″	27° 31′ 38″	−11° 56′
72.	Messene	Sanctuary Asklepeios	Temple Asklepios	Hellenistic	Asklepeios	Doric	37° 10′ 32″	21° 55′ 13″	−12° 16′
73.	Messene	Sanctuary Asklepeios	Temple Artemis Orthia	Classical	Artemis	Doric	37° 10′ 33″	21° 55′ 12″	−22° 00′
74.	Messene	Sanctuary Asklepeios	Temple Artemis Orthia Phosphoros	Hellenistic	Artemis	Ionic	37° 10′ 32″	21° 55′ 12″	−12° 16′

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
75.	Miletos	Agora	Delphinion	Classical on Archaic foundations	Apollo	Doric	37° 31′ 48″	27° 16′ 51″	−16° 25′
76.	Miletos	Agora	Serapeion	Roman	Serapis	Ionic	37° 31′ 41″	27° 16′ 40″	−42° 19′
77.	Miletos	Agora	Temple of Athena (early)	Archaic	Athena	Ionic	37° 31′ 41″	27° 16′ 18″	−11° 10′
78.	Naxos	Sagri	Temple of Demeter	Archaic	Demeter	Ionic	37° 01′ 49″	25° 25′ 54″	−42° 23′
79.	Naxos	City	Temple of Apollo Portara	Archaic	Apollo	Ionic	37° 06′ 40″	25° 22′ 23″	−38° 14′
80.	Naxos	Sanctuary of Dionysos	Temple of Dionysos (early)	Archaic	Dionysos	Ionic	37° 04′ 43″	25° 22′ 53″	−43° 46′
81.	Naxos	Sanctuary of Dionysos	Temple of Dionysos	Archaic	Dionysos	Ionic	37° 04′ 43″	25° 22′ 53″	−44° 11′
82.	Nemea	Sanctuary of Zeus	Temple of Zeus	Classical	Zeus	Doric/Corinthian/Ionic	37° 48′ 63″	22° 42′ 66″	+16° 8′
83.	Nemea	Sanctuary of Zeus	Temple of Zeus	Archaic	Zeus	Doric	37° 48′ 63″	22° 42′ 66″	+16° 8′
84.	Olympia	Sanctuary of Zeus	Temple of Zeus	Classical	Zeus	Doric	37° 38′ 20″	21° 37′ 51″	+7° 28′
85.	Olympia	Sanctuary of Zeus	Heraion	Archaic	Hera	Doric	37° 38′ 24″	21° 37′ 51″	+3° 39′
86.	Olympia	Sanctuary of Zeus	Pelopeion	Classical	Pelops	Doric	37° 38′ 22″	21° 37′ 50″	−42° 8′
87.	Orchomenos	Upper city Agora	Temple of Artemis Mesopolitis	Hellenistic	Artemis	Doric	37° 43′ 46″	22° 18′ 94″	+27° 23′
88.	Perachora	Heraion	Temple of Hera Limenia	Geometric	Hera	Doric	38° 01′ 67″	22° 51′ 27″	+61° 33′
89.	Perachora	Heraion	Temple of Hera Akraia	Archaic	Hera	Doric	38° 01′ 75″	22° 51′ 18″	+03° 50′
90.	Pergamon	Acropolis	Temple of Athena	Hellenistic	Athena	Doric	39° 07′ 54″	27° 11′ 02″	−44° 19′

(continued)

Table 1 (continued)

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
91.	Pergamon	Acropolis	Temple of Dionysos	Hellenistic	Dionysos	Ionic	39° 07′ 56″	27° 10′ 57″	−46° 46′
92.	Poros	Sanctuary Poseidon	Temple of Poseidon	Archaic	Poseidon	Doric	37 °31′ 26″	23° 28′ 51″	+18° 17′
93.	Priene	Sanctuary of Zeus	Temple of Zeus	Hellenistic	Asklepeios or Zeus	Ionic	37° 39′ 31″	27° 17′ 53″	+1° 36′
94.	Priene	Sanctuary of Athena	Temple of Athena Polias	Classical	Athena	Ionic	37° 39′ 33″	27° 17′ 46″	+1° 43′
95.	Priene	Sanctuary of Demeter	Temple of Demeter	Classical–Hellenistic	Demeter	Doric	37° 39′ 39″	27° 17′ 46″	+4° 18′
96.	Rhodes	Kameiros	Temple of Pythian Apollo	Hellensitic	Apollo	Doric	36°20′ 17″	27° 55′ 17″	+53° 36′
97.	Rhodes	Kameiros	Temple of Athena Kameiras	Hellenistic	Athena	Doric	36° 20′ 10″	27° 55′ 17″	+09° 12′
98.	Rhodes	Ialyssos	Temple AthenaPolias	Hellenistic	Athena	Doric	36° 24′ 00″	28° 08′ 40″	−53° 57′
99.	Rhodes	Lindos, Acropolis	Temple of Lindia Athena	Archaic	Athena	Doric	36° 05′ 31″	28° 05′ 19″	+41° 21′
100.	Rhodes	Lindos, Acropolis	Temple of Lindia Athena	Hellenistic	Athena	Doric	36° 05′ 31″	28° 05′ 19″	+41° 21′
101.	Rhodes	Acropolis-Monte Smith	Temple of Pythian Apollo	Hellenistic	Apollo	Doric	36° 26′ 28″	28° 12′ 40″	−3° 58′
102.	Rhodes	Acropolis-Monte Smith	Temple of Athena Polias & Zeus Polieus	Hellenistic	Athena & Zeus	Doric	36° 26′ 42″	28° 12′ 43″	+10° 50′
103.	Samos	Heraion	Great temple of Hera	Archaic	Hera	Ionic	37° 40′ 22″	26° 53′ 10″	+8° 47′
104.	Samos	Heraion	Rhoecus temple	Archaic	Hera	Ionic	37° 40′ 22″	26° 53′ 10″	+8° 47′
105.	Samothrace	Sanctuary of Great Gods	Hall of Choral Dancers	Classical	Great Gods & Kabeiroi	Ionic	40° 30′ 03″	25° 31′ 49″	+31° 30′

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
106.	Samothrace	Sanctuary of Great Gods	*Hieron*	Hellenistic	Great Gods & Kabeiroi	Doric	40° 30′ 01″	25° 31′ 49″	+45° 28′
107.	Samothrace	Sanctuary of Great Gods	*Hieron*	Hellenistic	Great Gods & Kabeiroi	Doric	40° 30′ 01″	25° 31′ 49″	+23° 18′
108.	Samothrace	Sanctuary of Great Gods	Altar Court	Hellenistic	Great Gods & Kabeiroi	Doric	40° 30′ 03″	25° 31′ 49″	+23° 18′
109.	Segesta	Segesta	Doric temple	Classical	unknown	Doric	37° 56′ 29″	12° 49′ 56″	+7° 37′
110.	Selinous	Sanctuary of Demeter Malaphoros	*Megaron* of Demeter Malophoros	Archaic	Demeter	Doric	37° 35′ 13″	12° 49′ 03″	+21° 58′
111.	Selinous	Sanctuary of Demeter Malophoros	Temple of Zeus	Archaic	Zeus Melichios	Doric	37° 35′ 13″	12° 49′ 03″	+31° 37′
112.	Selinous	Sanctuary of Demeter Malophoros	*Megaron*	Archaic	Demeter	Doric	37° 35′ 13″	12° 49′ 03″	−03° 45′
113.	Selinous	Sanctuary of Demeter Malophoros	Hekataion	Archaic	Hekate	Doric	37° 35′ 13″	12° 49′ 03″	+33° 04′
114.	Selinous	Acropolis	Temple of Hera	Archaic	Hera	Doric	37° 35′ 12″	12° 50′ 05″	+02° 14′
115.	Selinous	Acropolis	Temple C	Archaic	Apollo?	Doric	37° 34′ 60″	12° 49′ 31″	−02° 58′
116.	Selinous	Acropolis	Temple D	Archaic	unknown	Doric	37° 34′ 60″	12° 49′ 31″	−03° 03′
117.	Selinous	Acropolis	Temple A	Classical	Leda & Artemis?	Doric	37° 34′ 60″	12° 49′ 31″	−05° 20′
118.	Selinous	East hill	Temple E	Classical	Hera	Doric	37° 35′ 06″	12° 50′ 09″	−04° 37′
119.	Selinous	East hill	Temple F	Archaic	unknown	Doric	37° 35′ 14″	12° 50′ 06″	−03° 26′

(continued)

Table 1 (continued)

	Location	Site	Structure	Date	Deity	Order	Latitude	Longitude	Dec.
120.	Selinous	East hill	Temple G	Archaic	unknown	Doric	37° 35′ 14″	12° 50′ 06″	−03° 26′
121.	Sikyon	Agora	Temple of Artemis Limnaia or Apollo	Archaic	Artemis or Apollo	Doric	37° 59′ 10″	22° 42′ 85″	−02° 49′
122.	Sikyon	Agora	Temple Artemis Limnaia or Apollo	Hellenistic	Artemis or Apollo	Doric	37° 59′ 10″	22° 42′ 85″	−02° 49′
123.	Sounio	Sanctuary Poseidon	Temple of Poseidon	Classical	Poseidon	Doric	37° 39′ 04″	24° 01′ 30″	−11° 37′
124.	Sounio	Sanctuary Poseidon	Great temple of Athena	Archaic	Athena	Doric	37° 39′ 14″	24° 01′ 40″	−6° 31′
125.	Sounio	Sanctuary Poseidon	Small temple of Athena	Classical	Athena	Doric	37° 39′ 15″	24° 00′ 41″	−10° 3′
126.	Sparta	Sanctuary of Artemis Orthia	Temple of Artemis Orthia	Archaic	Artemis	Doric	37° 05′ 03″	22° 26′ 15″	−5° 52′
127.	Sparta	Sanctuary of Artemis Orthia	Early temple of Artemis Orthia	Geometric	Artemis	Doric	37° 05′ 03″	22° 26′ 15″	−00° 44′
128.	Tegea	Temple of Athena Alea	Temple of Athena	Classical	Athena Alea	Doric/Corinthian/Ionic	37° 27′ 39″	22° 25′ 27″	+5° 29′
129.	Tegea	Temple of Athena Alea	Temple of Athena (side entrance)	Classical	Athena Alea	Doric/Corinthian/Ionic	37° 27′ 39″	22° 25′ 27″	+55° 11′
130.	Thermon	Ancient Thermon	Temple of Apollo Thermios	Archaic	Apollo	Doric	38° 33′ 39″	21° 40′ 08″	−45° 26′
131.	Tinos	Sanctuary Poseidon & Amphitrite	Temple of Poseidon	Hellenistic	Poseidon	Doric	37° 33′ 11″	25° 08′ 33″	+05° 05′

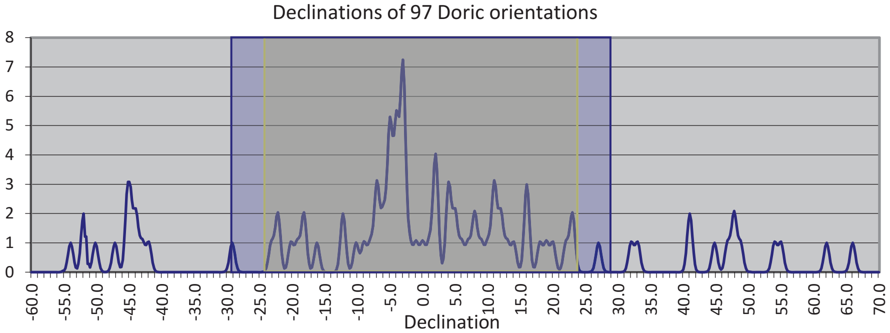

Fig. 1 Graph showing the distribution of 89 Doric temples with a total number of 97 orientations (including side entrances). Southern declinations fall between −60° and −40° (12 orientations); western and eastern declinations overlap in the centre (72 orientations); northern declinations fall between +40° and +70° (13 orientations). The area shaded in yellow in the centre of the graph represents the span of declinations across the horizon visited by the sun throughout the year. The area shaded in blue on either side marks the extreme positions of the moon between the minor and major standstills

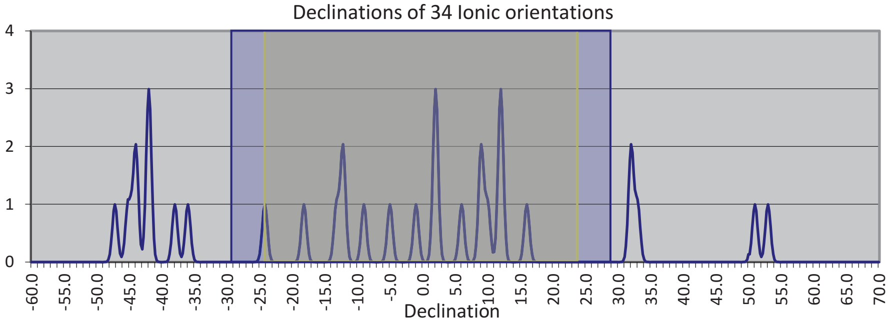

Fig. 2 Graph showing the distribution of 32 Ionic temples with a total number of 34 orientations (including side entrances). The southern cluster includes nine orientations, 19 structures are oriented in the centre of the graph (east and west) and six to the north

that do not conform to the conventional temple layout (such as altars and *tholoi*) (Boutsikas, 2020: 36–70). At first glance, no preference for certain orientations is detected for either the Doric or the Ionic orders.

On closer examination, the percentage of Ionic temples facing the sun's path during the year are fewer than the Doric. The study of 237 orientations of Greek religious structures which includes the same geographical areas as the present sample, has revealed that 55.7% of the structures are oriented in the part of the horizon visited by the sun in its annual path (Boutsikas, 2020). The present, more focused study, reveals a similar percentage: Ionic and Doric temples combined, facing this part of the horizon comprise 53.8% of the total sample of 131 orientations. When examining this trend separately for each architectural order, however, it is found that

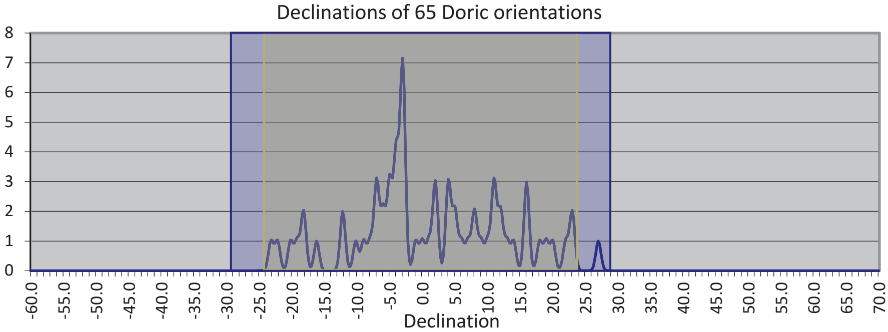

Fig. 3 Graph showing the distribution of only eastern Doric orientations

Doric temples are predominantly oriented towards the east (67%), whereas Ionic temples are less commonly oriented in this direction (40.6%).

The distribution of Doric and Ionic temples reveals a small difference in the orientations close to the sun's positions near the time of the equinoxes, whereas we observe a distinct peak and clustering of orientations between −2° and –7° in the Doric sample (Fig. 1). This data cluster is also present in the larger study of 237 orientations (Boutsikas, 2020: 36–70), but is absent in the group of Ionic orientations (Fig. 2). The orientations within this latter group are evenly distributed. If a trend is observed, this is a general clustering of the declinations falling within the solar range in general, with a few orientations at declinations +1° and +8° to +11°. The larger study of 237 orientation revealed these two peaks also. The data clusters observed in the current analysis could be interpreted as 'equinoctial', but (as is also the case in the larger study) data peaks are observed near the sun's position within a week from the equinoxes and not within ±2° of declination 0°, which is within a couple of days of the sun's position at the equinoxes. Similarly, the declinations of the sun's position on dates that approximate to the solstices show very little data concentration.

The concept of an equinoctial orientation assumes that the sun is observed from the structure, at sunrise, or sunset, since these are the moments when the sun's position will be due east and due west respectively. Since the orientations have been converted to declinations in the graphs presented here, the height of the local horizon is accounted for in the graphs, thus the peaks indicate the precise declinations when the sun would have been seen to rise or set from that location. As observed in Fig. 3, which includes only the eastern orientations of the Doric sample, the 'equinoctial cluster' comprises mostly of eastern orientations (21). Only four Doric readings are oriented to the west in the 'equinoctial cluster of Fig. 1, all from the island of Delos (the three temples of Apollo and the temple of Isis). A similar trend is also observed in the respective Ionic sample (Fig. 4).

One third of the Doric eastern orientations in the 'equinoctial cluster' (Fig. 3) belong to the temples in Selinunte (seven in total). Since Sicilian temples use exclusively Doric order and are oriented towards the east (Boutsikas, 2020), they are

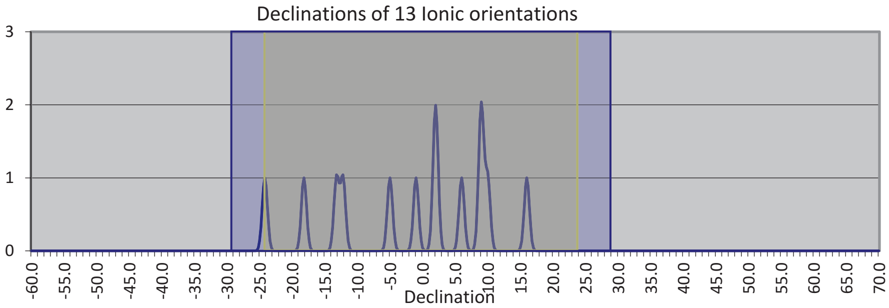

Fig. 4 Graph showing the distribution of only eastern Ionic orientations

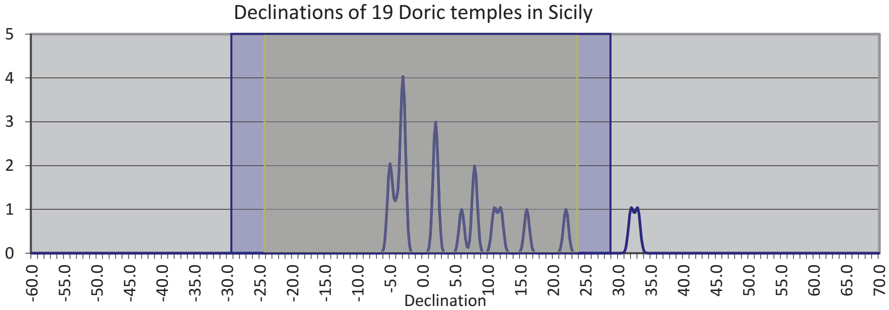

Fig. 5 Graph showing the distribution of Doric temple orientations from Sicily

good candidates for a survey of deliberate solsticial or equinoctial orientations. Of the 19 temples included in the Sicilian sample (Fig. 5), the declinations closest to the equinoxes belong to the temple of Hera in Selinunte (sixth century BCE) and the temples of Concordia and Herakles or Zeus in Agrigento (fifth century BCE). Belmonte (chapter 2 this volume) discusses an alternative idea for the orientation of the temples in Selinunte, one not linked to astronomical considerations. We cannot determine with certainty the reasons behind the orientation of these temples. However, we notice a general preference within a week from the equinoxes when isolating the Sicilian temple sample.

Of interest is also the southern cluster of data in the Ionic dataset. More orientations than those in the Doric order (relevant to the sample's size) fall between −35° to −47°: nine readings in total (Fig. 2) compared to 12 of the Doric sample, which is almost three times greater. This conclusion cannot be explained by the movement of the sun. It can also not be explained by regional, or chronological parameters, since it includes orientations from structures located in the Aegean islands (Delos, Lemnos, Naxos (four orientations from three different sanctuaries)) and Asia Minor (Miletos and Pergamon), which span from the Archaic to the Roman periods. Similarly, these structures are dedicated to different gods, even some of Egyptian origin, so a preference based on the deity venerated cannot be concluded. The cluster is quite tight, so it is possible that these orientations were determined by astronomical considerations, but since these cannot be solar or lunar, they may have been stellar and, quite possibly, not towards the same constellation or star. A further in-depth analysis of each of the specific cults and sanctuaries concerned might reveal more, but the length of such a study cannot be accommodated here.

4 Discussion

The analysis presented here reveals that if any general astronomical concerns were responsible for the placement of Greek Doric temples, the equinoxes seem to be the most likely candidate. Since the mid-90s when Clive Ruggles posed the question 'whose equinox' to conclude that archaeoastronomers should altogether do away with the term 'equinox' until models of 'conceptual structures' are developed for prehistoric cultures (Ruggles, 1997: 130), the concern of imposing cultural biases in ancient observational astronomy has been revisited a number of times (e.g. González-García & Belmonte, 2006; Ruggles, 2017: 134; and Belmonte and Steele chapters 2 and 3 respectively, this volume). These studies have offered compelling discussions on the meaning of the equinoxes when interpreting structural orientations and of potential cultural biases in such conclusions. As also noted elsewhere in this volume, the concept of the equinox is far from straightforward and could, in fact, mark three different occasions (see Steele chapter 3 this volume pp. 35–49) or as many as four (Ruggles, 1997: 127–128), since in a number of ancient cultures we do not know the precise occasion which would be defined as the equinox. This is not the case though for ancient Greece, where the equinox was identified as the time when the sun was located at the intersection of the ecliptic and the celestial equator (e.g. Steele chapter 3 this volume pp. 35–49).

In Greek culture, it was not only the change in the seasons and length of light and darkness that was of importance, but also the precise time in the year, when the day and night are of equal length. This moment in the year had eschatological significance in Greek cosmology, denoting an ideal state of balance and equality and the idea of a world composed of two opposite forms—light and day—which in ideal conditions are of equal length. Days and nights of equal length were believed to exist in the Valley of the Blessed in the underworld, but are also present in Pythagorean texts, which promote a notion of 'light and darkness having equal shares in the cosmos'.[7] Similarly, the belief in the importance of the equality of light and darkness is particularly prominent in Greek religious literature. Pindar, in particular, has been argued to have used the 'equinox as the form of the ideal cosmic equality' (Woodbury, 1966: 607), since it appears that the importance of equal day and night is a persistent idea in his Second Olympian Ode (Pindar, *Olympian,*

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[7] ἰσόμοιρά τ' εἶναι ἐν τῷ κόσμῳ φῶς καὶ σκότος, Diogenes Laertius 8.26; also in Aristotle, *Metaphysics* 1.986a22; Parmenides B9.3-4*VS;* Boutsikas, 2020: 163 n. 49).

2.61–3). There is much to discuss on the connotations associated with the importance of this balance in a number of contexts, which for example, can be also conveyed to political values of equality like democracy or ancient Greek admiration of the temperate climates found in the equatorial regions, praised by Herodotos and others (e.g. Herodotos 1.142.1–2; Hippokrates, *On Airs, Waters, and Places,* 12). Although these links can offer support to the importance of the concept, they would take us away from the scope of this paper, so it will suffice to state here that for the Greeks, the equinox signified more than just an observation of sunrise or sunset in the distant horizon. It more importantly stood as an ideal state of balance and equality.

Ancient Greek astronomers defined the equinoxes as the time when the day and night are of equal length; we know that a variety of methods were used to calculate the time of the equinoxes. The philosopher Anaximander for instance, is believed to have used the shadow cast by a gnomon, in the sixth century BCE (Couprie, 2011: 31, 34–35). The equinoxes were watched for in ancient Greece also for calendric purposes, as this time marked the beginning of the year in a number of Greek cities: in Chios and fourth-century-BCE Miletos for instance, the year started around the spring equinox, whereas in Sparta, Rhodes, Crete, and pre-fourth-century-BCE Miletos around the autumn equinox, etc.

We observed the clustering of Doric temple orientations around declinations visited by the sun within a week from the equinox, but not at the equinox. In cultures where the identification of astronomical occurrences relies on observation, an important parameter needs to be considered: accuracy. Let us briefly explore one such example. Pliny, in a section of his *Natural History*, reports the time of observing the setting of the Pleiades according to three different ancient Greek observers (Hesiod, Thales and Anaximander). Following Pliny's testimony, Couprie calculated that the autumn equinox occurred between 28 and 30 September in the years between 700–350 BCE. According to this calculation, at Hesiod's time, in the seventh century BCE, the equinox occurred on 30 September of the Julian calendar. This is a calculation assigned to Hesiod following Pliny's testimony, but Hesiod's original work, from which Pliny argues to have taken this quote, does not survive (*Naturalis Historia* 18.213, DK 12A20; on this see also Couprie, 2011: 17). In the sixth century BCE, the time of Thales and Anaximander, the event occurred on 29 September. Couprie, has furthermore estimated that by the fifth and fourth centuries BCE (the time of the other two significant Greek astronomers Euktemon and Eudoxos), this occurrence took place on 28 September (Couprie, 2011: 18). But the situation is not as simple as it may seem. Couprie made these calculations based on the mentions of these ancient works, which use the autumn equinox in order to count the number of days after the autumn equinox when the cosmical setting of the Pleiades became visible. So Couprie is working backwards: Anaximander places the setting of the Pleiades 'on the 29th day from the equinox' (White, 2002: 10) and Thales on the 25th day after the autumn equinox. Couprie knows exactly when the occurrence would take place in ancient Greece during the centuries that these observations were made, and so counts backwards to estimate the time of the equinoxes. This method, however, complicates matters, as the setting of the Pleiades was determined through direct observation in antiquity and cannot be compared to modern computed simulations. Unlike computed simulations, astronomical observations are subject to weather conditions and atmospheric extinction and refraction (and light pollution in modern times), not to mention the height of the local horizon, all of which can render an event invisible for several days. Indeed, discrepancies between Thales' observation of the Pleiades' setting and that of Anaximander are noted. It has been estimated that Thales was 10 days late when he saw the Pleiades set, whereas Anaximander had supposedly sharp eyesight and saw the star cluster set less than half an hour before sunrise (Wenskus, 1990: 53, 60). However, it seems unlikely that stars of the magnitude of the Pleiades could have been observed in the west half an hour before sunrise, no matter how sharp eyesight one possessed. Instead, it has been proposed, that the aim of the two ancient astronomers, was not to fix the precise moment in time when the Pleiades were observed to set cosmically, but instead, to estimate their true cosmical setting, since these astronomers wanted to calculate the precise occurrence of astronomical events, rather than note the time they were able to observe them. In doing so, they had to estimate when they thought the star cluster would set, by estimating the time needed to elapse between the last observed setting and the true setting. This estimated calculation could have caused their 10-day discrepancy (Couprie, 2011: 19).

For archaeoastronomers, a discrepancy of 10 days is regarded too great considering that the measurements of structural orientations are quoted to within a few minutes of arc, in order to argue for the significance of precise alignments. Here could lie another culturally determined approach. What we, in modern day, consider as significant (i.e. extremely precise orientations to provide very accurate alignments), may not have been as significant to the ancient cultures on which our conclusions are inflicted. A few days earlier or a few days later may have been perfectly acceptable to ancient cultures, which may on occasion have been more concerned with true rather than apparent occurrences. To continue on the same example, this idea may be present also in Pliny's account of Hesiod, whose date of the cosmical setting of the Pleiades, would, in fact, have witnessed the star cluster set almost 2 h after sunrise. On the other hand, Hesiod, was not an astronomer and it is not certain that he had observed for himself the dates he provided for the various risings and settings in his *Works and Days*. Neither do we know whether he had collected these dates from farmers and subsequently provided them as second hand information. Furthermore, as we saw in the discussion on the cosmological importance of the equinox in ancient Greek culture, once these astronomical observations enter the religious sphere, the symbolic, and cosmological significance they acquire, detaches them from their astronomical function. In the religious sphere, the emphasis is placed on the meaning of these occurrences in the specific ritual context and the cognitive associations sought for the participants, rather than their value in timekeeping for which accuracy is required.

We see then that in the case of ancient Greece, as many as three different types of equinoxes may have existed—practical, cosmological and astronomical. As far as Greek religion and astronomy are concerned, all three types seem to indicate that the equinox was perceived as the equality of day and night. With this background in mind, let us now return to the data presented here. Around 600 BCE the sun's declination on the day that daylight and night were equal was −0° 50′ (Gregorian 25 March) and occurred 2 days before the sun was at declination 0° (Gregorian 27 March). Similarly, around the time of the Autumn equinox, day and night were of equal duration on 1 October, when the sun's declination was at −0° 54′, again within a couple of days from the day when the sun's declination was at 0°. These declinations fall at the northern extreme of the −1° to −7° peak seen in the Doric orientation histogram. The absence of data on the sun's declination on or near the solstices remains intriguing considering the equally important calendric significance of this time of the year in ancient Greek culture. In Athens and Delphi, for example, the year started with the first new moon after the summer solstice, whereas in Boeotia and Delos it started after the winter solstice (Thomson, 1948: 53).

We could tentatively propose that if the 'equinoctial' peak of the Doric temples was indeed deliberate. In light of the absence of 'solstitial' orientations, the reason behind this preference could be sought in the cosmological connotations that the equinox had acquired in Greek religion. The cosmological balance seen in the equality of light and darkness may have been translated to a significant concept that was subsequently incorporated in Greek temple architecture. However, it is not possible to discern why this concept is predominant in Doric structures and in the general distribution of a larger data set which includes other religious structures, but not in Ionic temples. The possibility that the long and narrow Doric *sekos* called for temple orientations towards the rising sun in order to illuminate the dark interior, cannot explain these results. In this case we would expect an even distribution of temple orientations across the declinations visited by the sun in the year, in conjunction with the time in the year the temples were mostly visited. Such an association is not present. The temple of of Apollo in Delphi for instance, does not face the February rising sun, nor do the temples of Apollo in Delos, or Artemis Orthia in Sparta, to mention but a few examples.

It is certain, nevertheless, that the data cluster within the solar range has clear boundaries. The absence of data between the major and minor lunar standstills paired with absence of ancient references to these occurrences indicate that the lunar standstills were not associated with religious architecture and festivals in ancient Greece. The present analysis has demonstrated that two thirds of the Doric temples are oriented towards the east (67%). Such a high frequency of eastern orientations is intriguing, as it is not found either in a general distribution of a much larger sample, which includes all architectural orders and altars, nor is it comparable to the distribution of Ionic temples. This frequency cannot be explained as the result of overrepresentation caused by the Sicilian temples which are all noted to face towards the east, as of the 65 Doric declinations only 17 east facing Doric temples are located in Sicily. A distinct preference for eastern orientations has been revealed for Doric temples.

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The Stars in Ancient Greece

Robert Hannah

1 Introduction

I first met Clive Ruggles at a conference in Stockholm in 2001, but we had also recently collaborated, unaware of each other, on a book, *The Discovery of Time*. We have since met on a number of occasions, in some far-flung parts of the world: from his home base in Leicester, to another conference in Peru with an add-on trip to the towers at Chankillo, and from my home base at the time at the University of Waikato in Hamilton, New Zealand, where I invited him to give a talk about Hawai'ian astronomy, to Hawai'i itself, where we both happened to be for different reasons but where we found a good reason to meet and talk about indigenous astronomies again. These places happen to represent only a smidgeon of Clive's wide-ranging knowledge of astronomies around the world, a knowledge that I have had cause to call on in person and in his many published works over the years. It is a pleasure to be able to offer a paper to Clive in this collection.

2 The Cycle of the Stars

In this paper I wish to focus on one of the older mechanisms for marking time, the cycle of the stars, because it still raises questions about our understanding of the practices of ancient astronomy and the social contexts in which it was conducted.

One great advantage that the stars offer over other celestial bodies is that they rise and set always at the same points on the horizon for a given location. Where the Pleiades rise in June, is where they will rise every month of the year for several

R. Hannah (✉)
University of Waikato, Hamilton, New Zealand
e-mail: roberth@waikato.ac.nz

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decades. In this respect they differ markedly from the sun and the moon, whose size and brightness otherwise naturally attract us to them over and above the tiny stars, but their movements are very variable in space and time due to their proximity to the earth. The sun shifts up and down the horizon with the seasons. While the moon does this too, to further confuse us it rises and sets at considerably different times of the month, making tracking it more complicated. With the stars being much further away from the earth, on the other hand, all that changes in the course of the year, for all practical purposes, is the period of visibility for each star. We can see the Pleiades rise just before dawn in June, but at other times of the year they rise at other times of the night or day. At some point people also realized that those stars that rise and set are visible only in certain seasons but invisible in others. Therefore they could be used as seasonal or monthly markers. The question is, of course, to what ends?

3 The Peopling of the Sky

In the ancient world, the mechanisms for marking time via the cosmic cycles are usually found to be tied to religious beliefs and practices. We must mentally work our way into a religious context, however hard that is now at the theoretical level—what do we mean by 'religion'?—let alone at the practical level. Fortunately, one modern aspect of this investigation is in our favour. Our night sky is still populated by constellations, many of whose names reflect their origins in Classical (or pre-Classical) antiquity. The Pleiades, Pegasus and Perseus are just a few of the ancient Greek configurations which populate the modern celestial map. These names represent originally mythological figures, who were 'catasterized', or transformed into stars, by the Greeks and Romans—a gradual process reflected in a long literary tradition from the eighth century BCE onwards (Kidd, 1997; West, 1978), and perhaps of even earlier vintage, if one accepts that Aratus's constellations represent a fossilisation of much earlier, Bronze Age knowledge (Frank, 2014; see MacGillivray, 2004, 2009; Kyriakidis, 2005, Hannah and Moss 2003 for modern attempts to identify Bronze Age constellations). Of course, people from time immemorial appear to have created pictures by joining the dots that are the stars in the night sky, although the further back we go in time, the harder it is to be certain that the images we have from the Paleolithic, Neolithic or Bronze Age periods do indeed constitute 'star charts' of some sort or constellations, because the words which might tell us this do not survive (cf. Magli, 2009). Even if the words did survive, would we understand them, and how literally should they be taken?

In the western tradition, it is not until we get to Egyptian and Babylonian written records that we can be sure that people were not only observing the night sky in a systematic fashion, but were mapping it as well (cf. Hunger & Pingree, 1989). The constellations which these peoples created, some of which were passed on to the Greeks and then to the Romans and so to us, represent complex processes of comprehension, conceptualisation and categorisation, which have allowed observers then as now to locate bodies in the celestial sphere (Hannah, 2002). In this regard, NASA is no different from the nameless scribes of Babylon: all have recourse to the mapping facility offered by the constellations, however arbitrary and culturally-situated they are.

Before the Greek astronomers from Hipparchos to Ptolemy, between the second century BCE and the second century CE, developed a coordinate system for placing stars on the celestial globe (Dilke, 1987), these constellations provided the usual means of situating anything in the night sky. In the third century BCE Aratos wrote a poem which described the stars in a pre-coordinate fashion. It is clear from him that the imaginary mythological or zoological figures, which formed the constellations, also provided rough-and-ready means of navigating one's way across the sky:

> Let the left shoulder of Andromeda be a sign for the northern Fish, for it is very near to it. Both of her feet indicate her bridegroom, Perseus, as they move always on his shoulders. He is taller than others in the north. His right hand is stretched out towards the seat of his mother-in-law's throne, and as if pursuing on foot he lengthens his stride, running in the world of his father Zeus. Near his left knee altogether are the Pleiades. Not much space at all holds them all, and they are faint to observe.
>
> (Aratos, *Phaenomena* 246–256; trans. Hannah)

But mapping is one thing, and a complex thing at that (see further on this example Hannah, 2020a). Knowing why people map is another. Why did the Babylonians and Greeks—since this is the tradition we still work in—populate the sky with these particular figures?

The earliest records suggest the night-sky was mapped initially for practical purposes, such as navigation (even in the Egyptian afterlife) or the timing of agricultural activities (e.g. Hesiod, *Works and Days*). This process is made complicated because of the apparent movement of some of the celestial bodies. The band of sky which the sun itself appears to move across in the course of a year encompasses stars which were gradually parcelled out from around 3000 BCE by the Mesopotamian peoples into what was eventually called the zodiac by the Greeks, because of the animate forms into which they configured the stars (a bull, a lion, a scorpion, etc.). This zodiacal band of stars was regarded as special because it was seen to be populated not only by the light-giving sun and moon but also by those stars which were not fixed in place relative to others, but which moved or wandered—the planets, as the Greeks called them, from their word for 'wanderers'. These special stars, or planets, were deified by these societies, and regarded as having power over human events and eventually, under the Babylonians, Egyptians and Greeks, over individual human lives (Barton, 1994; Jones, 1999; Neugebauer & Van Hoesen, 1959; Rochberg, 1998, 2004, 2010).[1]

Having set aside the wandering stars, which included the sun and moon, and other occasionally periodic oddities like comets and meteors, the ancients were left with a vast number of dots in the sky, which remained in the same position relative to one another. Of course, these so-called 'fixed' stars have their own proper motion,

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[1] Note, however, the caveat expressed by Rochberg (1998): 1–3 regarding the dissimilarities between Babylonian and Greco-Egyptian 'horoscopes', with the former deserving to be classified more as 'astronomical' than 'astrological' in light of the absence of prognostications.

but that is not important at this level of observation. To any casual observer they look utterly unconnected, as indeed most are in reality, being made by our eyes to look as though they are lights on a two-dimensional canopy of the sky.

Yet some do seem to stand out for one reason or another in certain configurations, perhaps because of the surrounding blackness of the sky once our eyes move outside that thickly populated band which we call, with the Greeks and Romans, the Milky Way. At other times we can assume that the 'en-figuring' of the night sky occurred in the way it did because certain stars could be readily grouped into configurations which were easily recognisable within certain cultures. The longevity of some configurations shows how some shapes have stood the test of time and culture: the Scorpion is a good example in the Middle Eastern–Mediterranean worlds, since it was devised by the Babylonians and passed on to the Greeks and Romans, all of whom knew what a real scorpion looks like. Egyptian constellations, on the other hand, seem not to have filtered across and remain today difficult to identify (cf. Lull & Belmonte, 2006, 2009). The stars that we call Pegasus were seen by the Babylonians, not unreasonably, as simply a Field, whereas the Greeks imagined them as the body of a Horse, which eventually came to be identified with the mythological Pegasus (Boll & Gundel, 1924–1937: cols. 928–931; Kidd, 1997: 258–259). It is not that the Babylonians were simply more prosaic than their Greek neighbours, for they could certainly picture elaborate figures in the sky, and they could coordinate these thematically, if they wished. The constellations which we call Aries, Auriga, Taurus and Orion, for example, the Babylonians called the Hired Man, the [shepherd's] Crook, the Bull, and the True Shepherd of Anu, all reflecting agricultural influence and all rising at dawn in spring time, when work in the fields would start up again (Hunger & Pingree, 1989: 137–138). But the Babylonians seem not to have had an inclination to use mythological stories which connected one constellation with another. This the Greeks did with gusto, creating thus a celestial carpet of interconnected catasterism myths linking the constellations with one another.

But again, this simply states the obvious, that the Greeks told stories through the stars. Why did they do so? To answer that, we may start by asking: who are these 'stars' of the celestial stage?

The particular constellations relating to the myth of Perseus seem to have been placed in the sky in what looks like a conscious project at the end of the fifth century BCE (in what follows it will be clear that I do not follow the belief in a Bronze Age date for the Classical Greek constellations). We find this reflected—not necessarily initiated—in the plays of Sophokles and Euripides (according to pseudo-Eratosthenes, *Catasterismi* 15, 16, 17, 36, and Hyginus, *Astronomica*. 2.9–11), who between them place as constellations in the sky the princess Andromeda, her mother and father Cassiopeia and Cepheus, and the sea monster Cetus. Perseus must have been sent up there too then or earlier, but the record does not survive to tell us so.

The constellation Perseus therefore belongs to a new class of figures in the sky whose source lies in narrative mythology. Extensive areas of the sky were now populated by inter-connected characters from Greek mythology. In this way the heavens were mapped out in a manner which we continue to utilize today, and this very process of mapping, this method of articulating a way through the whole panorama of the stars, is part of the reason why these catasterisms were invented.

4 Navigation

Navigation has been posited as a cause for early mapping of the sky, whether one was traversing the Middle Eastern deserts or the Mediterranean Sea. But that begs the question why should people need to navigate their way *through the sky*. One obvious answer lies in the need for peoples in the Mediterranean to find their way from one landfall to another in their seafaring journeys (see Pimenta, 2014 for a good overview; and for detailed examples Bilić, 2005, 2009, 2014; Medas, 2004; Coldstream & Huxley, 1996; Fresa, 1969). This is illustrated early on in Greek literature in a famous, if contentious, passage in Homer's *Odyssey*, in which Odysseus is given sailing instructions by the goddess, Athena:

> Glad with the wind, noble Odysseus spread sails. Sitting down, he skillfully held it straight with the steering-paddle, and sleep did not fall on his eyelids as he looked to the Pleiades and late-setting Boötes, and the Bear, whom they also name Wagon, which turns round about there and watches Orion closely, and alone is without a share in the baths of Ocean. For Kalypso, noble among goddesses, commanded him to pass over the sea, keeping the Bear on his left hand. Seventeen days he sailed, passing over the sea, and on the eighteenth day there appeared the shadowy mountains of the land of the Phaiakians, where it was nearest to him, and it looked like a shield on the sky-like sea.
>
> Homer, *Odyssey* 5.269-81 (trans. Hannah)

I have attempted to interpret this passage from a practical point of view, even though the literary context is one of fantasy in the story of Odysseus, and I believe the interpretation has its merits (Hannah, 1997).[2] Certainly in the realm of sailing the use of large constellations rather than tiny pinpoints of single stars makes a great deal of sense, as research on star navigation methods in other cultures, like those of the Polynesians, has demonstrated (Lewis, 1994; Lusby, Hannah, & Knight, 2010a, 2010b). But lists of constellations are more likely to have been kept in seafarers' heads than in city centres, and yet it is precisely in city centres—arguably Classical Athens itself and certainly Hellenistic Miletos—where we happen to have found them archaeologically (Hannah, 2001). These findspots demand another explanation for the peopling of the sky.

5 Agriculture

A traditional role of observational astronomy in ancient Greece was—at least in literary form—to provide indications of pivotal moments of change in the seasonal year. For Homer and Hesiod, at the dawn of Greek literature, the rising and setting of just a handful of stars and constellations served as agricultural 'event markers', much like calendar dates, signalling or reflecting the appropriate time for various

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[2] The brief and remarkably uninformative discussion of the navigational technique implied by Homer in as authoritative a text as McGrail (2001): 101 is unfortunately typical of literature on this passage.

activities. In particular, Hesiod's wisdom-poem, *Works and Days*, provides a rough-and-ready calendar for activities down on the farm, each often timed by the appearance or disappearance of a star (West, 1978). So, for example, the time of winter ploughing is signalled by the dawn setting of the Pleiades, the Hyades and Orion (*Works and Days* 614–617). Hesiod exhorts his farmer to start the harvest at the dawn rising of the Pleiades, at the end of their 40-day period of invisibility (*Works and Days* 383–387, 571–573). Elsewhere he mentions the culmination of Orion and Sirius at the time of Arcturus' dawn rising to indicate the period of the grape harvest in September (*Works and Days* 609–611). In all, he provides just nine observations of the risings or settings of five stars or star groups—Sirius is mentioned once, while the Pleiades, the Hyades, Orion, and Arcturus are all noted twice—and he adds the culmination of Orion and Sirius to the rise of Arcturus. These observations are so arranged that the farmer seems to have been given a remarkably economical safety-net of successive warnings of the appropriate date for a certain activity on the land (Reiche, 1989).

But these same stars can do double duty. Let us recall that for Hesiod the dawn rising of the Pleiades marked the time of summer harvesting. In fact, harvesting and threshing would span a long period, about May-to-July in our terms, and during this time not only the Pleiades but, of course, the Hyades and Orion would also rise successively just before dawn. Simultaneously, the Bear—neither rising nor setting—reached its lower transit across the meridian, just skimming the northern horizon. The relationship of the Bear to the other three star-groups is a close one in the geometry of the sky, and it would seem also in the related activities on the land, where ploughing and sowing are first signalled, and later harvesting. We may also see the significance of the Bear's second name, the Wagon, a useful vehicle at harvest time (Hannah, 2005: 20–25).

We might wonder how Hesiod knew when the Pleiades and other stars would first appear before dawn, especially as the Pleiades cluster, although distinctive enough, is hardly bright, unlike Sirius which the Egyptians observed at dawn to warn of the next flooding of the Nile. Which in turn governed the land's economy. What traditional methods had he inherited? Or did he gain this knowledge from the East, where these data were already long known? In the East it was knowledge used for the purposes of predicting astronomical events that were understood to have influence over human lives, but that would not be a feature of Greek society for several hundred years still. If the data were adopted from the Babylonians, did the Greeks, as they were wont, adapt them to their own purposes?

6 Religion

The agricultural cycle was also intimately bound up with the religious cycle in ancient Greece, and for me it is in the latter area that we may find the real reason for the increased mapping of the night sky by the Greeks. After all, as Anthony Aveni once astutely pointed out, 'perfection was unnecessary in meteorological or agricultural prediction; the answer lies in the spiritual realm' (Aveni, 1979: 63). A farmer could simply look to the weather and test the soil with his finger to know when best to sow; he could look at his ripening crop to know when to harvest; he did not need to consult star charts. But festivals of ploughing, sowing and harvesting articulate both the agricultural and the religious year. The particular association of the Pleiades, the Hyades, Orion and the Bear/Wagon with agricultural activities that we have just seen, may go deeper still in ancient Greek society. The great agricultural and religious festivals of Demeter and Persephone in Athens occurred, not surprisingly, at times significant to agricultural activity. These festivals took place within fixed months of the Athenian festival calendar (Mikalson, 1975). However, this calendar was not a solar one like ours is, but a lunisolar one, tied to both lunar and solar phenomena, like the Jewish religious calendar or the Asian calendars or the New Zealand Māori calendar today. This means that in any given year in antiquity, we cannot usually tie a given Athenian date to a given modern equivalent. (We say 'usually' because on very rare occasions it is possible to pin down a date if it is related to a phenomenon like a lunar or solar eclipse, which we can date independently of the ancient calendar.)

Because of the wandering character to the Athenian calendar, even with the periodic insertion of an intercalary month, it is practically impossible to be precise about when in terms of our calendar an event in the past took place. But we can be sure of the season, and as a result we can see that the festivals held in honour of the agricultural goddesses, Demeter and Persephone, occurred not only at significant moments in the agricultural cycle, as we would expect, but also at astronomically significant times. As Efrosyni Boutsikas has pointed out (Boutsikas, 2017), the Proerosia or Proarktouria, a festival in honour of Demeter and Kore, celebrated in anticipation of a successful harvest, was—as its name indicates—celebrated at the time of the heliacal rising of Arcturus. A calendar from Thorikos places the Proerosia in the Attic month of Boedromion (Parker, 1987; Hannah, 2005: 66), and so somewhere between (roughly) mid-September and mid-October, which suits well the heliacal rising of Arcturus, as this took place around 21 September (Julian) in this period. A sacrificial calendar for Eleusis has the festival being celebrated on 5 Pyanepsion (it is assumed), which would correspond to sometime in late October (Dow, 1968).

7 Euktemon's Parapegma

In comparison with Hesiod's nine observations of star phases, 42 observations of 15 stars or star-groups survive from the late fifth century BCE data-set attributed to Euktemon, which we find incorporated in later Hellenistic and Roman collections of star observations, the parapegmata (see Lehoux, 2007 on these diverse tables of star and other data). Whether Euktemon's parapegma originally recorded more, we have no way of knowing now (see Lehoux, 2007). So large an increase in star observations may have resulted from a desire to secure the placement of seasonal, and hence solar, events related to the agricultural year within the awkwardly mobile lunar calendar that Greek city-states maintained. In particular, agriculturally-focussed religious festivals could have benefitted from a more stable calendar to maintain synchrony between nature and ritual.[3] It is unlikely that this increase was the result of an attempt to 'weatherproof' the observations (i.e. by having more observations for the same time period the chances of missing the desired moment in the year because of poor weather conditions may be greatly reduced). Should this have been the reason for the great increase in the recording of fifth century observations we would expect that the majority of added star phases would have been during the winter months when bad weather conditions are more likely to occur, which is not the case.

How was a 'first' or 'last' sighting measured? Much later in the first century CE the Roman encyclopaedist, Pliny the Elder, tells his readers that the sun should be 'at least three-quarters of an hour' below the horizon for a star's first or last sighting at dawn or dusk (Pliny, *Natural History* 18. 218; see further, Fox, 2004). Importantly, he is promoting a measure of time, not brightness of the star (magnitude) for the observation. This part-hour measure was not available to the eighth century farmer, or the reader of a farmer's almanac like Hesiod's *Works and Day*, and it is expecting too much precision to think it might be something of this scale that Hesiod had in mind. But we know something like this measure was in use in Babylonia by the sixth century BCE, because it constitutes the equivalent of two lots of 24 min, and one 24-min measure was six UŠ which waterclocks could measure (Fermor & Steele, 2000). The same measure of 24 min would continue much later into Indian astronomy in historical times, and be able to be measured by some remarkably simple bowls that would sink into buckets of water at this given rate of 24 min (Sarma, 1994, 2018: 3645–3711). I could accept that some such simple mechanism, in the form of a small pottery bowl with a hole in its bottom and a larger pottery jar to hold the requisite water, was available in fifth century BCE Athens, when Euktemon put his parapegma together. We just have to find them …

Reasonable cause to look for such mechanisms is given by an analysis of the surviving data from Euktemon's parapegma. If we take as an example the 'observations' ascribed to the 'month' when the sun is in Taurus, as preserved in the collation of parapagmata in Geminos's *Introduction to Astronomy* from the first century BCE, we find some interesting results[4]:

> *Day 13 (= May 7), according to Euktemon Pleiades rise (Pleiades morning rising); beginning of summer; and there is sign of weather.*

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[3] Contrast Sider and Brunschön (2007): 9 n. 26–27, 37 n. 94–95, who seem to regard the parapegmata as inherently impractical on the basis of their perception that Theophrastos's treatise *On Weather Signs* is also impractical. Their comparison confuses different genres.

[4] The text used is that published by Aujac (1975). The fact that Geminos organises the parapegmata according to the zodiacal months indicates that Euktemon's original parapegma, composed before the institution of zodiacal months around 300 BCE, has been forced to some extent into a foreign framework. Such a manoeuvre may mean some accuracy has been sacrificed in the transmission, but we have no way of knowing.

> Comment: In Euktemon's time, on May 7 when η Tau (mag. 2.86) was rising, the sun was 9° 29′ below the horizon. This is technically not 'visible'—with a flat horizon first visibility would occur about May 23, with the sun 16° below the horizon. If we allow an extinction angle of 'Thom's Rule + 1', as suggested by Mann (Mann, 2011: 252–253, for Thom's Rule, see Thom, 1967: 15; see also Ruggles, 1999: 52), then we would have η Tau (mag. 2.86) at an altitude of about +4° and the sun at –16° below the horizon, and this occurred around May 29. However, given the mountainous nature of much of the Greek landscape, I do not think that we need worry too much about allowing for an extinction angle, as the high hills tend to obviate the need (cf. Ruggles, 1999: 230 n. 23). So the actual date of heliacal rising was considerably later than the date provided by the parapegma. But the parapegma's date of May 7 puts the sun 52 (equinoctial) minutes short of rising, which practically suits Pliny's criterion.
>
> *Day 31 (= May 25), according to Euktemon Eagle rises in the evening.*
>
> Comment: This refers to the evening rising of Aquila. On May 25 when α Aql was rising, the sun was 7°10′ below the horizon. This is 'visible'—with a flat horizon last visibility would occur on May 25, with the sun 7° below the horizon, so long as we do not include an extinction angle. Adding the extinction angle, in this case of about 2°, shifts the date to around May 27. As it is, the date of May 25 and α Aql on the horizon would have the sun 41 (equinoctial) minutes after setting, which also suits Pliny's criterion.
>
> *Day 32 (= May 26), according to Euktemon Arktouros sets at dawn; there is sign of weather …. Hyades rise at dawn; there is sign of weather.*
>
> Comment: This refers to the morning setting of Arcturus, and the morning rising of the Hyades.
>
> (a) On May 26 when α Boo (Arcturus) was setting, the sun was 2°08′ below the horizon. This is technically not 'visible'—with a flat horizon first visibility would occur about 4 June, with the sun 7° below the horizon and no extinction angle allowed for. Adding an extinction angle of about 2° would shift the date to around May 30. A date of 26 May puts the sun only 12 (equinoctial) minutes short of rising, which does not suit Pliny's criterion. Technically, then, this counts as a true and therefore invisible morning setting. Morning settings are characteristically not this parapegma's forte in terms of accuracy, whereas morning risings and evenings settings are better. I am not sure what this tells us, except that a star phase nearer the sun seems easier to plot than one at the opposite horizon.
>
> (b) At dawn on May 26 when α Tau (the prime star in the Hyades) was on the horizon, the sun was 6°38′ below the horizon. This is technically not 'visible'—with a flat horizon first visibility would occur about June 4, with the sun 11° below the horizon. Including an extinction angle of about 2° delays the first rising even further to about June 7. But a date of May 26 puts the sun 38 (equinoctial) minutes short of rising, which practically suits Pliny's criterion.

The short analysis of a very small data set here might suggest that the star risings and settings were not physically observed, but calculated (see Hannah, 2020b, for an analysis of another part of the parapegma producing similar results).

8 Conclusion

This discussion overall suggests that awareness of the movement of stellar bodies permeated ancient everyday life and activities. It can be argued that the ability to make use of astronomical knowledge was for the ancient Greeks not restricted to specific classes or groups. Whether educated or not Greeks could identify at least a handful of constellations and stars, enabling themselves thus to be both cardinally orientated and to estimate the time of the month or year. Such a practice and knowledge may seem unusual to us, when the use of clocks and diaries have distanced us from our astronomical/celestial surroundings. The importance of this knowledge should, however, not be downplayed. Nor should the significance of the night-sky in everyday life be overlooked. The night-sky was for the ancients an inseparable part of their perceived environment, a part that was not only embedded in daily activities but also in their belief systems, cosmologies, religious practices and civic activities (see Boutsikas, 2017). The elements of the night-sky were a kind of time device that could influence all activities, from those on which the subsistence of the community relied (e.g. agriculture and navigation), to those which guaranteed economic and civic stability, as well as the maintenance of the cosmic order through the performance of religious festivals at the correct time.

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Why Are There Seven Sisters?

Ray P. Norris and Barnaby R. M. Norris

1 Introduction

The Pleiades, or Seven Sisters, is an open stellar cluster of hot, blue, young stars, which were formed about 115–125 million years ago (Stauffer, Schultz, & Kirkpatrick, 1998; Ushomirsky, Matzner, Brown, et al., 1998), and they are still surrounded by a blue reflection nebula. The cluster is called the "Seven Sisters" in many cultures, with a remarkable similarity in the stories surrounding it.

The importance of the Pleiades in many cultures has been listed by several authors (e.g. Allen, 1899; Avilin, 1998; Burnham Jr., 1978; Dempsey, 2009; Krupp, 1994; Kyselka, 1993; Sparavigna, 2008), from the first written record by the Chinese in 2357 BC through to the present day. In most cultures, the Pleiades are seen as seven young women, or 'daughters' (Krupp, 1994). The oldest representation of the Pleiades is thought to be on the Nebra disk, found in Germany, and constructed around 1600 BC (Ehser, Borg, & Pernicka, 2011), but that representation consists of six stars arranged symmetrically around a seventh, and is therefore probably symbolic rather than a literal picture of the Pleiades.

R. P. Norris (✉)
Western Sydney University, Penrith South, NSW, Australia

CSIRO Astronomy & Space Science, Epping, NSW, Australia

B. R. M. Norris
Sydney Institute for Astronomy, School of Physics, University of Sydney,
Camperdown, NSW, Australia

Sydney Astrophotonic Instrumentation Laboratories, University of Sydney,
Camperdown, NSW, Australia

AAO-USyd, School of Physics, University of Sydney, Camperdown, NSW, Australia
e-mail: barnaby.norris@sydney.edu.au

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In Greek mythology, the Seven Sisters are named after the Pleiades, who were the daughters of Atlas and Pleione. Their father, Atlas, was forced to hold up the sky, and was therefore unable to protect his daughters. But to save them from being raped by Orion the hunter, Zeus transformed them into stars. Orion was the son of Poseidon, the King of the sea, and a Cretan princess. Orion first appears in ancient Greek calendars (e.g. Planeaux, 2006), but by the late eighth to early seventh centuries BC, he is said to be making unwanted advances on the Pleiades (Hesiod, Works and Days, 618–623).

Curiously, similar stories about the Pleiades and Orion are told in Aboriginal Australia. For example, most Aboriginal cultures associate Orion with a hunter, or a young man, or a group of young men, or a male ceremony, and many have stories in which the men in Orion are trying to chase and rape the girls of the Pleiades (e.g. Massola, 1968; Mountford, 1939, 1976). The similarity between the Aboriginal and Greek stories of the Pleiades and Orion includes three specific elements: both identify the Pleiades as a group of young girls, both identify Orion as male, and both say that Orion is attempting to have sex with the girls in the Pleiades.

These strong similarities suggest a common origin, which appears to predate European contact with Aboriginal Australia.

This comparison is particularly interesting because there has been almost no cultural contact between the European (i.e. Greek) and Aboriginal Australian cultures from about 100,000 BC, when the ancestors of both cultures migrated out of Africa, until 1788 when the British invaded Australia. Nevertheless, there is a remarkable similarity between the stories in both cultures. Norris and Norris (2009) first suggested that one explanation for this similarity is that the roots of the Seven Sisters story could date back to 100,000 BC, thus providing a common ancestry for this story in all modern human cultures. This paper examines this "Out of Africa" hypothesis.

A related puzzle concerns the number of stars in the Pleiades. Although, in principle, ten stars in the Pleiades are sufficiently bright ($mv < 6$) to be seen with the naked eye, most people with good eyesight, in a dark sky, see only six stars (Kyselka, 1993). This is not a new phenomenon: even in the third century BC, the Greek poet Aratos of Soli gave the names of the Seven Sisters (Halcyone, Merope, Celaeno, Electra, Sterope, Taygete, and Maia) but then reported that "only six are visible to the eyes" (Krupp, 1991). Thus, while many cultures regard the cluster as having seven stars, they acknowledge that only six are normally visible, and then have a story to explain why the seventh is invisible.

These "lost Pleiad" stories are found in European, African, Asian, Indonesian, Native American and Aboriginal Australian cultures (Burnham Jr., 1978; Gibson, 2017). In Greek mythology, one of the sisters, Merope, was ashamed of falling in love with a mortal and therefore faded from sight (Sparavigna, 2008). In Australian Aboriginal mythology, one (or occasionally two) of the sisters has died, is hiding, is too young, or has been abducted, so only six (or five) are visible (Fuller, Norris, & Trudgett, 2014; Kyselka, 1993). Krupp (1991) gives a story from the Onondaga Iroquois in which one of the stars sang as they ascended to the sky and thus became fainter. In Islam, the seventh star fell to earth and became the Great Mosque

(Ammarell & Tsing, 2015). It is hard to escape the conclusion that once upon a time there really were seven easily visible stars, one of which is no longer visible. Hertzog (1987) describes this phenomenon as “the combined testimony of numerous societies, spanning continents and millennia, for a seventh easily visible … Pleiad which subsequently dimmed”.

2 The Astronomy of the Pleiades

The Pleiades is one of the nearest open clusters to the Sun, at a distance of about 135 pc (Melis, Reid, Mioduszewski, Stauffer, & Bower, 2014), and one of the youngest, with an age of ~115–125 million years) (Stauffer et al., 1998; Ushomirsky et al., 1998). The Pleiades contains stars spanning a wide range of masses, but the brightest visible stars are all B stars. The dynamics of the cluster as a whole are well-studied (e.g. Converse & Stahler, 2010) but subsequent discussion in this paper is limited to the ten stars that are, in principle, visible to the human eye, with mv < 6, listed in Table 1.

Table 1 The visible stars of the Pleiades, taken from the Hipparcos catalog (van Leeuwen, 2009)

Name	RA (J2000)	Dec (J2000)	Brightness (m_v)	PM (RA) (mas/yr)	PM (Dec.) (mas/yr)	Spectral type
Celaeno*	03 44 48.20	+24 17 22.5	5.45	20.73	−44.00	B7IV
Electra*	03 44 52.52	+24 06 48.4	3.72	21.55	−44.92	B6III
18 Tau	03 45 09.73	+24 50 21.7	5.66	19.03	−46.64	B8V
Taygeta*	03 45 12.48	+24 28 02.6	4.30	19.35	−41.63	B6V
Maia*	03 45 49.59	+24 22 04.3	3.87	21.09	−45.03	B8III
Asterope*	03 45 54.46	+24 33 16.6	5.76	19.44	−45.36	B8V
Merope*	03 46 19.56	+23 56 54.5	4.14	21.17	−42.67	B6IV
Alcyone*	03 47 29.06	+24 06 18.9	2.85	19.35	−43.11	B7III
Atlas	03 49 09.73	+24 03 12.7	3.62	17.77	−44.70	B8III
Pleione	03 49 11.20	+24 08 12.6	5.05	18.71	−46.74	B7p

Those corresponding to the Pleiades of Greek mythology are marked with an asterisk. Asterope is a binary with a separation of 2.5 arcmin, so the two stars are indistinguishable to most human eyes. The combined brightness of the two stars is $m_V = 5.66$. The columns marked PM give the proper motion in Right Ascension and Declination, in milliarcsec per year

B stars are often variable (e.g. Waelkens & Rufener, 1985) and the variability of the Pleiades has been well-studied (e.g. White, Pope, Antoci, et al., 2017). Several have been observed to be variable, and Pleione is known to be an irregular variable, varying by as much as 0.5 magnitude in the last century (Burnham Jr., 1978). However, such studies are only sensitive to short-term variability (on a timescale of days to years). On a timescale of tens of millions of years, comparable to the lifetime of the star, the star is expected to gradually increase in luminosity because of its expansion as it moves across the main sequence (Langer, 2012), but the change over a period of 100,000 years is probably still too small to be visible to the human eye. Additional variability may also be caused by motion of the obscuring dust that veils the Pleiades. Because of these unknown factors, we have no information on how the brightness of these stars varies on timescales of thousands of years.

The proper motion of these stars has been measured accurately by Hipparcos (van Leeuwen, 2009). Gravitational forces from the mass of the cluster, or from tidal friction, are negligible over human timescales, and so we can linearly extrapolate their motion back to prehistoric times, as shown in Fig. 1.

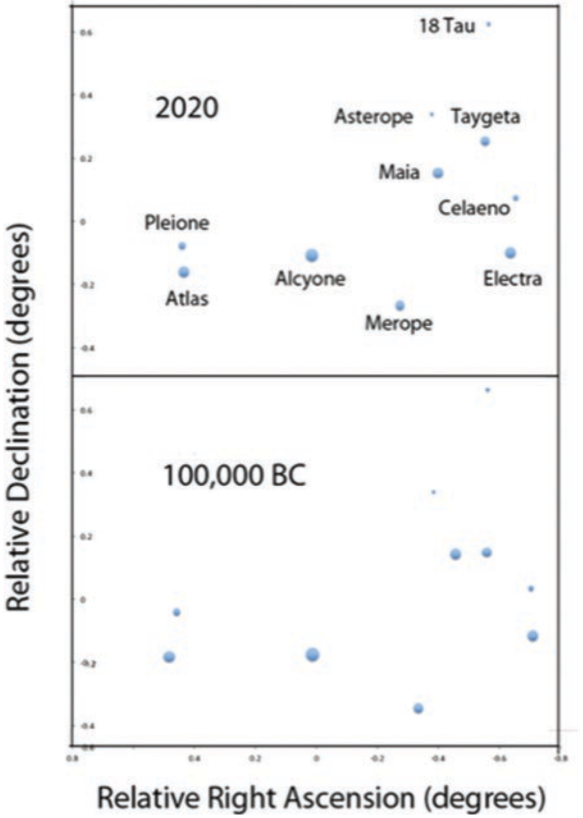

Fig. 1 The appearance of the Pleiades at present and at 100,000 BC, assuming linear motion and no variability. The area of each symbol is proportional to (6 − m_v), where m_v is the apparent magnitude

3 The Seven Sisters and Orion in Aboriginal Australia

3.1 Aboriginal Astronomy

Astronomy is a central part of many Aboriginal cultures. An extensive review, citing all known publications in this field at the time of writing, is given by Norris (2016). Mountford (1976) reported that some Aboriginal people knew the name of every star as faint as fourth magnitude, and knew myths associated with most of those stars. Even now, some elders can name most stars in the sky visible to the naked eye, and have an intuitive understanding of how the sky rotates over their heads from east to west during the night, and how it shifts over the course of a year (Norris, 2016). Maegraith (1932) says that 'The most interesting fact about Aboriginal astronomy is that all the adult males of the tribe are fully conversant with all that is known, while no young man of the tribe knows much about the stars until after his initiation is complete … The old men also instruct the initiated boys in the movements, colour and brightness of the stars.' Dawson (1881) reported that astronomy was 'considered one of their principal branches of education … it is taught by men selected for their intelligence and information'.

3.2 Orion

Most Aboriginal cultures associate Orion with a hunter, or a young man, or a group of young men, or a male ceremony, and many have stories in which the men in Orion are trying to chase and rape the girls of the Pleiades (e.g. Massola, 1968; Mountford, 1939, 1976). Examples include:

- A Yolngu story that the three stars of Orion's belt are three brothers in a canoe, with Betelgeuse marking the bow of the canoe, and Rigel the stern. The Orion nebula is a fish, attached by a line to the canoe, shown in Fig. 2. They were blown into the sky by the Sun-woman as punishment for eating their totem animal, a king-fish, in violation of Yolngu law (Davis, 1989; Norris, 2016; Wells, 1973).
    - The Kaurna story (Gell, 1842; Teichelmann & Schuermann, 1840) that Orion is a group of boys who hunt kangaroo and emu on the celestial plain.
    - The Murrawarri story (Mathews & White, 1994) that Orion wore a belt, carried a shield and stone tomahawk, and their name for the constellation (Jadi Jadi) means either 'strong man' or 'cyclone'.
    - The report by Bates (1925) that people over a great area of central Australia regarded Orion as a 'hunter of women', and specifically of the women in the Pleiades, and that the male initiation ceremony includes an enactment of Orion chasing and raping women. The ceremony may only take place when Orion is *not* in the sky, which is consistent with the report (Fuller et al., 2014) that, in Kamilaroi culture, Orion's setting in June is associated with the male initiation ceremony.

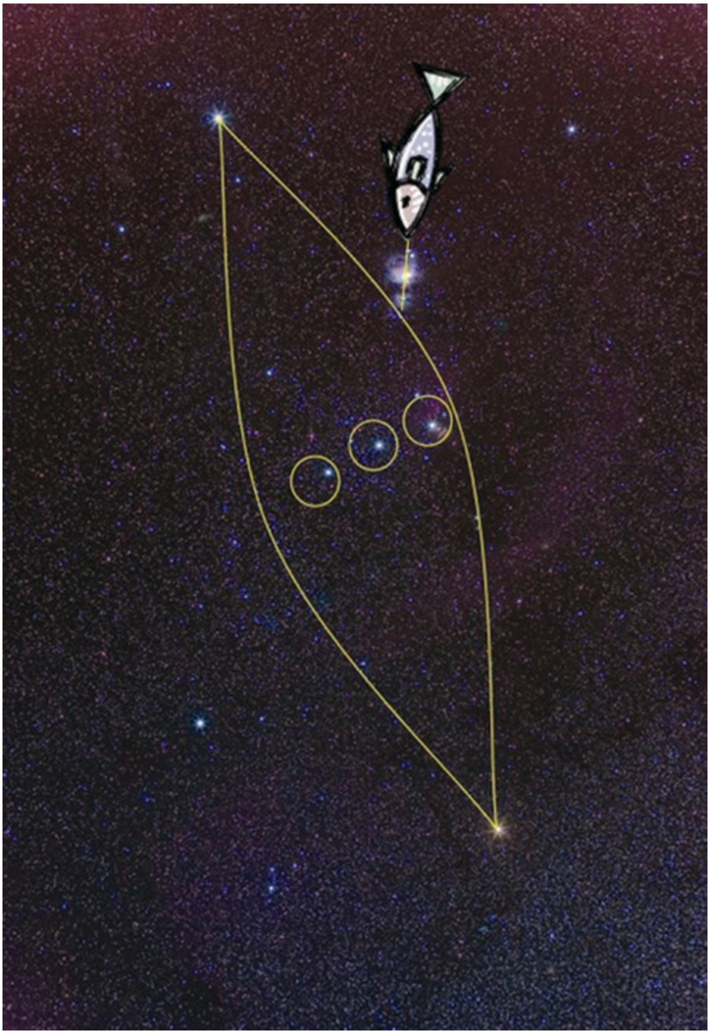

Fig. 2 An Australian Aboriginal interpretation of the constellation of Orion, known as "Djulpan" in Yolngu, from the Yolngu people of Northern Australia. The three stars of Orion's belt are three young men who went fishing in a canoe, and caught a forbidden king-fish, represented by the Orion Nebula. Drawing by the author based on Yolngu oral and written accounts

3.3 Pleiades

The Pleiades are one of the best known features of the Aboriginal sky and its stories have been described extensively (e.g. Andrews, 2005; Clarke, 2009; Johnson, 2011; Norris, 2016) so only a brief description will be attempted here. In nearly all Australian cultures, the Pleiades are female, and are often called the Seven Sisters

(Johnson, 2011; Norris, 2016). They are generally identified with a group (usually seven, but sometimes six) of young girls, or sisters, often fleeing from the man or men in Orion (or occasionally from the Moon or another celestial body). They are frequently associated with sacred women's ceremonies and stories. The Pleiades are also important as an element of Aboriginal calendars, and in several groups their heliacal rising marks the start of winter. For example, Norris (2016) report an account in which 'Seven sisters come back with turtle, fish, freshwater snakes and also bush foods like yams and berries. The stars come in season when the food and berries come out, They give Yolngu bush tucker, they multiply the foods in the sea that's why Yolngu are happy to see them'.

Johnson (2011) divides the Pleiades stories into four groups, to which I add a fifth based on the presence of a protective dingo. The five groups are then as follows:

- In most areas of mainland Australia, the Pleiades are portrayed as girls chased by the young men in Orion which is very similar to the Greek myth
- In Arnhem Land, stories portray the Pleiades as partners of the men in Orion. In some versions of the story from NSW and Victoria, Orion consists of boys who dance at night to music made by the girls in the Pleiades (Parker, 1905; Smyth, 1878).
- In south-west Australia, the stories often feature the girls being protected by their dingoes. Because this detail is absent in stories from south-east Australia, Tindale (1983) argued that the story predates the arrival of dingoes in Australia in about 5000 BC. The association of the Pleiades with dingoes may also stem from the harvesting of dingo puppies by several groups as a food source at the heliacal rising of the Pleiades (Harney, 1963; Norris, 2008; Tindale & Lindsay, 1963).
- In the Torres Strait Islands, they are (with Orion) part of the crew of Tagai's boat that perished at sea after Tagai caught them stealing, and threw them overboard.
- In Tasmania, there is no known Pleiades story.

Stories in which there are six are usually accompanied by a story explaining how the "lost Pleiad" has been raped, or murdered, or has been captured by Orion, or is in hiding from Orion.

Many Aboriginal stories refer to the sisters as pursued by the young men in Orion (Tindale, 1983), For example, Harney (1959) reports a Central Desert version in which the girls are being chased towards Uluru by the young Orion men from the North, and escape by fleeing into the sky. Similarly, in Kamilaroi culture, Orion is known as the young men who loved, and pursued, the Pleiades (Mountford, 1976; Parker, 1905).

The Aboriginal stories of Orion and the Seven Sisters are so widespread throughout Australia, and occur in so many different Australian Aboriginal cultures, with local variations, that these stories are probably thousands of years old, certainly predating the European occupation of Australia (Johnson, 2011).

4 Human Perception of the Pleiades

Although most people see six stars, some see far more. For example, the first non-Aboriginal Australian astronomer, William Dawes, claimed to be able to see 13 stars (Burnham Jr., 1978), so evidently was able to see stars fainter than sixth magnitude. There are several other accounts of individuals with exceptional eyesight who can see large numbers of stars. Nevertheless, most people see six stars, a few can see eight, and rarely, those with exceptional eyesight see even larger numbers of stars. However, there is significant disagreement over *which* stars are included in the Seven Sisters.

The "Seven Sisters" of Greek mythology are unambiguous and are indicated by asterisks in Table 1. Most modern people with good eyesight can easily see the brightest five: Alcyone, Merope, Electra, Maia, and Taygeta, all of which are mv = 4.3 or brighter. Atlas (mv = 3.6) is often included as one of the Seven Sisters even though, in Greek mythology, Atlas is the father of the sisters. Pleione is the next brightest star (at mv = 5.05), and so is the obvious candidate for the seventh star, although in Greek mythology she is the mother of the Seven Sisters. However, Pleione is very close to the bright star Atlas, making it hard to see, as will be discussed below. The remaining three stars (Celaeno, 18 Tau, and Asterope are all very faint (at mv = 5.45 or fainter), close to the human limit of sensitivity, and cannot be seen by most people. Thus the six stars of the Seven Sisters as pointed out by many contemporary observers (e.g. King, 2014) are Alcyone, Merope, Electra, Maia, Taygeta, and Atlas, with a seventh, Pleione, just visible to those with exceptional eyesight.

5 The Physiology of Seeing Stars

There are several distinct physiological effects that limit the human perception of stars.

First, the sensitivity of the human eye limits the vision of most people, in a dark sky, to stars brighter than sixth magnitude. Indeed, the system of measuring a stars brightness by its "magnitude" was initially based on defining a sixth magnitude star as one that was just visible to the human eye (Heifetz & Tirion, 2004).

Second, the resolving power of the eye, in bright light, is limited to about 1 arcmin (which is the distance between the arms of the E on the bottom line of an optometrist's Snellen chart) (Yanoff & Duker, 2009), so that two stars closer than this will appear as one. This is a few times worse than might be expected according to the Rayleigh criterion for a diffraction-limited aperture, because of aberrations in the eye.

If these were the only two effects, then most humans would see the ten stars listed in Table 1, as they are all brighter than sixth magnitude and are all separated from each other by at least 1 arcmin. Most people are unable to see Pleione because of two other factors.

First, the 1 arcmin resolution is only obtained in bright light, when the resolution, or point spread function (psf), of the human eye is dominated by the cones of the retina. In faint light, human vision relies more on the rods that are sparsely distributed around the retina, and have a much broader psf.

A second factor, called "glare function" by physiologists, is what prevents you from seeing details next to car headlights pointing at you. The glare function depends on the dynamic range and psf of the human eye. Imperfections in the human eye give it a psf which has a broad base a few arcmin wide (Ginis, Perez, Bueno, & Artal, 2012), which in turn limits the dynamic range.

As a result, faint stars cannot be seen within a few arcmin of bright stars. The precise value of the measured half-width half-maximum (HWHM, at which the psf falls to half of its peak value) of the human psf depends on age, ethnicity, eye colour, and pupil dilation. For example, Australian Aboriginal people have statistically better acuity than Europeans (Taylor, 1981), although it is not known whether this affects the glare function. Here we assume the results from Fig. 5 of Ginis et al. (2012), from which HWHM appears to be in the range 3–4 arcmin for most people.

Pleione is 5 arcmin from the star Atlas, which is about four times brighter than Pleione, and the resulting glare from Atlas prevents most people from seeing Pleione.

6 Discussion

6.1 *The Lost Pleiad*

Although the Pleiades do not appear as seven stars to most humans, could they have appeared as seven stars in the past? There are two potential reasons why they may have done. First, we have already noted that many of the Pleiades are B stars, which are often variable. While we have no evidence of any long-term major changes in brightness, and the long-term variability of B stars is poorly understood, we cannot discount the possibility that one of the faint stars was much brighter in the past.

Here we suggest an additional reason. Because of Pleione's measured proper motion, Pleione was further from Atlas in the past, as shown in Fig. 3. In 100,000 BC it was 8.4 arcmin away, significantly decreasing the glare from Atlas. Figure 4 shows a simulated image of the two stars for an individual with HWHM of 3 arcmin. Even ignoring variability, Pleione was visible as a separate star from Atlas in 100,000 BC, so that the Pleiades would appear as seven stars to normal human eyes.

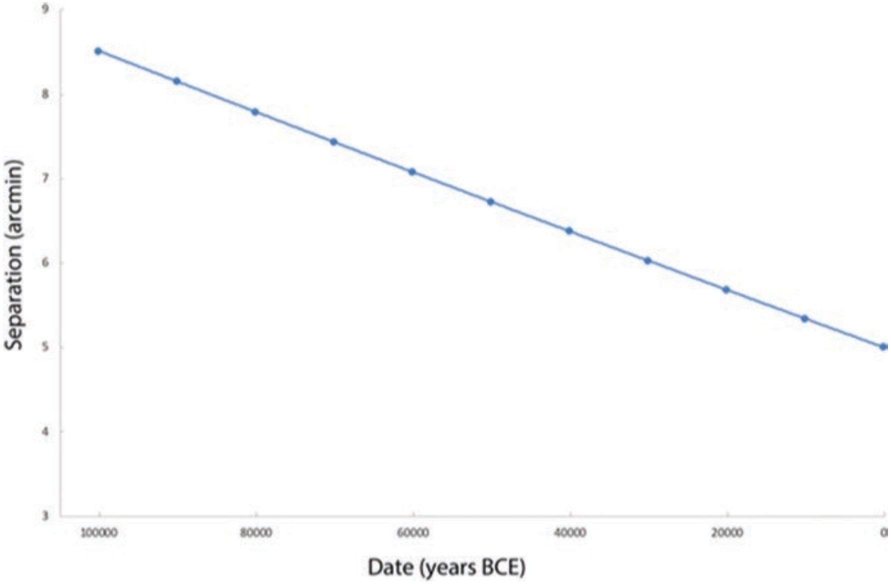

Fig. 3 The separation of Atlas and Pleione as a function of time

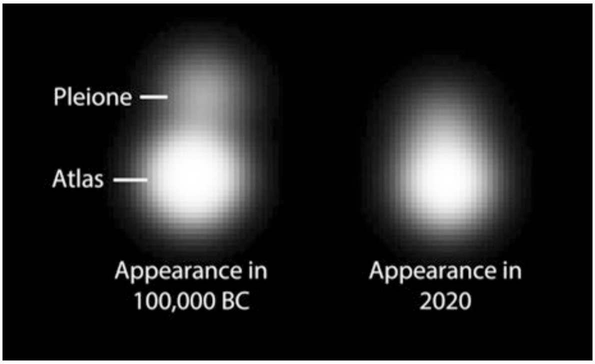

Fig. 4 The simulated visual appearance of Atlas and Pleione at the current epoch and at 100,000 BC, as viewed by individuals with a psf HWHM of 3 arcmin

6.2 Out of Africa

The ancestors of Aboriginal Australians left Africa in about 100,000 BC. DNA and archaeological studies (Harvati, Roding, Bosman, et al., 2019; Rasmussen et al., 2011) show that they were closely related to the ancestors of modern Europeans who left Africa at around the same time. The Australians followed the coast of India and China, crossed through Papua New Guinea, and arrived in Northern Australia (Hudjashov et al., 2007), probably in a single wave at least 40,000 years ago (O'Connell & Allen, 2004). Radiocarbon dating of Mungo Man showed that they had reached NSW by 40,000 BC (Bowler, Johnston, Olley, et al., 2003). A number of recent DNA studies (e.g. Nagle et al., 2017) place the departure date from Africa around 100,000 BC and the arrival date in most of Australia at about 50,000 BC.

From 50,000 BC onwards the Aboriginal people enjoyed a continuous, unbroken culture, with very little contact with outsiders, other than annual visits from Macassan trepang collectors to the far north of Australia over the last few hundred years. Aboriginal culture evolved continuously, with no discontinuities or significant outside influences, until the arrival of the British in 1788, making Aboriginal Australians among the oldest continuous cultures in the world (McNiven & Russell, 2005).

When the Australians and Europeans were last together, in 100,000 BC, the Pleiades would have appeared as seven stars. Given that both cultures refer to them as "Seven Sisters", and that their stories about them are so similar, the evidence seems to support the hypothesis that the "Seven Sisters" story predates the departure of the Australians and Europeans from Africa in 100,000 BC.

7 Conclusion

We have shown the great similarity between the Aboriginal and Greek stories of the Pleiades and Orion. Specifically, both (in common with many other cultures) predominantly:

- call the cluster "Seven Sisters", although most humans nowadays see six stars, and then have stories to explain why the seventh is invisible.
- identify the Pleiades as a group of young girls
- identify Orion as hunter, or young man, or group of young men
- have stories in which Orion is attempting to catch or rape the girls in the Pleiades

These strong similarities suggest a common origin, which appears to predate European contact with Aboriginal Australia. This similarity includes an insistence on there being seven stars, even though only six are visible to most people, together with a story to explain the "lost Pleiad". The evidence presented above shows that, because of the proper motion of Pleione, the Pleiades would indeed have appeared as seven stars to most humans in 100,000 BC. We conclude that the Pleiades/Orion story dates back to about 100,000 BC, before our ancestors left Africa, and was carried by the people who left Africa to become Aboriginal Australians, Europeans, and other nationalities.

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Remarks on the Lunar Series and Eclipse Cycles in Late Classic Maya Records

Stanislaw Iwaniszewski

1 Introduction

The Dresden Codex occupies a central position in the history of Maya astronomy. Its sections, known as the Eclipse, Venus and Mars Tables, together with other almanacs, provide by far the most extensive available body of evidence of Maya celestial calculation (see Bricker & Bricker, 2011 for a very comprehensive treatment). This information agrees with other Maya Late Postclassic (1250–1521)[1] codices (long strips of bark paper folded into pages as a screen fold) providing the most revealing and explicit information of their astronomical methods. Some of this material was initially composed in the Late Classic period (600–800) and eventually updated in the Postclassic period. Together, these texts provide the largest body of evidence of the Maya understanding of the regularities of the apparent motion of the Sun, the Moon and planets, the Milky Way and the brightest stars.

Besides tracking time and its cycles, the Maya codices tell us about how the entire cosmos worked. Astronomical-calendric cycles expose relationships among different entities acting upon the world. In order to track events over time, the Maya day-keepers used a complex structure known as the Long Count, a strict counting of days from a mythical zero-point date, which they inherited from their epi-Olmec neighbours. The use of the Long Count system allowed them to perform deep-time computations, as well as to represent heavenly movements in the form of arithmetic-

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[1] All years are C.E. unless otherwise noted. Throughout this paper, the term "month" refers to the lunar month unless qualified by another term such as "20-day month" where it refers to a calendrical unit of 20 days comparable to our modern month.

S. Iwaniszewski (✉)
Escuela Nacional de Antropología e Historia—Instituto Nacional de Antropología e Historia, Ciudad de México, Mexico

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calendric cycles. They also attempted to commensurate all temporal cycles with the 260-day divinatory calendar (*tzolk'in*).[2]

Astronomical information found in Maya manuscripts can only rarely be compared with the content of hieroglyphic texts displayed on stone monuments, stuccoed walls, pottery, or bones. The astronomical almanacs preserved in the codices represent a finished product of astronomical thinking of the Maya day-keepers. All astronomical data they include is part of a well-defined body of celestial knowledge obtained from earlier, mostly unknown attempts to find out a proper astronomical-calendrical procedure. A few astronomical texts and tables occasionally painted on the walls, such as the ones discovered at Xultún, could have represented such developments. On the other hand, little is known of direct celestial observations and in the monumental inscriptions of the Classic period; explicit astronomical records are rare.

It has long been recognized that much of Mesoamerican celestial knowledge derived from astronomical observations based on the periodicities of the 260-day cycle. Therefore, it should not be surprising that the Maya scribes identified temporal cycles unknown in Old World astronomies. For instance, there is no evidence they ever had a formal lunar calendar like in the Ancient Near East, Greece, or China. Instead, they devised a unique scheme for lunar reckoning called the Lunar Series. It contains three primary components: the moon's age in the current month, the number of days assigned to the lunar month (either 29 or 30), and the name of the lunar month and its positions in the groups (or "bundles", from the Classic Mayan *k'al,* "to bind, fasten, enclose"; Kettunen & Helmke, 2020: 93) of 6 and 18 (=3 × 6) lunar months. The origin of the concept of 6-month grouping is unknown.

2 Basic Maya Calendrics

Classic Maya scribes employed three overlapping calendrical systems called by epigraphers the Long Count, the *haab'* and the *tzolk'in*. The Long Count is a count of days elapsed since the mythical starting point on 13.0.0.0.0 4 Ajaw 8 Kumk'u, which according to the Goodman-Martínez-Thompson correlation, is taken either as 6 September, 3114 B.C.E. or as 8 September, 3114 B.C.E. (Gregorian), and which at noon corresponded to 584,283 or 584,285 JD, respectively. The Long Count system is usually composed of five units representing a period based, with one exception, on the vigesimal system. The units are:

1 *k'in* = 1 day
  1 *winalk (winal in colonial Yukatek)* = 20 days
  1 *haab'* (*tun* in the Colonial times) = 360 days
  1 *winikhaab'* (*k'atun* in the Colonial times) = 7200 days
  1 *pik* (*bak'tun* in the current times) = 144,000 days

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[2] The spelling of Mayan words may be problematic. For the sake of simplicity and following the long scholarly tradition, throughout this paper the names of calendric periods, days and months are rendered in Yucatec Mayan using the current orthography. This also refers to Classic Period inscriptions.

The Long Count is a positional system, usually arranged in descending order. Thus, for instance, the date 9.17.19.13.16 means a total of 1,425,516 days elapsed from the start of the count.

The Maya used a *haab'* solar or vague year consisting of 18 20-day units each and five additional days added at the end. The *haab'* year drifted in relation to the seasons. The names of the 20-day months (in Colonial Yucatec) are: Pop, Woh, Sip, Sotz', Tzek, Xul, Yaxk'in, Mol, Ch'en, Yax, Sak, Kej, Mak, K'ank'in, Muan, Pax, K'ayab, Kumk'u, and Wayeb. The month names are accompanied by a numerical coefficient referring to the day of a month.

The 260-day *tzolk'in* cycle has 20 day names combined with 13 day numbers, ranging from 1 to 13. This combination produces 260 different days. The day names vary among Classic Mayan cities. However, here I will make use of the Colonial Yucatec names (maintaining traditional orthography): Imix, Ik', Ak'bal., K'an, Chikchan, Kimi, Manik', Lamat, Muluk, Ok, Chuwen, Eb, Ben, Ix, Men, Kib, Kaban, Etz'nab, Kawak, and Ajaw.

Combining both calendrical cycles, the *haab'* and *tzolk'in*, creates a greater cycle, which is usually referred to as the Calendar Round. They were anchored at the zero-date, thus, the Long Count date 13.0.0.0.0 is taken to be *tzolk'in* day 4 Ajaw and *haab'* day 8 Kumk'u.

Maya rulers celebrated time reckoning. They often commissioned new monuments at important stations of the *k'atun* cycle and celebrated anniversaries of their birthdates or enthronements.

3 Eclipse Table

Our knowledge of ancient Maya eclipse predictions comes from the Mayan Dresden Codex table known as the Eclipse Table.[3] The table covers 11,960 days, or 33 years minus three lunar months, and consists of 69 groups of 5- or 6-month intervals associated with 46 rounds of the *tzolk'in* (46 × 260 = 11,960 days). The history of the composition of the Eclipse Table remains unknown, but its layout makes it reasonable to suppose that it was not a new text. The table has two base dates, written in the Long Count format, one corresponding to 755 CE and the other to 1210 CE.

It has been hypothesized that the table is based on earlier (unattested) attempts to predict eclipses using a 135 lunar month cycle (first noticed by Guthe, 1921) known as the tritos (Meeus, 1997: 51, Table 9a) during which a pattern of 23 eclipse possibilities repeats itself. The table represents a modified sequence of three successive tritos series. While it is plausible to suggest that a tritos series was discovered simply by adding two inferior eclipse periods, of 88 and 47 months,[4] following the rule

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[3] In describing the Eclipse Table I am following the discussion given by Bricker and Bricker (2011: 249–366). However, my treatment of eclipses is derived from Britton (1989).

[4] For theoretical justification consult Hartner (1969) and Britton (1989: 8, Table 2).

described by Britton (1989: 8), the knowledge of both cycles has yet to be proved. An important step in this direction has already been taken by Smither (1988) and Justeson (2017), who had argued for the Mesoamerican use of an 88-month eclipse period. The Maya noticed that three repetitions of tritos are commensurate with their divinatory calendar (*tzolk'in*) of 260 days (3 × 135 = 405 months = 11,960 days = 46 × 260). So, the table provides the dates for 69 eclipse possibilities.

As mentioned above, the concept of 6-month intervals appears to have been a significant factor in the establishment of the Lunar Series throughout the Classic period. Some of the scholars may be quick in identifying multiples of 6 months as suitable series to define intervals between any two eclipses (including occasional 5-month intervals). However, this has yet to be proved. My argument for questioning this hasty interpretation derives from the concept of the seasonal year found among the indigenous groups inhabiting the US-Mexican border. The concept of two 6-month periods defined by the solstices appears to have been a primary factor in the determination of rituals among the societies from southern California, New Mexico, and Sonora (Kroeber, 1922: 323; Spier, 1955: 16–30; McCluskey, 1982: 44–47).

According to Teeple (1931: 54–61), who decoded the significance of the Lunar Series, during the so-called "Period of Uniformity", between 687 and 756, all Maya cities utilized 6-months periods keeping the same count. Later research has proved that other versions of Uniformity were in use at different times by various Maya cities (see Aldana, 2006). The problem is that the idea of fixed sequential 6-month periods discards their utility for eclipse tracking because 5-month eclipse intervals also appear. Despite these circumstances, it is not implausible to suggest that the Lunar Series could have occasionally been tied to the eclipses (Brauer, 2013; Justeson, 1989).

Scholars have long recognized that the Eclipse Table was assembled to predict or anticipate eclipses. The history of research shows that the process of decipherment and analysis of the table has undergone significant changes.[5] It also shows that the limited amount of contextual evidence produced differing interpretations. For example, the recent divergences between two sets of interpretations seem to stem from the different understandings of the purposes for which the tables were made.[6] Thus, one group of interpretations suggests that the Mayan day-keepers were attempting to predict the days when the eclipse was expected to occur (Justeson, 2017: 508). An alternative group of interpretations argues in favor of "eclipse seasons" (Bricker & Bricker, 2011: 254), i.e., intervals within about 18 days of the nodal passage of the Moon when eclipses can occur.[7]

Apart from the Table itself, Bricker and Bricker (2011) identified several almanacs in Mayan codices recording eclipses and, together with other astronomical and

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[5] For a general overview of the history of the research of the Eclipse Table, see Bricker and Bricker (2011: 261–275).

[6] This distinction was observed by Justeson (2017: 508).

[7] Bricker and Bricker (2011: 254) define an "eclipse season" as a period of 37 days centered on the node, during which (solar, lunar) eclipses may occur. Justeson (2015: 301–302; 2017: 508) defines an "eclipse station" as a date on which an eclipse (solar or lunar) may be expected to occur.

Fig. 1 Maya eclipse glyphs. Left side: eclipse glyphs as they appear in codices. Right side: eclipse glyph from Stela 3 at Santa Elena Poco Uinic, author’s drawing after Peter Mathews (Schele & Grube, 1995: 156)

calendrical data, used them as a means of provisionally dating of them. Though the almanacs lack the Long Count dates, the methodology devised by the authors allowed them to treat the almanacs both as records of real-time observations and as tools for various weather and agricultural predictions. Ongoing research has proved that during the Postclassic period (1000–1521), eclipses were portents of seasonal weather changes (especially of precipitations e.g., Knowlton, 2003; Vail & Hernández, 2013: 169–174). The almanacs collect links between eclipse and weather events, all set at specific calendrical intervals. Another purpose of the Table was to equate eclipse intervals with the heavenly motions of Venus (Davoust, 1994; Bricker & Bricker, 2011: 214–215, 311–315, 357–366; Vail & Hernández, 2013: 324–328). It implies that for the Maya, the Eclipse Table was a tool for tracking eclipse possibilities while the almanacs served to treat eclipses as weather signs.

The majority of almanacs, which include references to eclipse events, refer to the Postclassic period (1000–1521) while the Eclipse Table appears to have been composed originally during the Late Classic (600–800) recording eclipses for the epoch around 755. It remains a puzzle as to what observation practices and earlier rules of thumb provided the structure for the Eclipse Table, which comes from previous schemes of computations (Justeson, 2017). It should be noted that in the absence of any observatory records, the form and structure of the Table remain our primary source of the methods by which the Mayas determined eclipse possibilities.

The Table contains a glyph for which the meaning of “eclipse“has been suggested (Macri & Vail, 2009: 174). It consists of two “wings”, one is white, and the other is black (see Fig. 1). A “sun“or a “moon“sign occupies the central part of the glyph, possibly referring to solar or lunar eclipses. Recent epigraphic research on the reading of this glyph is ambiguous. Prager (2006) found that the glyph means *nam* “to hide, conceal”, while Love (2018) proposed to read the glyph as *yihk’ in* “darkened (*yihk’ in k’ in* “darkened sun“and *yihk’ in uh* “darkened moon“, respectively).

Even though the Maya considered eclipses as important portents (Sánchez de Aguilar, 2008: 143–144), it is generally accepted that, with few exceptions, glyphs for “eclipse” are almost exclusively found in the codices. One of the monumental texts that scholars have interpreted as a possible eclipse record is found at at Santa Elena Poco Uinic, a seat of a small Late Classic kingdom situated among the areas of influence of three regional polities located in Toniná, Bonampak, and Chinkultic (Taladoire, 2015: 58–59, Map 1). The archaeological remains of the site were first brought to light by Enrique J. Palacios (1928: 109–140), who visited the site in 1926 and provided photographs, drawings, and a detailed description of its Stela 3. Palacios (1928: 139) supposed the glyph in question denoted the equinoxes or solstices, but his reading of the text was not correct. It should be observed that the text displayed on the upper part of the stela is almost unreadable because of damage. Two years later, Frans Blom visited the site and was able to correctly date the text (Palacios, 1928: 115). Subsequently, Teeple (1931: 115, Fig. 19) reproduced the glyph, which he identified with a total solar eclipse of 16 July, 790 (see Fig. 1b). The value of a possible eclipse record as a means of providing an absolute chronology to the Maya Long Count was also quickly acknowledged and Teeple (1931: 115) used this information to support the G-M-T correlation.[8] Later, Thompson (1935: 74), who, at that time, proposed his own correlation constant with JD 584,285, used the date of the solar eclipse to discredit the correlation proposed by Martínez (JD = 584,281), though he noticed that the date of the solar eclipse was correct only if the correlation 584,286 (JD 584,286 = 13.0.0.0.0 4 Ajaw 8 Kumk'u) was used. The lack of agreement on the correct calendar correlation has recently motivated Martin and Skidmore (2012), who revived the validity of a 584,286 correlation. Such oversimplified statements must be used with care.

Despite the remoteness of the site, Mathews (2006) visited the place, providing up-to-date information on the Stela 3 hieroglyphic text. Stela 3 was commissioned by Yax B'alam, a local ruler who was in power from 782 to 790 (?) and recorded a series of events in his life culminating in a monument dedication at the period-ending date 9.18.0.0.0 11 Ajaw 18 Mak (790). Likely carved around 9.18.0.0.0, it bears information which uses the eclipse glyph, referring to the total solar eclipse that occurred 84 days before the monument dedication. A total solar eclipse is, without any doubt, a remarkable event that could have still been recorded while preparing the text for the monument. Table 1 lists the events displayed on Stela 3.

All events fall within 24 years, from 766 (the birthdate of the ruler) to 790 CE (stela dedication). At this point, it is necessary to notice that though the Maya usually commemorated period endings based on the *tun* (*winikhaab'*) cycles of 360 days, they occasionally celebrated *haab'* (365-day cycles) anniversaries. Calendrical manipulations are identifiable through the repetitive use of 14 Kej and 5 Kib dates. So, when Yax B'alam acceded to the throne, he was exactly 16 *haab'* years old. Curiously, this period of 5840 days equals ten canonic synodic Venus cycles. On the day of his enthronement, the planet was around the same phase as on his birthdate, perceived in the sky as the Evening Star, approximately 177 days (or 6 lunar months) after the superior conjunction (Meeus, 1995: 422). On the other hand, the date associated with the solar eclipse uses *tzolk'in* multiples: it falls 11 × 260 days after Yax B'alam's accession. It is also noticed that 11 × 260 = 2860 days

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[8] The starting point of the Maya Long Count, 13.0.0.0.0 4 Ajaw 8 Kumk'u, according to the Goodman-Martínez-Thompson 2 (GMT2) correlation is taken as 11 August, 3114 BCE (proleptic Gregorian) which is (at noon) a Julian Day Number (JD) of 584,283. This correlation is used by Bricker and Bricker (2011). The so-called GMT family of correlations produces correlation constants between JD 584280 (= 8 August, 3114 BCE) and JD 584286 (=14 August, 3114 BCE). For more details, consult Kelley (1976: 30–33; 1983: 157–160) and Bricker and Bricker (2011: 90–99).

Table 1 Date in the hieroglyphic text of Stela 3 of Santa Elena Poco Uinic. All data from Mathews (2006)

No.	L.C. date	Calendar round	Correlation constant 584,283	Event
1.	9.16.15.10.16	2 Kib' 14 Kej	17, Sep, 766	Birth?
2.	9.17.11.14.16	5 Kib' 14 Kej	13, Sep. 782	Enthronement
3.	9.17.19.13.16	5 Kib 14 Ch'en	13, Jul. 790	Solar eclipse
4.	9.18.0.0.0	11 Ajaw 18 Mak	5, Oct. 790	period-ending, Stela Planting,

Observe that the total solar eclipse occurred on JD = 2,008,802 corresponding to 16 July, 790 (Julian) favoring the use of correlation constant 584,286. The 3-day shift in dates reflects the uses of different correlation constants

equals 8 × 360–20 days. Such peculiarities always raise questions about calendrical manipulations concerning astronomical events. The eclipse date offers an opportunity to check whether the inscriptional record on Stela 3 represents the knowledge recorded in the Eclipse Table.

The introductory section to the Eclipse Table provides three entry dates that allow it to be anchored in the Long Count. Though those entry dates consist of the Long Count and *tzolk'in* dates lacking the corresponding *haab'* cycle, scholars instead unanimously regard them as the dates given in the Long Count format as is given in case of monumental inscriptions. Lacking month names are given within the brackets. In what is written below, the lacking *haab'* details are inserted into the brackets. As seen, the dates are spaced by 15 days and painted either in black or in red:

9.16.4.10.8 12 Lamat [1 Muan] black
  9.16.4.11.3 1 Ak'bal. [16 Muan] red
  9.16.4.11.18 3 Etz'nab [11 Pax] black

Bricker and Bricker (2011: 276) determined that these dates denote 31-day intervals[9] and found that they can be compared to eclipse seasons, i.e., periods during which eclipses (lunar and solar) are possible. In other words, the dates of 9.16.4.10.8 12 Lamat [1 Muan] and 9.16.4.11.18 3 Etz'nab [11 Pax] functioned to indicate the limits (or the width) of the interval around the node within which eclipses were expected to occur. Astronomically, each such season can last between 31 and 37 days. Each of those three dates initiates a string of days that run through the entire cycle, finishing after the completion of 11,960 days. Bricker and Bricker (2011) tracked three strings of dates, separated by 15 days, examining their functioning at each of 69 eclipse seasons, noticing that at least one of those dates was found within the limits of each of those eclipse seasons (Bricker & Bricker, 2011: 277–282, Tables 9-2). They also found that the eclipse season shifted in relation to the three strings of dates provided by the table, so the inclusion of a 5-month group

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[9] Though it contains two 15-day periods, they count as 31 days because reckoning is from the last day before the start of this interval.

instead that of a 6-month group could have ceased this shifting for a while (Bricker & Bricker, 2011: 283, Figs. 9–17). After finishing the first round, another series of three dates start with different Long Count and *haab'* dates:

9.16.4.10.8 12 Lamat [1 Muan] + 11,960 days = 9.17.17.14.8 12 Lamat [16 Yax]
9.16.4.11.3 1 Ak'bal. [16 Muan] + 11,960 days = 9.17.17.15.3 1 Ak'bal. [11 Sak]
9.16.4.11.18 3 Etz'nab [11 Pax] + 11,960 days = 9.17.17.15.18 3 Etz'nab [6 Kej]

However, the cycle of eclipse seasons moves backward by (at least) 1 day per cycle. Contrary to the suggestions of other scholars, Bricker and Bricker (2011: 291–292) proposed to retain the starting point on 12 Lamat but instead to shift 1 day backward the start of the eclipse season. The first recycling and the inception of eclipse season start on 12 Lamat. The second round starts with 12 Lamat again; however, the eclipse season begins a day before, on 11 Manik' (Bricker & Bricker, 2011: 292). The second recycling of the Table will be important here because it leads to the date of the solar eclipse displayed on Stela 3.

The second round starts with the count of 6, 6, and 5 months (177, 177, and 148 days, respectively) corresponding to the numbers in columns 1 (=70), 2 (=71), 3 (=72). Moving on, and crossing the drawing, we reach the next column of 177 days (6 months), summing up to 679 days from the start (see Fig. 2). It is necessary to subtract 1 day from 2 Manik' to arrive at [9.17.19.12.6] 1 Kimi [4 Mol] to find out the eclipse season. This date begins the eclipse season which moves twice 15-day periods forward:

[9.17.19.12.6] 1 Kimi [4 Mol] + 15 = [9.17.19.13.1] 3 Imix [19 Mol] + 15 = [9.17.19.13.16] 5 Kib 14 Ch'en

In other words, using the layout of the Eclipse Table and following the rules suggested by Bricker and Bricker, it is possible to find out that the date displayed on Stela 3 at Santa Elena Poco Uinic indicates eclipse possibility. It is important to

6 K'an	1 Imix	6 Muluk	FIGURE	1 Kimi
7 Chikchan	2 Ik'	7 Ok		2 Manik'
8 Kimi	3 Ak'bal	8 Chuwen		3 Lamat
177	177	148		177

Fig. 2 Scheme of eclipse computations on Dresden 53a (after Villacorta, Antonio, & Villacorta, 1976: 116)

observe that Bricker and Bricker (2011) apply the 584,283 correlation constant. The borders limiting eclipse seasons are wide enough to accommodate various GMT correlation constants. It only shows that attempts to establish correlation after examining only one case are doomed to failure.

4 Determining the Lunar Series for Santa Elena Poco Uinic Stela 3

Unfortunately, Stela 3 does not record the Lunar Series. The eclipse date only identifies the day of the new moon. The eclipse date is only 84 days before the *k'atun* ending at 9.18.0.0.0, and since the Maya often commissioned monuments to celebrate such period endings, it is possible to find lunar records attached to that date. By adding 84 days (= 59 + 25 days),[10] we arrive at the Moon Age of 25 days at 9.18.0.0.0 (84 = 59 + 25). The moon age reckoning can vary from polity to polity and has never been defined clearly. The starting point of the Maya lunar month may be counted from the day of any of the three: last visible old moon/first invisible moon ("last moon"), astronomical new moon ("new moon"), or first visible lunar crescent ("first moon"). Unfortunately, the only legible lunar records are found in north-central and eastern Maya regions, located relatively far from Santa Elena Poco Uinic (see Table 2). So they may convey different numbers of days of the age of the Moon. The critical distinction here is the day of the solar eclipse, since it precisely defines the moment of the astronomical new moon. In this case, one would expect the moon age to be determined with care, from the (astronomical) new moon date corresponding to the solar eclipse.

In spite of this, the Lunar Series inscriptions for 9.18.0.0.0 (Table 2) show that Mayan polities used different ways of determining the Moon age. A 3-day shift in calculating the moon age is noticed. It can only be explained by different moments of the lunar cycle previously selected to mark the start of each month (see Fig. 3). Thus, the moon age of 23 or 24 days implies that the start of the count was on the day when the lunar crescent was first observed in the sky. The moon age of 25 days indicates the starting point at the new moon (eclipse date). Finally, the moon age of 26 days means the start of the month with the first invisibility of the moon.[11] In this way, the eclipse record helps to capture the differing times of the start of the lunar count month. Interestingly, no evidence from Table 2 matches lunar reckoning from the astronomical new moon.

Conclusions derived from the last section cannot be considered as definitive. The question of finding the proper layout of schematic lunar months must be revised in light of the lunar data painted on the walls of a late eighth-century Structure 1 at Bonampak. Room 1 contains the courtly scene, with the participation of the

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[10] It should be reminded that the Maya used schematic 29-day and 30-day months.

[11] For the sake of space I assume the Maya tallied the moon from zero through 29 or 30.

Table 2 Occurrences of the Lunar Series on 9.18.0.0.0

Site	Monument	Lunar Series			Source
		Moon age (Glyphs E and D)	Semester (Glyphs C + X)	Lunar Month (Glyph A)	
Calakmul	Stela 80	26	5Cj	30	Ruppert and Denison Jr (1943: 119)
Ixkun	Stela 1	24	6C[j] X6	29	Laporte and Mejía (2005: 177–178)
La Muñeca	Stela 4	23	4C		Ruppert and Denison Jr (1943: 124)
Nim Li Punit	Stela 21	24	6Cj III.6/X-iv	–	Stuart and Grube (2000)
Quirigua	Zoomorph O	23(?)	6Cj] III.6/X-iv	30	González and Eugenia (2012: 186)
Sacul	Stela 9	23	6Cj III.6/X-iv	29	Escobedo (1993: 11)
Lunar Uniformity		24	6Cj	29	Author's own calculation

Glyphs D and E give the day of the lunar month, or the moon age, up to 29 or 30 days. Glyphs C and X inform about the number of the month in a cycle of 6 and 18. Each semester is identified by three distinct head variants: the Death God (s), the Tonsured Maize God (m), and the Jaguar God of the Underworld (j). The forms of Glyph X follow the proposals by Rohark (1996) and Grube (2018). Finally, Glyph A gives the length of the schematic lunar month (either 29 or 30 days)

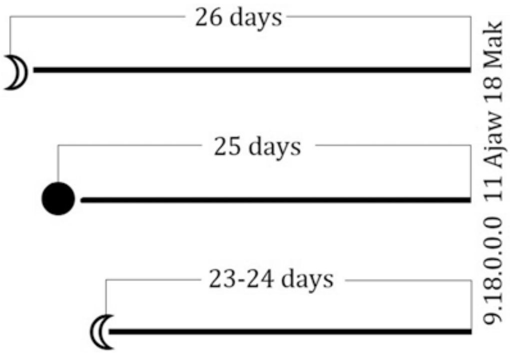

Fig. 3 Different moon ages according to various possible starts of the lunar month. Author's drawing

Bonampak ruler Yajaw Chan Muwan II, who reigned between 776 and 795 (Bíró, 2011: 252–259).

The date 9.18.0.3.4 (790) falls 64 days after the celebration of *k'atun* ending at 9.18.0.0.0 and is associated with the Lunar Series. What makes the text even more interesting is that this date is 148 days (5 lunar months) after the solar eclipse recorded at Santa Elena Poco Uinic (Schele & Grube, 1995: 158). These circumstances allow a new insight, at the regional level, into the complexity of the moon reckoning. As is usual, the reading of the record is not fully legible. It probably gives no numerical statement to describe the moon age. Since the descriptive forms of Glyph D usually refer to the "dark moon", the period when the moon is not visible, it may describe the new moon phase. Glyphs C, X, and A are fairy legible denoting 3Cs I.4/X-vi 30, so in total, it should be read as 0 or 1 3Cs 30. The number of 148 days agrees with three 30-day months and two 29-day months. Using the data from Table 2 and Fig. 2, we arrive at the following possibilities:

1. [0 4Cj 30] + 84 = 24 6Cj 29 + 64 = 0D 3Cs 30

The month sequence is 30-30-29-30-29-30 days, so the 3rd month is that of 6Cj 29. Months with 29 days appear in Sacul and Ixkun, but the number of days associated with the moon age suggests the start of the month 2 days later, probably with the first-sighted lunar crescent day.

2. [0 4Cj 30] + 84 = 25 6Cj 30 + 64 = 0D 3Cs 30

The month sequence is 30-29-30-30-29-30 days, so the 3rd month is that of 6Cj 30. This lunar reckoning is similar to that of Calakmul (though the month numbering is different). The Calakmul moon age suggests the start of the month with the disappearance of the moon, a day before the new moon day.

Lack of concern for the inclusion of eclipse dates into the Lunar Series at sites mentioned in Table 2 contrasts with later, Postclassic manuscripts and colonial epoch sources, where eclipses are perceived as portents for dangerous events.

5 Conclusions

Concepts regarding the lunar cycle are but one form of engagement with the heavens. They represent a particular point of view that is embedded in social networks and relationships with the surrounding world, rather than in a fixed body of current knowledge. The lunar cycle was often reckoned according to local computing schemes, determining the time for the start of a month, reckoning a particular 29-day month while others might count a 30-day month instead, or changing the numbering of the month. The Lunar Series associated with the Long Count was intimately related to the lives of the rulers who, through ritual action, erected monuments on calendrically significant dates. Sometimes, the rulers assumed control of the Lunar Series and could initiate new calculating schemes when they started to reign (Fuls, 2007: 279).

Though the Lunar Series can have intervals correlating to eclipses, the Lunar Series was, in many ways, a local expression of the type of engagement with the nocturnal landscape. According to Houston et al. (2006: 85–87), the rulers themselves embodied time and its passage, so their power over the Lunar Series should be viewed as a means of asserting the idea of divine kingship. It remains to determine whether eclipse predictions were under the control of the rulers.

The research perspective on Mayan Eclipse Table and Stela 3 from Santa Elena Poco Uinic, which I hope to show here, makes it evident that the reconstruction of astronomical methods should not be entirely dependent on or guided by calendar correlations.

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Part III
Heritage

The contribution of Clive Ruggles to the study of Cultural astronomy has been seminal also in his collaboration with ICOMOS and IAU's Commission C4 towards placing Cultural Astronomy (and Archaeoastronomy) on the World Heritage List. In his own research, Ruggles had already indicated the significant relationship between the study of astronomy and heritage several years earlier (e.g. Ruggles, 2000). This research paved the ground for acknowledging the importance of astronomy in world heritage. Several of his papers have explored and converged on the importance of locations from where astronomical observations were made, rendering these places significant cultural landmarks both for ancient and modern cultures (Ghezzi & Ruggles, 2007; Ruggles, 2010a, 2010b, 2020; Simonia, Ruggles, & Chagunava, 2008). Ruggles' work recognised this tight relationship and this is perhaps most evident in his research in Hawaii and the Pacific, which is pioneering in going beyond the study of the complex relationships between the Hawaiian temple system, landscape, and the heavens, to preserve also ethnographic material (Johnson, Mahelona, & Ruggles, 2015). Ruggles poured his vision on astronomical heritage into his long-term engagement with what later evolved to the IAU Commission C4 on World Heritage and Astronomy (formerly IAU's Working Group on Astronomy and World Heritage) and produced the first thematic studies in science heritage. It was the first time the study of astronomy, and more importantly the study of ancient astronomy, had achieved such a universal milestone. The two ICOMOS-IAU Global Thematic Studies on Astronomical Heritage (Ruggles & Cotte, 2010, 2017), present a universal vision on astronomical heritage and set the blueprint for what entails astronomical "outstanding universal significance to humankind" and associated issues. By doing so, they set the groundwork for identifying universal astronomical significance to humankind.

All the papers in this section relate to Ruggles' work towards establishing a strong Heritage of Astronomy.

Michel Cotte, who has collaborated with him since the early steps of promoting the Heritage of Astronomy in 2009, under the auspices of ICOMOS and has joined efforts in developing a World Heritage list, recounts Ruggles' contribution to these developments and the importance of including Scientific Heritage on the World

Heritage list. Cotte describes how Ruggles' efforts changed the perception of archaeoastronomy from a marginal sub-branch of archaeology, to a subject that has impacted the preservation of heritage. The paper outlines his contribution to viewing astronomy beyond the modern concept of 'true' science—perceiving the discipline as a modern achievement cut off from its past—by embracing its historic development through the millennia. The paper also considers Ruggles' contribution in attracting awareness and establishing the astronomical significance of an array of remarkable sites across the globe, eventually resulting in their listing as World Heritage sites.

This aspect of Ruggles' work is exemplified in Ghezzi's paper, which presents the importance of cultural astronomy in heritage through an analysis of the site of Chankillo in Peru, a site on which Ghezzi and Ruggles collaborated for a number of years. The discussion offered on Chakillo as a unique example of a calendric observatory and a site which encompasses the significance of landscape, astronomical practices, and ancient engineering, demonstrates aptly the cultural impact of astronomy. This impact is twofold: first as a science—for enabling ancient societies to structure and organize their existence by tracking the seasons and timekeeping—and secondly through the immense cognitive impact of astronomy in allowing ancient societies to understand and comprehend the cosmos, particularly when combined with religion. For ancient cultures, astronomy and religious practice have a particularly tight relationship demonstrating in the most palpable manner the inseparability of astronomy from the shaping of cosmovisions, and thus from forging and maintaining identities. The discussion on the carefully timed and staged religious performances at Chankillo, resulting in hierophany, enhanced the sense of identity and cohesion within the group, whilst reaffirming the established social and religious outlook of these peoples.

The final paper in this section, by Gudrun Wolfschmidt, offers an outward outlook towards the future development of the Heritage of Astronomy by considering future submissions of Observatories to the UNESCO World Heritage List, dating between the Renaissance and the twentieth century. Although it focuses on observatories which bear significant cultural importance, the paper considers also the instruments associated with these structures, offering thus a complete and valuable list for potential future work on the Heritage of Astronomy. The paper addresses the UNESCO requirement that renders ineligible for the World Heritage list candidates which are either missing the original buildings or are heavily damaged. It suggests a resolution by proposing the inclusion of such sites in an independent IAU list of cases of "outstanding Astronomical Heritage", for which the condition of preserved architecture is not a requirement.

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Finally, A Very Fruitful Interdisciplinary Cooperation…

Michel Cotte

I don't remember exactly the date and circumstances of my first meeting with Clive Ruggles. It was surely during a meeting related to the question of astronomical heritage, where I represented ICOMOS (the International Council of Monuments and Sites). Initially, the World Heritage Centre recommended to the IAU Commission members to meet ICOMOS and to examine a possible joint venture to promote the heritage of astronomy. It seems for me that happened October or November of the year 2008, in the ICOMOS office in Paris, and a working relationship was launched at the end of 2008, that quickly developed early in 2009.[1] Context was the joint UNESCO and IAU international year of Astronomy (2009), which strongly stimulated initiatives and meetings of different bodies and persons.

If I do not remember very well the location and exact topic of this initial meeting, I clearly remember the first impression given by Clive's character. I immediately perceive his Latin volubility and prompt movement of arms and face illustrating his talk; that sounded as something unexpected from a British citizen but very sympathetic. In other words, it is not possible to ignore Clive's personality among a range of experts and scientists drawn from many scholarly fields.

At that time and perhaps even today, ICOMOS and beyond ICOMOS the World Heritage Committee were not very much aware of scientific heritage and didn't pay notable attention to it. As usual, what is not well known by an individual or a community has little importance and value for them. Furthermore, at that time, some notable nomination projects of scientific heritage had met important difficulties

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[1] The two most ancient joint mutual working documents in my personal archives are: an orientation paper from Clive related to "Astronomy and World Heritage" including a series of comments from I from December 2008, and the first version of the Thematic Study Plan mutually elaborated from January 2009.

M. Cotte (✉)
University of Nantes & ICOMOS, Nantes, France

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along ICOMOS evaluation and were recommended as "not inscribed" on the World Heritage List. So the atmosphere was not very positive and not very constructive on the side of the World Heritage Convention. Nevertheless, some astronomers and scientists, as Clive, remained enthusiastic and thought it would be relatively easy to reach the World Heritage List; that what they needed were some good examples supported by committed stakeholders.

For ICOMOS there were notable difficulties with astronomers related to heritage at that time. The first one issued from the marginal status of archaeoastronomy among archaeologists during the 2000s. World Heritage recognition of classical archaeological sites was already very important on the List, coming from every parts of the World and supporting at each time a large set of cultural evidences issued from ancient civilisation perceived as a whole: architecture, urbanism, material life and symbolic associated value. Therefore, archaeologists had long been an important and influential group inside ICOMOS. For them, and consequently for ICOMOS, archaeoastronomy seemed to be a not very important branch in the global field of archaeology. It was perceived as a contextual attribute offering complementary information about the knowledge and beliefs of past civilisations, not more. It could not be a sufficient argument by itself to demonstrate an "outstanding universal value" for a given archaeological site. Furthermore, and to be honest, archaeoastronomy seemed for some of us not totally serious and a bit presumptuous, either related to an excess of hypotheses or to offering not totally convincing interpretations of celestial relationships, dealing with numerology and mania of sky influences on both human beings and nature.

A second matter of discordance was the idea that starlight at night could be a possible World Heritage nomination. It was supported and promoted by an active and enthusiastic group of astronomers. They thought that it was a brilliant idea, totally international and somewhere deeply ecologist; so people that do not understand, especially inside the World Heritage community, had a somewhat rigid brain and a total lack of imagination. Indeed, ICOMOS and other Convention advisory bodies had notable doubts about such an idea and they thought the Convention could not be applied to that question. Other tools were developed at that time as "Starlight Reserves" and seemed both better adapted to the idea and more pertinent. They thought that astronomers, even very sympathetic persons as Clive and some others, were not aware to be totally out the scope of the WH Convention and somewhere dreamers…

An associated question rose spontaneously, as frequently when a new heritage field emerges. Western countries had immediately site examples in their countries related to it and possibly applicant for the WH List … The study of European astronomical observatories issued from modern science was immediately promoted, both as monuments and evidences of the boom of astronomy in Europe and North America. Of course, it was legitimate to pay attention to nineteenth–twentieth century modern astronomical heritage, but one of the major missions of the Convention is to enlarge the concept of heritage to a large set of geographical areas and large diversity of civilisations and epochs.

The starting point of cooperation did not seem very promising, with notable possibilities of misunderstanding, but different factors played a decisive role; among them, the character of Clive and his open mind related to the World Heritage process played a decisive role. He early understood the existing gap between the willingness of the Astronomy and World Heritage Working Group of IAU Commission 41 on the History of Astronomy and the complex implementation of an international Convention, beyond diplomatic smiles and formal approvals. Consequently, he correctly appreciated the possibility of practical help and cooperation with ICOMOS, even if this body seemed *a priori* the most reluctant to his arguments.

On the side of ICOMOS, the situation related to scientific and technical heritage at that time was a bit controversial but under rapid evolution. On one hand, technical heritage, especially industrial heritage, achieved some notable successes in the listing process during this period. It was perceived as a promising new field of heritage with its monumental and specific architecture bearing a new set of value related to materialism, daily life and visible technology. Science heritage, in general, doesn't offer such range of obvious evidences and values and it was more complex to analyse in heritage terms. The paradigm of science heritage seems more sophisticated, relying upon a larger set of both tangible and intangible values, focusing more on instruments, experiments and scientific way of thinking than impressive architecture or monumental machines. So, the situation for science heritage was not so favourable and rare nominations in the field were matters of important debates inside the ICOMOS panel.

Nevertheless, a short number of ICOMOS advisers, I was among them, were sensitive to the potential and to the need of scientific heritage on the WH List; but for reaching such a goal, a new approach of scientific heritage and a complete work of confrontation for every facet of the heritage had to be launched and studied. Heritage of astronomy and archaeoastronomy offered to us an excellent study situation, with real possibility of interdisciplinary joint works. But human resources seemed largely unequal: on one hand a strong group of astronomers already trained to work together, deeply involved in the subject and willing it success; on the other hand mainly two persons mandated by the ICOMOS board: Mrs. Regina Durighello as director of the international secretary and myself. Regina was a key technical support and organizer for the Thematic Study. I acted as adviser in charge of the conformance of the different issues of the project to the World Heritage Convention implementation, both in text and spirit.

Launching together the Thematic Study was an adventure, a rich and productive adventure, which involved different working meetings with Clive, involvement in conferences and permanent exchanges during 4 or 5 years. Indeed, that is still the case today, but in a post Thematic Study way and more related to projects of nomination to the World Heritage List. An initial big question was to determine the goal and plan of the study, and second to gather a network of authors with sufficient individual competences related to the subject. Ambition was great even perhaps too much, to cover both a geographical and chronological ensemble as larger as possible, without *a priori* limits.

This program aimed to cover different regions and different civilisations of the World with equal treatment, e.g. a same importance for studying each case. In some situations, it was difficult to explain to some astronomers that option because for them astronomy started really with modern observatories and the independence of "true" science from popular beliefs such as astrology. Obviously, many past civilisations, and even European ones, were relied strongly both on rational observation of the sky and irrational beliefs. As we stated in the introduction: Every civilisation looked at the Sky and built a cosmology, and as stated in the conclusion: Astronomy is never alone and pure knowledge, but it must be understood in context.

At this step, archaeoastronomy gave us a pivotal point for credibility in two different ways, and it bore us a practical example of mutual reinforcement of our own requirements. As already stated, at that time, archaeoastronomy needed to be accepted as an autonomous field relying upon clear scientific assessment and methodology. The Thematic Study was a good opportunity to develop it in such a way and to confront it to different specialists from other academic fields, especially to develop structural relationships with other facets of archaeological methods and results. On the other hand, for the acceptance of the Thematic Study programme by a majority of contemporary astronomers we also needed to credibly treat the question of rational observation of the sky by different kinds of civilisations, relying on strong studies in archaeoastronomy.

The Thematic Study of astronomical and archaeoastronomical heritage was also ambitious related to the former ICOMOS Thematic Studies. It aimed to go beyond a simple analysis of categories and subcategories. First thematic studies frequently acted as a kind of pre selection of heritage themes or pre listing of remarkable places, consequently encouraged to prepare a nomination file. We tried to go beyond and to propose a real development of the theme of astronomical and archaeoastronomical heritage, first by a global overview of some major civilisations or epochs or cultural situations of "indigenous people". This did not forget the aims of the World Heritage Convention, helping to prepare an inventory of attributes, both tangible and intangible, and their understanding in context. It had to help to prepare conservation and valorisation of comprehensive places for visitors. Some examples of site strongly related to the selected themes of Thematic Study were studied in the global point of view of inventory and analysis issued from the experience of Convention implementation. They give examples of applied methodology to astronomical and archaeoastronomical heritage, but they are not a statement of value in anyway. Such ambitious goals have been met, thanks to authors and to the pivotal role of Clive acting as an efficient mediator between ICOMOS guidelines and remarks to individual authors studying field examples, with many back and forth of texts. The introduction and conclusion of the study by Clive and myself offered a wonderful opportunity of a joint work, exerting our mutual criticisms in a positive way and showing progressive convergence and enrichment of our personal ideas and concepts.

The Thematic Study works themselves were developed by a group of 40 authors coming from around 15 different countries including Europe, Middle East, Eastern Asia, India, Pacific, Latin America and North America. They worked during the years 2009 and early 2010. Volume one includes 16 chapters from early prehistory to space conquest from the end of twentieth Century. An electronic version was ready for June 2010, and it was officially presented to the 2010 plenary session of the World Heritage Committee in Brasilia (Ruggles & Cotte, 2010). The paper version was published in August 2011 (Ruggles & Cotte, 2011). A second volume could be edited some years after as a complement of the first, with some more conceptual point of view, e.g. about the concept of dark sky and its possible use for preparing credible WH nominations (Ruggles & Cotte, 2017). It contains also some important individual case studies in the field of astronomical and archaeoastronomical heritage. It was published in 2017 as joint thematic study by ICOMOS and IAU (Ruggles & Cotte, 2017).

In parallel, we assisted to some nominations of remarkable places illustrating the dynamic of the astronomical heritage, some years after the initiative; that was due to the duration of dossier writing and preparation of a complete management plan for a given site, which is never simple because of numerous stakeholders and variety of interests related to World Heritage sites. We can mention: Risco Caido cultural landscape in Gran Canarias for archaeoastronomy and Jodrell Bank radio astronomical observatory in United Kingdom. Another archaeoastronomical exceptional site is under evaluation for Peru, at Chankillo, with some reasonable hopes to get inscription by the World Heritage Committee of 2020. Finally, I wish to thank warmly Clive for his fine cooperation and permanent involvement even when his life crossed a horrible family drama. Thanks Clive for all you did.

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The Chankillo Solar Observatory and Ceremonial Centre: A Heritage for the World

Ivan Ghezzi

1 General Aspects

The Chankillo Solar Observatory and Ceremonial Centre (48.470 ha; 250–200 BC) is a planned prehistoric site with astronomical, ritual, defensive and administrative functions that integrates into its landscape by taking advantage of distinctive elements of the near and distant natural horizons for use as astronomical markers (Ghezzi, 2016). It is located on the north-central coast of Peru (NW of South America: 9°33′18″ Lat.S, 78°14′14″ Long.W), Ancash department, Casma province and district, 15 km east of the Pacific Ocean and 12 km south of the city of Casma (Fig. 1). The site faces the steep western slopes of the Andes Mountains (80–1180 masl), on a desert that has remained practically without major geological changes since the Pleistocene. Its surroundings are adjacent to the irrigated valleys of the southern branch—called Casma or Grande river—of the Casma and Sechin river basin, and made up of mountains, rocky outcrops, dry ravines, sand ramps and dunes, and carob tree forests, which largely retain their original conditions, but with considerable fluctuations in the course and the size of the river that have shaped the area into two different parts: on the one hand, a mountainous area formed by Mucho Malo mountain, and on the other, wide sand ramps and low hill chains occupied by the Chankillo site. From the latter, Mucho Malo forms a near, elevated horizon, while in the direction of the Chankillo site axis (118.8°), the horizon is distant, and relatively low. Additionally, the terrain includes a 1200 m tall mountain range to the West, which prevents the winter fog, common in coastal Peru, from entering this part of the valley, and creates exceptionally favorable conditions for the observation of celestial objects (Ghezzi & Guadalupe, 2013).

I. Ghezzi (✉)
Pontifical Catholic University of Peru, Lima, Peru
e-mail: ighezzi@idarq.org

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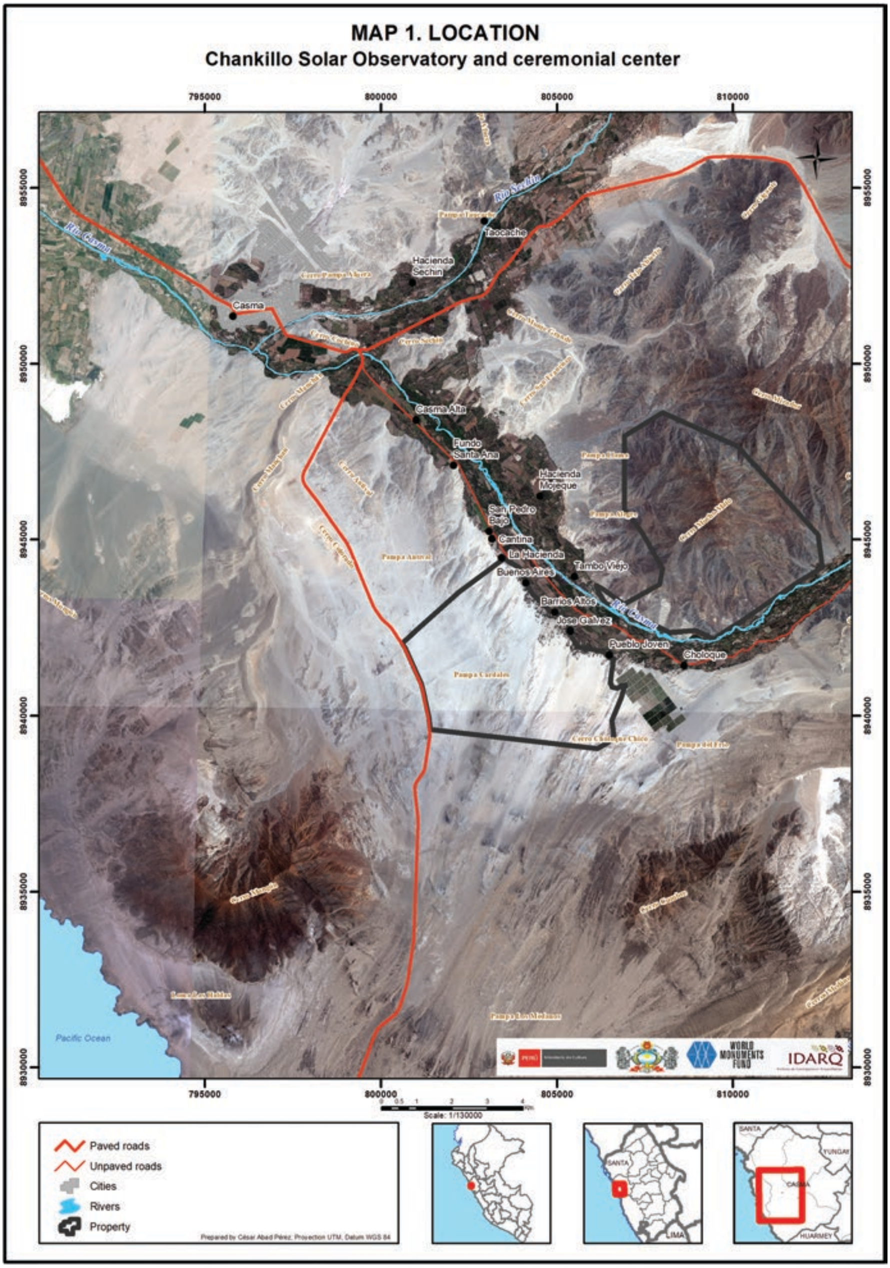

Fig. 1 General location map of Chankillo (country, department, province)

Multidisciplinary research and conservation carried out at Chankillo since 2001 (De las Casas, 2018; Ghezzi, 2002, 2003a, 2003b, 2004, Ghezzi & Rodriguez, 2015; Ghezzi, Salcedo, & Alvarez, 2013; Ghezzi, Suarez, & Navarro, 2017; Ghezzi et al., 2013; Ghezzi, Alvarez, Suarez, & Navarro, 2018; Ghezzi, Alvarez, Navarro, & De las Casas, 2019a, 2019b; Ghezzi, Gamboa, Cruz, & Romero, 2014; Ghezzi, Gonzales, Gargate, & Barrientos, 2014; Garcia, 2017; Guadalupe, 2012; Huayhua & Sueldo, 2018; Magadan, 2012; Morales, 2011, 2018; Moran, 2014; Padilla, 2017; Paz, 2017; Ruggles, 2017; Salazar, 2013a, 2013b; Vasquez, 2017) have allowed documenting and interpreting the site's chronology and construction history, as well as the functions and architectural details of many of its buildings, the relationship between astronomy and the set of associated cultural processes, and the violence with which the Fortified Temple was attacked. Two themes stand out: the visual integration of elements of the landscape, both natural and constructed, as indicators of the cyclical passage of the sun; and the relationship between war, power, and ideology, on which Chankillo gives us empirical information that is thus far unparalleled in the archaeology of the Andes. The span of the construction, occupation, destruction, and abandonment of Chankillo is very short, apparently lasting less than half a century, based in a large sequence of cultural materials dated by relative (pottery styles) and absolute (^{14}C and wiggle matching of dendrochronologically ordered ^{14}C dates) methods (Ghezzi, 2016).

2 Chankillo Monumental Archaeological Zone

It is the area occupied by Chankillo, a prehistoric ceremonial centre dedicated to a solar cult. Its orientation is defined broadly by the alignment between the single restricted entrance on the atrium of the Temple of the Pillars and the single direct entrance to the Administrative Centre (Fig. 2a, b), defining a site axis with an azimuth of ~120° that connects the Temple of the Pillars, the centre of the Observatory Building and the Administrative Centre, and passes through the gap between Towers 12 and 13, where the southern end of the line of towers bends round until it is perpendicular to the axis. This orientation is maintained throughout the site —even buildings not along the main axis share it—and it is broadly solstitial (Ghezzi & Ruggles, 2011a, 2011b, 2011c). The main buildings are the Fortified Temple (Fig. 3a, b), the Thirteen Towers (Fig. 4a, b) and Observatory Building (Fig. 5)—components of the Chankillo Solar Observatory—, and the Administrative Centre (Fig. 6a, b).

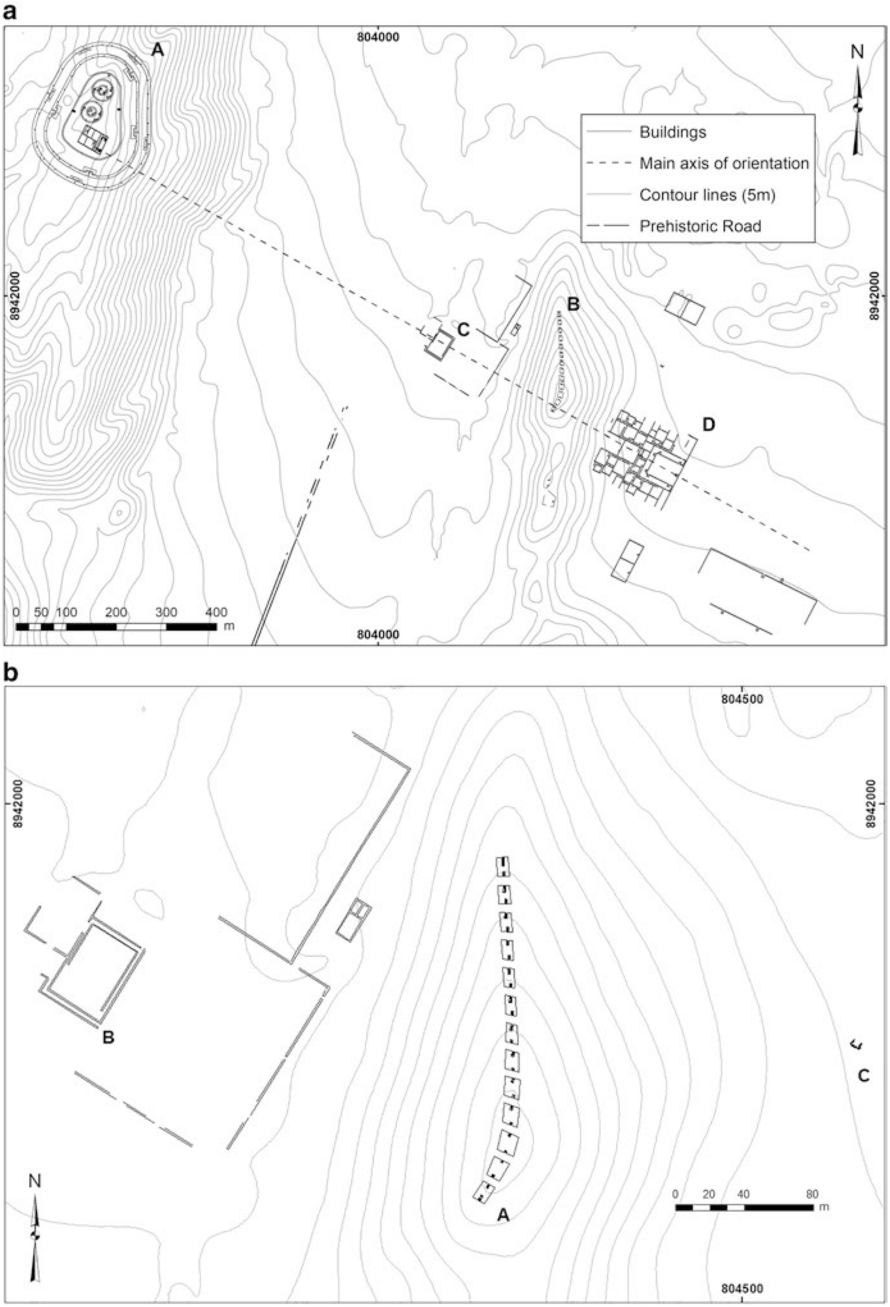

Fig. 2 Map of the main Chankillo monuments: (**a**) plan view and topography; (**b**) detail of the Chankillo Solar Observatory

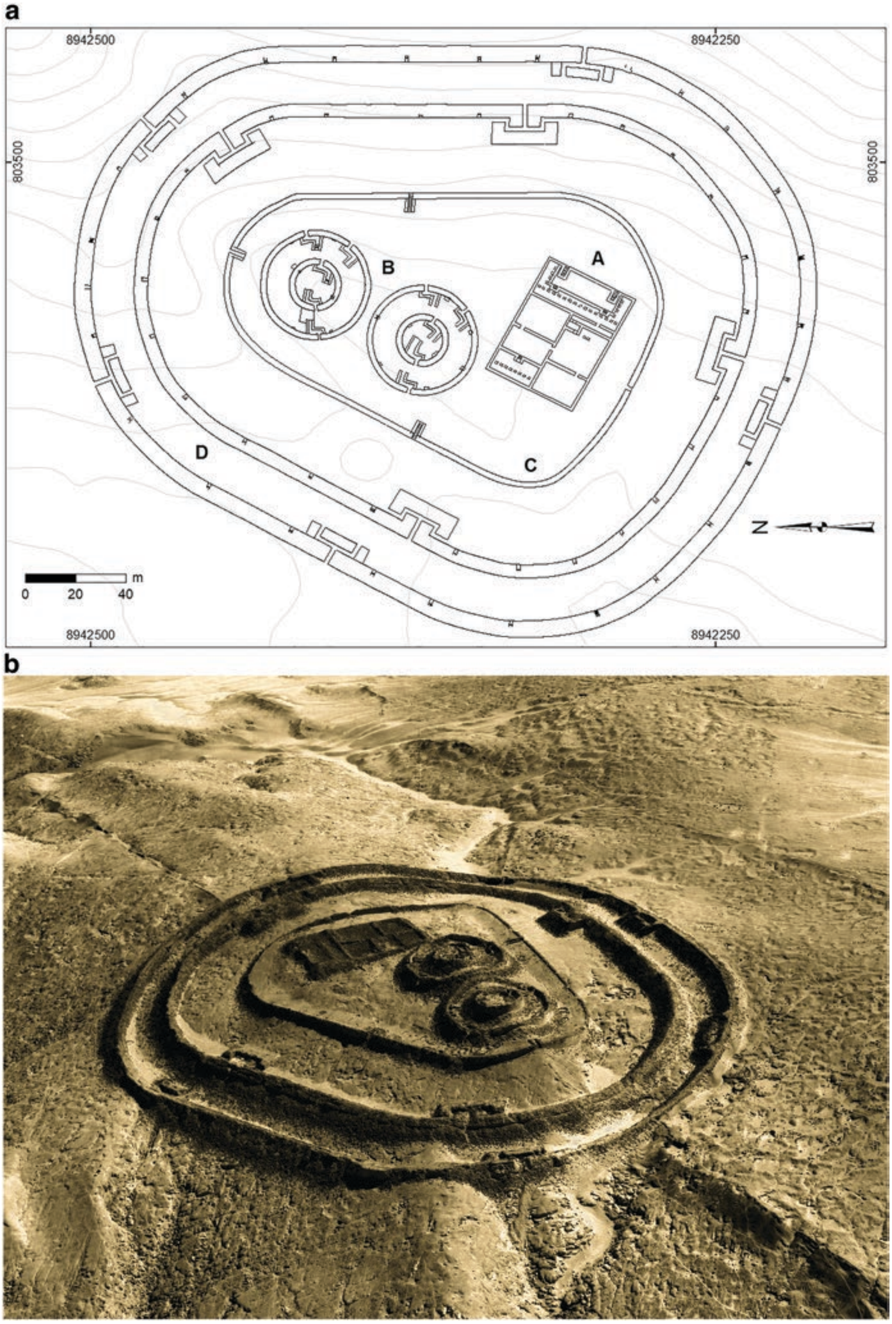

Fig. 3 The Fortified Temple: (**a**) plan view and topography; (**b**) general aerial view from the NNE towards the SSW (courtesy of Servicio Aerofotografico Nacional, Peru)

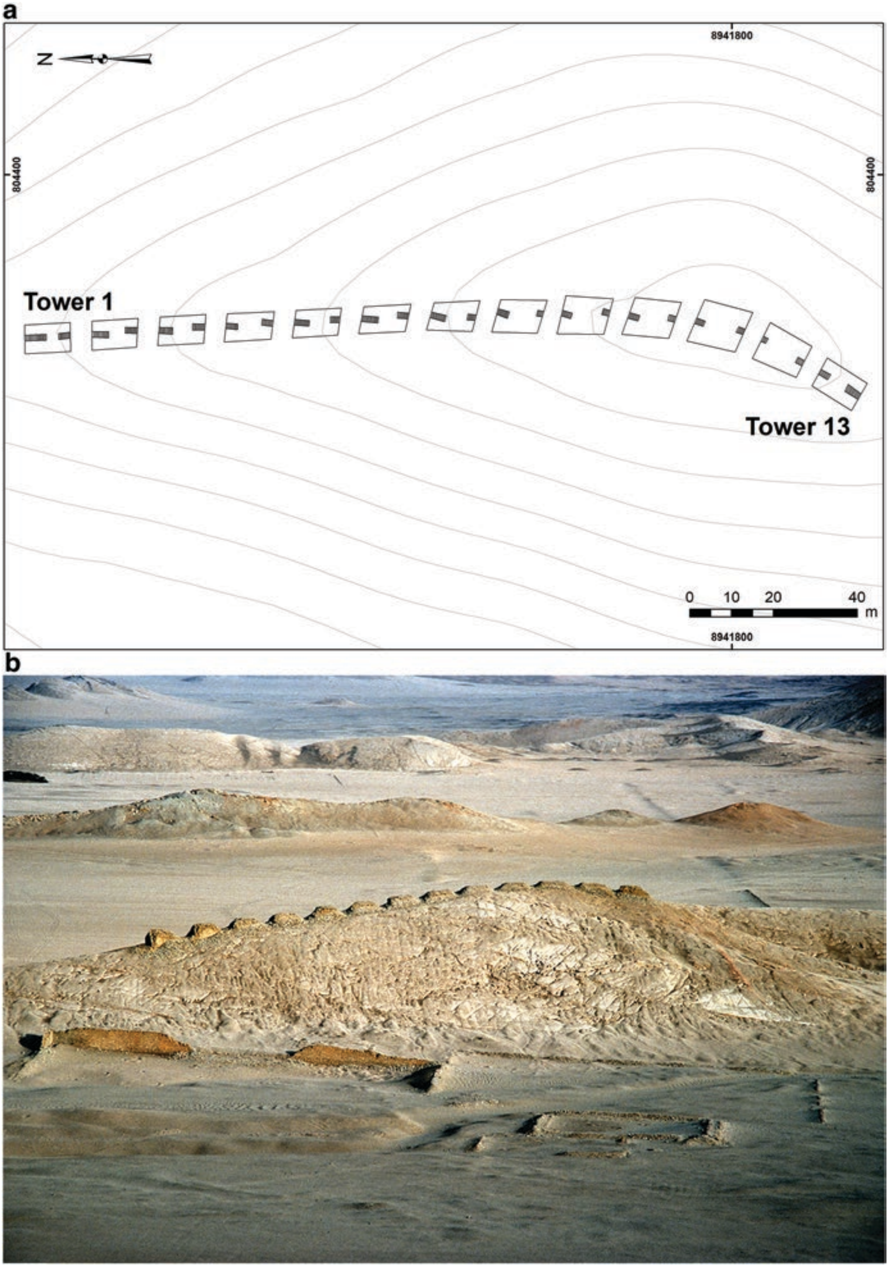

Fig. 4 The Thirteen Towers: (**a**) plan view and topography; (**b**) general view to the east

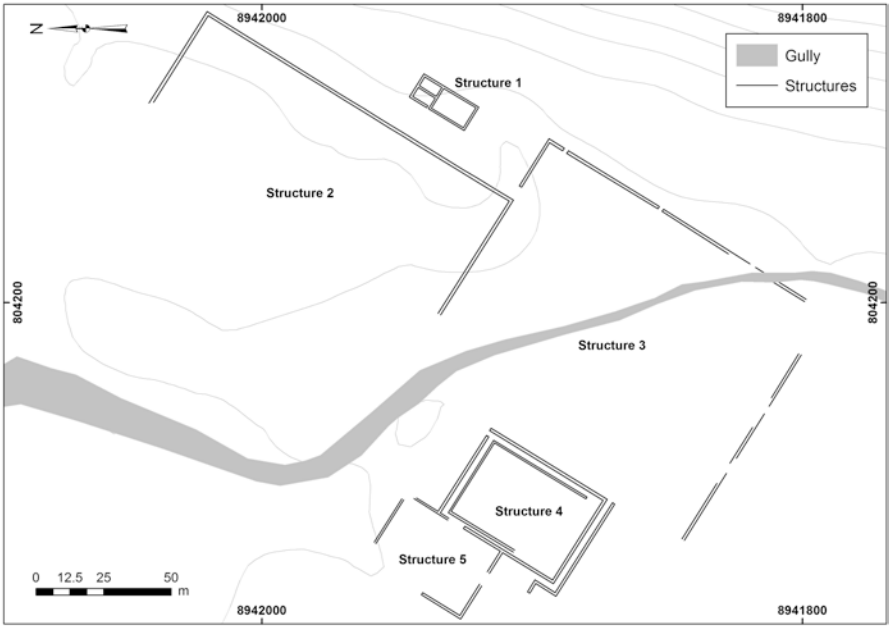

Fig. 5 Map of the Observatory Building and nearby structures

2.1 Chankillo Solar Observatory

It is composed of the Thirteen Towers, the Observatory Building, which includes the Western Observing Point or WOP, and a small building that includes the Eastern Observing Point or EOP (Fig. 2b).

2.1.1 The Thirteen Towers

The towers are a row of thirteen cuboidal constructions built of stone and mortar, regularly spaced and running broadly N–S along a low ridge roughly at the centre of Chankillo, although Towers 11 through 13 turn noticeably southwest to become perpendicular to the site axis. Since 2007, it has been recognized that the towers were horizon markers enabling privileged observers to track accurately the seasonal passage of the sun throughout the year. From two observing points to the W and E, the towers span, respectively, the entire range of sunrise and sunset positions as the sun moves between its limits at the solstices, including a part of Cerro Mucho Malo to complete the profile in the former case (Ghezzi & Ruggles, 2007).

The towers are well preserved, except Towers 4 and 13, whose east walls and fills have largely collapsed, but enough of their fabric survives to recognize the main components of their design and construction. Each tower is composed of four retain-

Fig. 6 The Administrative Centre: (**a**) plan view and topography; (**b**) subdivisions of the building according to transit patterns

ing walls, with steep stairways built between parallel walls recessed into the north and south walls, holding a fill of carefully laid stone and mortar. The stone blocks—mostly tonalite, with some granite—tend to be smaller, and basal stones can be the same size or small than those in the rest of the wall. Most towers were built directly over leveled bedrock, without a foundation, except Tower 13, which presents a large foundation.

The ground plan of the towers varies from rectangular to rhomboidal (e.g. inner angles at Tower 7: 73–109°). Their size (75–125 m^2) and height (2–6 m) also vary widely, with the northernmost towers being higher than the rest, apparently to compensate for the descent in the height of the hill in this end. The towers are regularly spaced (4.7–5.1 m). Additionally, Towers 11 and 12 have an area greater than the average; combined with the change in orientation, Tower 13 would be hidden to some observers to the east. On each of the shorter walls (north and south), a flight of stairs leads up to the summit. The northern stairways are usually centered along this side, though not always aligned with the long axis of the tower. The southern stairways, on the other hand, are often offset towards the east side. All the stairs are narrow (1.4–1.5 m wide), and their height varies widely (1.3–5.2 m).

Tower 9 was excavated (Ghezzi, Alvarez, et al., 2013), determining the stairs were built with stone blocks and slabs; each step is composed of several blocks joined with mortar, and relatively larger blocks are found in the landing. Often the blocks have two faces, so they form the treads, or part of the stair that was stepped on, and the risers, or vertical portions between each tread. Usually a block laid on the edge of a step is interlocked with the sidewalls. The steps in the northern stairway of Tower 9 have treads 0.24 m deep, and risers 0.24 m high, while those in the southern stairway have 0.24 m deep treads and 0.18 m high risers. These dimensions would suggest that the northern stairs favored going up, while the southern stairs favored going down (Hoskins & Milke, 2013). However, the stairways, which are less steep than those in the Fortified Temple, were not meant for defense, and such differences in the heights of the risers may be related to the direction of ritual ascent and descent from the towers, as suggested by Malville (2011). Likewise, the importance of the concept of duality has been documented in the Andes, and its manifestation in these dual stairs, as well as in those in the entrance plaza to the Administrative Centre and the atrium of the Temple of the Pillars, the observation of both the sunrise and the sunset at the Thirteen Towers, and the use of the double-step motif in the slitted pillars of the temple and in sculptural pottery vessels found at Chankillo, reflect the symbolic importance of the dual stairs of the Thirteen Towers (Ghezzi, 2016). Some tower summit floors have been partially preserved. They consist of a layer of coarse sand, which may have been covered with mud. The existence of the stairs strongly suggests that the summits were important loci of ritual activity related to the solar cult.

2.1.2 Observatory Building and Western Observing Point (WOP)

Structures 2 and 3, immediately west of the towers, are walled courtyards largely destroyed by a prehistoric flood. Aerial photos and contour maps suggest that Structure 2 was square, 130 m on each side. Only its eastern side remains; a very tall wall that still stands at 7 m high. Aeolian and flood deposits cover its base, suggesting that it might have been even taller. Despite its height, it is not interpreted as defensive. A small direct entrance between the surviving walls of both structures leads to Structure 1: a small, well-preserved building with three rooms and surface evidence of food and drink preparation and serving. It is curtained from view by the high wall of Structure 2. Possibly, the intended function of the high wall is to separate visually the service area of Structure 1 from the sacred area directly to the west.

Structure 4 is rectangular (53.6 × 40.3 m). Its northeast entrance leads to two internal corridors running along the perimeter walls, which exit to the opposite side (south) of the interior courtyard. Another corridor, this time external, runs along the southwest perimeter wall; it presents a right-turn baffled entrance —unusual at Chankillo, because left-turn baffles protect against attackers carrying shields on their left, exposed by the turn (Keeley, Fontana, & Quick, 2007). Such access suggests non-military control of the entrance to the corridor. The corridor widens towards its eastern end exit, an open doorway that is unique at Chankillo for lacking the typical wall niches that hold doors in all other entrances, large and small, known at this site. From this open doorway, the view of the towers and their surroundings is unimpeded, and important votive offerings were found in the area around the exit. Thus, the purpose of the corridor was not to channel traffic from its access restricted for social control at one end to the interior of the structure, but to the doorway facing directly the Thirteen Towers on the other end. Owing to these attributes and its location, the open doorway was identified as the WOP, from which the Thirteen Towers and Cerro Mucho Malo were used as solar horizon markers (Ghezzi & Ruggles, 2007); thus, Structure 4 has come to be known as the ‘Observatory Building’.

Structure 5 is a rectangular building abutting the northwest corner of Structure 4. The adobe on its surface (a material that was not used until centuries after the abandonment of the site) suggests a later reoccupation of the Observatory Building. Applying principles of symmetry evident throughout Chankillo, it is proposed that this construction obscures a possible doorway in the Observatory Building at the corner opposite to the WOP. From here, the Fortified Temple stands out on the horizon, offering viewpoints in the westerly direction that could reference astronomical phenomena over the Temple skyline. Research suggests that this possible doorway could have been used for observations of the June sun descending over the Temple of the Pillars. In addition, ceremonies relating to both the sun and moon might have taken place at the full moon nearest the December solstice. Since the orientation of the corridor points toward the Southern Keep, it would imply that from the time of its construction, this keep was associated with the moon, just as the Temple of the Pillars was associated with the sun.

2.1.3 Eastern Observing Point (EOP)

A small building 200 m east of the Thirteen Towers contains what has been identified as the EOP (Ghezzi & Ruggles, 2007); the building no longer stands, due to its proximity to areas of human and animal transit, but its foundations partially survive below the surface, in their original orientation and position. The location of this structure mirrors almost exactly the WOP: it has the same distance to the towers and a similar elevation, and both are aligned on an E–W axis perpendicular to the Thirteen Towers.

No other built feature was identified by survey or excavation in this area (Ghezzi, 2003b). Recent subsurface remote sensing (Huayhua & Sueldo, 2018) confirms that this structure is completely isolated in a 200 m by 160 m survey area of open space bounded by the Administrative Centre and the hill where the Thirteen Towers are found. It is possible that the structure is larger than revealed by excavations. The small uncertainty in the exact location of the EOP is insufficient to affect the conclusion, clearly revealed by the archaeoastronomical data, that this small building, broadly solstitially aligned like the rest of the site, included an entrance or platform that acted as a fixed observing point to view the seasonal passage of the sun over the Thirteen Towers. From here, the line of visible towers coincides with the range of sunset positions throughout the solar year.

2.2 *Fortified Temple*

It is a large (55.134 m^2) hilltop building composed of three inner structures (a rectangular temple and two keeps with a circular ground plan) surrounded by three concentric ovoid defensive walls through which large baffled gates provide access to the interior.

2.2.1 Temple of the Pillars

A rectangular building (51.6 × 38.7 m, 1.992.7 m^2) composed of an atrium with four interconnected rooms at the back; perimeter walls yield a WNW–ESE orientation of 119.0°/299.0°, and a SSW–NNE orientation of 25.4°/205.4°, respectively; thus, they deviate by 3.6° from perpendicularity. The level of precision achieved at Chankillo —especially the geometrical precision of the Fortified Temple's defensive walls— implies that this was done for a reason beyond the uneven terrain. The WNW–ESE orientation is broadly solstitial, like the rest of the site. The SSW–NNE orientation coincides closely with that of the line of centres of the two circular structures inside the Platform and to some extent with that of the WNW segments of the defensive walls. It has no astronomical significance. The atrium is a rectangular two-level platform connected by pairs of stairways. The lower level was accessed from below by staircases on each side, each with nine steps and a landing. The upper level is U-shaped, with a central dais and two lateral extensions, built atop the lower level; it was accessed by shorter stairways (four steps and a landing) aligned with those below. The upper level of the platform has pillared galleries (sixteen pillars on the central dais, four on each arm), which originally supported a roof made of perishable materials.

A narrow doorway, aligned with the SSW flight of stairs, is the only entrance to the secluded rooms in the back of the temple. This circulation pattern, a two-level atrium with stairs on the NNE and SSW sides, where the only entrance to the rest of the building is a restricted access doorway on the SSW side, is repeated at the Administrative Centre. This entrance to the room(s) of the Temple of the Pillars is one of the most important symbolic positions at Chankillo. The archaeoastronomical evidence supports the idea that elite individuals could have made sudden public appearances here, emerging at auspicious times relating to the solar cycle, and presiding over ceremonies taking place in and around the buildings and plazas below (Ghezzi & Ruggles, 2008). The timing would have meant that they became part of a sacred manifestation or hierophany. Thus, from certain areas in the plaza, temple officials standing at the entrance to the Temple of the Pillars could have been seen with the sun setting behind them, thus providing a sort of “hierophany for the masses”. The association apparently relates to the concept of the Sun’s Temple, where it dwells during the solstices (Bauer & Dearborn, 1995). A similar hierophany would have worked for the moon, which, as seen from the Plaza, sets behind the Temple of the Pillars on certain dates.

The distant eastern horizon is clearly visible from the single entrance and the atrium of the Temple of the Pillars. This spectacular mountainous profile, with a variety of prominent natural features, would have provided natural foresights marking the changing rising position of the sun. This horizon calendar might well have been the precursor of, and inspiration for, the later construction and use of the Chankillo Solar Observatory for an astronomical purpose (Ghezzi & Ruggles, 2011a, 2011b, 2011c).

The temple entrance leads to four secluded rooms that were probably used for ritual functions or elite habitation. It is not a simple, direct entrance: towards the left, a blind corridor disguises the true access to the right, which leads to the interior through an entrance baffled by two small blocking walls and offset doorways.

Direct entrances interconnect the rectangular rooms. The excavations suggest that each entrance had wooden lintels and doors. Room 3 stands out because it is the largest (347 m^2) and is the only one that includes a platform. The patio in front of the platform is rectangular and though it is half the total area (173.43 m^2), it is relatively small, when compared to other patios at the site. Two direct entrances connect this patio to other rooms.

2.2.2 Pillared Galleries

The platform in Room 3 (153.05 m^2) is elevated 1.5 m above the patio floor. It is formed by a retaining wall holding a fill, with a small stairway (four steps, one landing) at its centre. Atop the platform, eight decorated pillars (with slits forming a double-step motif) define the gallery space near the back wall.

Excavations throughout the temple reveal that its platforms and some of its rooms were partially covered by semi-open, shaded areas known as pillared galleries, also found in the Lower Casma and Nepeña valleys at Huambacho, Sute Bajo, Caylan, Samanco and San Diego (Chicoine, 2006; Chicoine & Ikehara, 2010; Cotrina, Peña, Tandaypan, & Pretell, 2003; Ghezzi, 1997; Helmer, 2014) and hypothetical reconstructions of the structures have been published (Ikehara & Chicoine, 2011).

The pillars are rectangular (~1.0 × 0.8 m), built of small tonalite and micaceous andesite blocks, laid with mortar, and finished with mud; their strip footing foundation prevented them from sinking into the platform fill, despite the weight of the superstructure supported. Their original height is unknown, owing to their systematic destruction, but a reasonable estimate is 2 m. Chicoine (2006) found those at Huambacho to be to 5 m tall, 3 m of which were under the floor. At San Diego, excavations uncovered a platform with pillars that were sunk 1.8 m into the fill. It was interpreted that a pillared gallery on a patio, 1.8 m high, had been transformed into a pillared gallery atop a platform (Ghezzi, 2004).

The pillars at Chankillo are found in rows of four to sixteen—depending on the length of space to be covered— parallel to and at 2.9–3.5 m from the back wall of the platform or room. They supported a partial roof made from perishable local materials, such as cane, covered in mud. The roof was laid between the row of pillars and the nearby wall to form a covered gallery space. The exact dimensions of any gallery are unknown, but the distances between the pillars and nearby walls are an indication of the area covered. In the atrium of the Temple of the Pillars, the central dais of the upper U-shaped platform has the pillars located 3.5 m from the back wall and 2.15 m from the front wall. In the side arms, they are located on the edge of the platform, 3.5 m from the back wall, and only 0.5 m from the front wall. A row of small wooden posts excavated next to this wall suggests that the roof extended past the platform, covering adjacent staircases. In the platform of Room 3, the pillars are located 3.3 m from the back wall and 5.7 m from the front wall. Here, large impressions on the excavated floor indicate that some posts probably lent additional support to the roof, indicating that it may have extended ~10 m from the back wall, to cover the entire platform. In Room 1, a row of pillars was excavated 2.9 m from the back wall. These measurements indicate that, although the intention was to cover as much of the room or platform as possible, the distance between the pillars and the back wall of the gallery was limited to 3.5 m, probably because this was the maximum distance a simple cane superstructure could cover without additional support.

Very little of the pillared galleries has survived. The excavations carried out in the Temple of the Pillars revealed that the walls, pillars, and religious images were

Fig. 7 Slitted pillar preserved in Room 3, Temple of the Pillars. The foundation can be seen under the pillar

intentionally destroyed and buried under a layer of rubble, an event probably due to a violent conflict with some external power, which ended with the defeat of Chankillo and the abrupt abandonment of the site (Ghezzi, 2006, 2007).

One pillar was relatively well preserved, though, protected by the very fill that was meant to bury the building: its excavation showed that its function was not just structural, because it was adorned with a double three-step motif, similar to known pottery designs at Chankillo, deeply recessed (0.07 m) into its front (ESE) and back (WNW) bases (Fig. 7). The steps face each other, and on the outer edge of each motif the recess continues to become a narrow, extended slit that runs straight through the pillar. There is an additional slit between the two motifs. The three slits (0.2 m high; 0.08 m wide; 0.77 m deep) have an approximate WNW–ESE orientation of 120°/300°. Indicators for the presence of the same slit feature were found in the remains of pillars in the Atrium, though no example was as well preserved as the one in Room 3. It is likely that several other pillars at the temple, although not preserved, had such slits, as examples found at Huambacho and Caylan (Chicoine, 2006; Chicoine & Ikehara, 2010), and at least a few have a similar orientation (Chicoine, personal communication, 2015).

The rubble from the destruction of the pillars was dumped at the platform, and its excavation recuperated fragments with hollow spaces, round and straight edges, white or yellow paint, etc. This indicates that the lost portions of the pillars were also modeled and painted to represent sculptural figures. Additionally, stones excavated from the collapsed wall in Room 3 at the back of the pillared gallery contain remains of mud finish with geometric incisions, suggesting that this surface had mural decoration.

The pillared galleries at the back of the atrium faced the eastern horizon, unblocked by intervening walls: the low retaining wall at the front of the platform only stood to a height of ~0.3 m below the bottoms of the slits (Ghezzi, 2016), and the surrounding defensive walls drop away in the easterly direction. In Room 3 there was, in addition to a similar low platform-retaining wall, an eastern wall across the patio from the pillars. The calculations suggest with confidence that the top of this wall would have been no less than 0.2 m below the bottoms of the slits on the pillars. All these pillars would have been able to catch the early morning sunlight; thus, a slowly changing pattern of sunlight beams shining through and between the pillars would have created a spectacular display on the dark back walls of both the long gallery of the atrium and the Room 3 gallery.

Archaeoastronomical analysis supports the suggestion that the pillars were designed for the projection of spectacular lights and shadows, orchestrated to cover the whole year, accurately marking the solstices and equinoxes, and offering another type of calendar indicator at Chankillo. These solar hierophanies would have been observed by very few. Thus, these light-shadow casting devices offer insight into the social differences between the elite audiences at the very secluded Temple of the Pillars and Observatory Building and the more public EOP and Plaza solar alignments and corresponding ceremonies at Chankillo. Unfortunately, the spectacular effects at the Temple of the Pillars are no longer visible, both because the temple space is no longer enclosed and because most of the pillars with their slits have been destroyed.

2.3 Cerro Mucho Malo

Cerro Mucho Malo is a rocky massif (1180 masl in height) which forms part of the foothills of the western chain of the Andes Mountains on the Peruvian coast. Its exposed bedrock belongs to the Lower Cretaceous period. During the millions of years that have since elapsed there was substantial elevation of tectonic plates, fluvial and pluvial erosion in the area. There were also considerable fluctuations in the course and size of the river. But Cerro Mucho Malo is composed mainly of andesite rock, which is much harder than the surrounding tonalite rock that characterizes the Chankillo area, so the differential erosion explains why Cerro Mucho Malo is much higher in elevation, and why at this point the Casma River surrounds it.

The horizon to the east and southeast—viewed from the Temple of the Pillars—is low and distant, ideal for astronomical purposes, as it covers most of the solar rising arc. Cerro Mucho Malo forms a nearby, high horizon to the ENE (Ghezzi & Guadalupe, 2013); it can be seen forming the horizon at the point of June solstice sunrise. For this reason, its southern slope was used as a natural marker: as viewed from the WOP, its intersection with the artificial profile of the Thirteen Towers forms a continuous astronomical horizon that coincides with the range of sunrise positions throughout the solar year, with the intersection itself marking the position of the June solstice.

3 Tangible Manifestations of Astronomy at Chankillo

In the previous section, various tangible astronomical elements at Chankillo were presented in their broader archaeological context. Here we describe various astronomical viewsheds, sightlines and light-and-shadow displays, focusing upon the nature of these astronomical elements themselves, including necessary technical detail, and their interrelationships. These elements, which feature both constructed and natural sub-elements, can be summarized as follows:

(a) Chankillo Solar Observatory (Thirteen Towers, WOP, EOP), from which the profile of the towers spanned the annual sunrise and sunset arcs, respectively:

    - The viewshed from WOP to the Thirteen Towers, together with part of Cerro Mucho Malo: the WOP, an open entranceway on the ESE side of the Observatory Building, is well attested archaeologically both as a viewing position and a location of considerable ceremonial importance accessible only to elite participants;
    - The viewshed from EOP to the Thirteen Towers: the EOP was a room or platform in an isolated small building in the plaza to the east, now largely destroyed, except for its foundations.

(b) The viewshed from the entrance to the Temple of the Pillars to the distant mountainous horizon profile to the east, which features a prominent horizon notch precisely at the position of equinoctial sunrise. Together with part of Cerro Mucho Malo, this profile includes the annual solar rising arc; it is a solar horizon calendar that is a likely precursor for the Chankillo Solar Observatory;

(c) The viewshed from the WNW entrance of the Observatory Building to the Fortified Temple, which dominates the horizon in this direction, where astronomical observations would have focused upon the setting moon;

(d) The back walls and slitted pillars of the Atrium gallery and Room 3 gallery within the Temple of the Pillars. Although the *in situ* physical evidence is largely destroyed, it is highly likely these would have produced a series of spectacular light and shadow effects during the minutes following sunrise, orchestrated to span the entire year, with the slits producing particularly dramatic effects for a few weeks around the December solstice;

(e) The sightline from certain limited areas in the plaza to the entrance to the Temple of the Pillars, a key position from which high-status individuals could have presided over ceremonials, but also where they would have stood in full view at the point of entry to (or emergence from) the Temple itself. From certain small areas in the plaza, Temple officials standing at the entrance could have been seen with the sun or moon setting behind them, thus providing a kind of 'hierophany for the masses'; and,

(f) The solstitial axis connecting the Temple of the Pillars, the Observatory Building and the Administrative Centre, which also passes through the gap between Towers 12 and 13, where the southern end of the line of towers bends round until it is perpendicular to this axis. The orientation of this site axis is followed to within 3° throughout Chankillo, resulting in the broadly solstitial alignment of all the principal buildings at the site.

3.1 Nature of the Data Underlying the Archaeoastronomical Conclusions

The conclusions presented here are based on accurate measurements of actual locations, both on the site and in the natural landscape, and the orientations between them, using a combination of data from Differential GPS surveys (2005, 2008) and Total Station surveys (2011, 2017), georeferenced using terrestrial (CyArk, 2011) and aerial (Paz, 2017) laser-scanning data.

3.2 Solar Observatory

3.2.1 Viewshed from WOP to the Thirteen Towers Together with Part of Cerro Mucho Malo

The WOP and the configuration of the towers, as viewed from it, is the leading element that makes Chankillo unique and outstanding in a global context. It was an open doorway offering an unimpeded view of the towers and their surroundings; a scattering of votive offerings was excavated around it, indicating that this was a place of considerable ritual importance. The SSW corridor of the Observatory Building, along which the WOP was accessed, follows the orientation constraints of the overall grid: it is oriented some 7° to the right of the right-hand side of Tower 13, and consequently the artificial horizon of the towers would have remained hidden to someone walking along the corridor until they came very close to the opening itself, surely adding to the sense of veneration at this spot. As seen from here, the towers themselves are well above the observer and dominate the eastern horizon. The southern slopes of Cerro Mucho Malo, 3 km away, meet the much closer ridge on which the towers are constructed just to the left of the northernmost tower, Tower 1. The visual effect is to provide a 'thirteenth gap' of similar width to those between each pair of adjacent towers down the line.

As the sun reached the southernmost limit of its annual passage, at the December solstice, it would have been seen from here to rise directly up from the top of the southernmost tower, Tower 13. At its northernmost limit, at the June solstice, it rose from Cerro Mucho Malo to the left of the 'thirteenth gap' (Fig. 8a). The position of sunrise progressed up and down the towers at intermediate dates, mostly appearing for just 1 or 2 days in each gap and then for a period of ~10 days between them, but slowing down closer to the solstices. This device permitted the time of year to be accurately determined, not just on one date but throughout the seasonal year.

Fig. 8 Solar observations using the Thirteen Towers: (**a**) June solstice sunrise, as seen from the WOP; (**b**) September equinox sunset, as seen from the EOP

The fact that the equinox sun rose in a narrow gap (between Towers 6 and 7) supports the idea that the tower profile was a constructed reflection and elaboration of earlier observations using the natural horizon. This unique and remarkable example of a monumental solar horizon calendar is entirely practical in nature. Even though the interval of time between the sun's appearance in successive gaps is ~10 days in most cases, this time interval increases towards the solstices, and there is no evidence to suggest that specific divisions of time were being deliberately marked or were conceived as important. In particular, there is no evidence to suggest that either the dates of 'zenith sunrise' (sunrise on the days when the sun will reach the zenith at noon, which occur when the declination of the sun is equal to the latitude of the site, i.e. –9.55°) or those of 'antizenith sunrise' (sunrise on the days when it reached the nadir at midnight, which occurs when the declination of the sun is equal to the minus the latitude of the site, i.e. +9.55°) were of any particular cultural significance at Chankillo, although they are thought to have been significant during much later Inca times (Zuidema, 2014: 857–858).

3.2.2 Viewshed from the EOP to the Thirteen Towers

There is only one small area on the site from which the Thirteen Towers on the skyline to the west span the sunset arc. It coincides with the location of an isolated small building. The June solstice sun would have been seen from here to set into the top of the northernmost tower, Tower 1, just as from the WOP the December solstice sun rose from the centre of the southernmost tower, Tower 13 —thus following principles of symmetry evident elsewhere on the site. These facts strongly support the idea that this was indeed a viewing point for the setting sun against the towers, even though it is less well attested archaeologically due to poor conservation.

The line of towers towards the south bends away from an observer at the EOP and disappears over the hill, unlike the situation at the WOP where the southernmost towers bend round to face the observer. As a result, there are no visible gaps between the southernmost four towers, and Tower 13 would not have been visible at all: thus, while the December solstice sun set in the direction of this tower, the leftmost limit of the solar arc did in fact occur over natural terrain rather than a tower, in common with the eastern profile from the WOP, and arguably manifesting another symmetry between the western and eastern profiles.

3.2.3 Viewshed from Temple of the Pillars' Entrance to the Distant Mountainous Horizon Profile to the East

Regarding the principal 'stations of the sun':

- June solstice sunrise occurred over Cerro Mucho Malo close to, but not quite at, a slight dip at 65.4° azimuth; the solstitial sunrise occurred at little to the left, at a distance of 6.38 km and +64.3° to +64.8° azimuth. The declination of the dip itself is +22.8°, corresponding to sunrise around Jun 4–8 and Jul 6–10 (in the Gregorian calendar);

- December solstice sunrise occurred at an easily identifiable point on the horizon, a discernible dip to the left of a small isolated peak, distant 55.93 km at 114° azimuth. This dip has 113.6° azimuth, 3.6° altitude and −23.8° declination, so the December sun would have risen directly out from this dip;
- A prominent dip, 50.08 km away in the mountainous horizon to the east, the lowest point on this distant ridge, at the intersection of two mountain ranges, coincides with sunrise at the two equinoxes. The bottom of the dip has −0.15° declination: at the astronomical equinox, the sun spans −0.25° to +0.25° declination; and,
- There is no obvious feature on the horizon marking ‘zenith sunrise’ (sunrise on the days when the sun passes across the zenith at noon, an event of significance among various tropical cultures in the Americas), which occurs at −8.55° declination over the horizon 49.03 km away.

Regarding other prominent features on the horizon itself:

- At azimuth 103°–105° and 49.88 km away, there is a prominent ‘half-moon’-shaped dip within the highest part of the horizon, with yet more distant horizon rising to a rounded peak beyond: this has attracted attention as a possible foresight. The declination range, −13.5° to −15.2°, corresponds to sunrise between approximately February 7–12 and October 27–November 1 (in the Gregorian calendar);
- At azimuth 106.5°–107.5°, distant 42.88–42.96 km, again within the highest part of the horizon, there is a feature resembling a stepped pyramid, which has also attracted attention as a possible foresight. The declination range here, −17.0° (peak) down to −17.8° (bottom of right-hand slope), corresponds to sunrise between approximately January 29–31 and November 8–10 (in the Gregorian calendar).

In any natural horizon used as a solar horizon calendar, the features and foresights available to provide accurate markers of sunrise on certain dates are positioned, in effect, randomly, although the dates when the sun rises behind them may acquire cultural significance as a consequence (Ruggles, 2014: 24–25). In the case of Chankillo, the most prominent horizon notch coincides precisely with the position of equinoctial sunrise, as viewed from the entrance to the Temple of the Pillars. Notwithstanding that there is much specialist discussion about the precise definition and cultural significance of the equinox (Ruggles, 2017), it strongly suggests that this location acquired cultural significance as the appropriate viewing point, and was therefore chosen as the site of the Temple of the Pillars. It is also likely that this spectacular mountainous profile, with a variety of other features that would have provided natural foresights marking the changing rising position of the sun, provided a precursor of, and inspiration for, the construction and use of the towers for this purpose.

3.2.4 Viewshed from the WNW Entrance of the Observatory Building to the Fortified Temple

The Observatory Building (OB) had an entrance facing WNW, symmetrical with the WOP facing ESE. The adjacent later building, Structure 5 (here referred to as ‘OB2’) is also likely to have had an entrance facing WNW, although that part of the structure has been destroyed. Symmetry principles operating elsewhere on the site suggest the possibility that astronomical observations were also made from the OB entrance or both entrances. The WNW entrances to the two buildings faced the Fortified Temple, which stands out prominently on the horizon. The NNE wall of the OB (301.7° azimuth) is aligned upon the centre of the circular Southern Keep (301.8° azimuth) as seen from the WNW entrance. Similarly, that of OB2 (300.8° azimuth) is aligned upon the centre of the circular Southern Keep as seen from its entrance (301.0° azimuth). However, the declination (+29.0° from OB1NW, +27.7° from OB2NW) is well outside the solar range.

In fact, a second century BC viewer standing at the OB entrance in the late afternoon at the June solstice would have seen the sun above the southern wall of the Temple of the Pillars moving slightly to the left while descending, eventually setting into the gap immediately to the left of the Temple. The right-hand side of the solar disc, at declination +24.0°, would just have touched the base of the outer side of the Temple’s southern wall. At all other times of year, the sun would have set further to the south: in other words, it would never (quite) have been seen to set behind the Temple itself.

The declination of the Southern Keep does, however, correspond closely to the theoretical northernmost setting point of the moon ($\delta = +28.9°$ around 200 BC, falling slightly to +28.6° by the early second millennium AD). While the rising or setting position of the moon (unlike that of the sun) changes a great deal from day to day (further complicated by the moon’s changing phases), the significance of this is that the full moon close to the December solstice, towards which the Chankillo site is broadly oriented, would have set as far north as this in favorable years within the 18.6-year lunar node cycle (a time known technically as the ‘major lunar standstill’).

Added to this, the declination of the foot of the outer side of the outer enclosing wall as seen from the entrance to the OB, +18.6°, corresponds almost exactly to the northern minor standstill limit (+18.6° around 200 BC, falling slightly to +18.3° by the early second millennium AD). This limit (being the minimum of the monthly maximum limits of the moon’s motions over the course of an 18.6-year lunar node cycle) is extremely unlikely to have had cultural meaning in itself outside a modern Western cultural context (Gonzales-Garcia, 2014), but the fact that the highest part of the Temple profile spans the range between the northern major and minor standstill limits could be significant. This represents the range of positions (over an 18.6-year node cycle) where the full moon would have been seen to set at dawn around the time of the December solstice, the very time when the sun would be seen to rise out of the top of Tower 13 as viewed from the opposite entrance (WOP). Most often, the full moon would have been seen to set close to the Southern Keep (at around the time of the major standstill) or close to the outer walls (at around the time of the minor standstill) rather than towards the centre of the range.

It cannot be proved that these alignments were deliberate, but they do highlight the possibility that sunrise observations from the WOP were preceded or accompanied by observations of full moonset over the Fortified Temple from the opposite entrance. Ceremonies held at the full moon nearest a solstice, combining observations of the rising sun and of the setting full moon, are documented in other cultures (Ruggles, 2014). At Chankillo, it is likely that ceremonies relating both to the sun and moon took place at the full moon nearest the December solstice.

3.3 Light-and-Shadow Hierophanies: The Back Walls and Slitted Pillars of the Atrium Gallery and Room 3 Gallery Within the Temple of the Pillars

The slitted pillars lining the galleries at the back of the atrium and Room 3 in the Temple of Pillars faced the eastern horizon directly, unblocked by intervening walls. In the darkened spaces of the pillared galleries, the early morning sunlight, shining in between the pillars and (at certain times of year) through the slits, would have created a spectacular display on the back walls.

3.3.1 Sunlight on the Back Walls

If the roof of the long gallery in the atrium was 2 m high and it extended beyond the front of the platform, then it would have measured some 7.5 m from front to back. If so, then once the sun's altitude exceeded ~15°, sunlight could not reach the back wall. In the case of the gallery in Room 3, assuming a height of 2 m and an extent about 10 m from front to back, this would have been true once the sun reached an altitude of ~11°. At Chankillo, the sun reaches an altitude of 11° ~20–30 min after sunrise, and an altitude of 15° ~40–50 min after sunrise, depending upon the time of year. Thus, ~25 min after sunrise each morning during the year, sunlight would have been low enough to light the back wall of the gallery in Room 3; while for ~45 min it would have been low enough to light the back wall of the long gallery in the atrium. If a given roof extended out further, the length of time during which sunlight could have struck the corresponding back wall would have been somewhat less; if the gallery roof was higher it would have been somewhat greater.

On days around the December solstice, when the sun rose close to the direction faced by the Temple (119.0°) and at altitude of 3.6°, the effect in both galleries would have been to create vertical stripes of light and shade of more or less equal width (1.0 m), extending up the back wall to about 0.45 m from the top, in the case of the long gallery in the atrium, and about 0.65 m, in the case of the Room 3 gallery. If the height of the platform retaining wall (front wall) was no more than

0.45 m above the floor in the case of the long gallery in the atrium, or 0.65 m in the case of the Room 3 gallery, then even at altitude 3.6° the sun would already have been high enough for sunlight to reach to the bottom of the back wall. Otherwise, the bottom of the wall would have remained in darkness at this point. As the sun rose in the sky and moved slightly to the left, the top of the lit stripes would gradually have descended the wall. At the same time, they would have narrowed somewhat (while their centres remained equally far apart) and moved slightly to the left. They would also have extended further down onto the floor.

At other times in the year, the height of the bright stripes at first glance would have varied slightly because of the variation in the altitude of the eastern skyline, distant 50 km, from a minimum of 3.2° at the equinoxes to a maximum of 6.6° at the June solstice. A more noticeable difference would have occurred because sunlight now entered the galleries from a direction no longer perpendicular to the back walls and lines of pillars. The width of the bright stripes would have been noticeably narrower. Whether by accident or design, the width of the bright stripes shrinks to zero more or less exactly at the time of the June solstice. In other words, the width of the bright stripes offered another calendrical indicator, simple and direct, that operated throughout the year.

Furthermore, at the equinoxes the displacement of the stripes was almost exactly equal to the distance from one pillar (or space) to the next, meaning that a viewer looking directly into the back gallery from the atrium or Room 3 patio would have seen the bright stripes on the back wall aligning in the gaps between the pillars. This only happened around the December solstice (no displacement), the equinoxes (displacement by one pillar) and the approach to the June solstice (displacement by two pillars), by which time the stripes would have been very narrow. At other times, the bright stripes would have been partially or completely hidden behind the pillars.

3.3.2 Effect of the Slits

Around the December solstice, each 1 m-wide dark stripe would have additionally contained three bright rectangles produced by sunlight passing through the three slits in the pillar concerned. These would have been most pronounced at the moment of sunrise on days very close to the solstice, when the sun would have shone more or less directly through the slits, producing full-size (0.20 × 0.08 m) rectangles of light on the walls behind. As the sun rose in the sky the slits would have decreased in height (and slightly in width) as well as descending the walls. A few days after the solstice, the images of the slits would have become noticeably narrower, as sunlight began to enter the galleries at a significantly oblique angle. For the central 0.77 m long slit, once this horizontal angle had exceeded 5.9°, sunlight was no longer able to penetrate the length of the slit. For the side slits, where the incision may have decreased the effective length to, say, 70 cm, the angle was about 6.5°. This occurs when the sun's azimuth falls below about 110°, which happens around 30 days either side of the December solstice. In other words, the pattern of 'bright patches' caused by the slits would only have been visible for about a 2-month period around the December solstice.

4 Discussion

4.1 'Site Axis' and the Broadly Solstitial Site Alignment of All the Principal Buildings at the Site

Other than the line of towers and the perimeter of the Fortified Temple defensive walls, the orientations of buildings and other structures over a wide area generally conform to an overall grid plan consistent to within ~6°. The orientations of the principal rectangular buildings and walls at Chankillo are as follows:

- Temple of the Pillars. The outer walls have a WNW–ESE orientation of 119.0°/299.0° and a SSW–NNE orientation of 25.4°/205.4°. They therefore deviate from perpendicularity by 3.6°;
- Observatory Building (OB). The outer walls have a WNW–ESE orientation of 121.7°/301.7° and a SSW–NNE orientation of 30.9°/210.9°. The walls therefore deviate from perpendicularity by 0.8°. The corridor on the SSW side widens towards the WOP at its eastern end and has a mean orientation of 121.1°/301.1°;
- Structure 5 adjacent to the Observatory Building ('OB2'). The east, west and north walls form three sides of a rectangle with an orientation of 30.8°/120.8°/210.8°/300.8°. However, the south wall deviates slightly from this, with an orientation of 121.5°/301.5°;
- Outer enclosure walls. The SSW–NNE enclosure wall to the ESE of OB and OB2, and the surviving parts of the adjacent enclosure walls, are oriented with azimuths of 30.5°/210.5°, 121.9°/301.9°, and 121.5°/301.5° respectively;
- Administrative Centre. Measurements of the sides of the atrium yield a WNW–ESE orientation of 115.6°/295.6° and a SSW–NNE orientation of 26.6°/206.6° respectively; and,
- Large rectangular building centreed at (E804760/N8941400). The long wall on the NNE side of this enclosure yields the most reliable orientation, 115.7°/295.7°, while the shorter wall opposite yields 115.1°/295.1°. The west and east walls yield 26.5°/206.5° and 25.3°/205.3° respectively.

A 650 m-long wall connected to several buildings in a further plaza to the east, running from approximately 1.3–2.0 km to the ESE of the towers, has approximately the same orientation (114.3°/294.3°) and means that the overall grid plan extends for well over 2 km.

A straight line drawn to connect the entrance to the Temple of the Pillars and the single direct entrance to the Administrative Centre would pass through the centre of the Observatory Building and also the gap between Towers 12 and 13, where the southern end of the line of towers bends round until it is perpendicular to this axis.

This ‘site axis’, with an azimuth of 118.8°/298.8°, appears to be the basis for the wider grid. Both the WNW–ESE and SSW–NNE orientations are consistent to within ~1° among each local group of structures, as would be expected if the construction followed a broad overall plan but used local foresights to achieve consistency within each specific locality. The fact that the opposite walls of large rectangular structures are generally only parallel to within about 1°, and that their walls are only perpendicular to within about the same amount, suggests that the required level of precision was no greater than this. The Temple of the Pillars, whose walls are 3.6° off the perpendicular, is an exception, implying that this occurred for a specific reason, but it is not obvious what this reason was (astronomical or otherwise).

The varying altitude of the horizon in either direction from different points around the site, due to the undulating landscape crossing valleys and ridges, makes it unlikely that a consistent type of astronomical observation could have been carried out repeatedly in order to set out the grid orientation in different areas. However, it is possible that an astronomical observation from a particular starting place originally defined the direction of the site axis, which was then propagated across the site by other means. The obvious candidate is the December solstice sunrise/June solstice sunset. Only the orientation of the Administrative complex and other buildings in the eastern plazas could have been directly defined in relation to the solstices, and in fact only in relation to the June solstice sunset. The remaining structures throughout the site broadly follow the solstitial alignment in consequence.

4.2 Sightline from Certain Limited Areas in the Plaza to the Entrance to the Temple of the Pillars

The entrance to the Temple of the Pillars offered a fine view of much of the Chankillo site: a key position from which high-status individuals could have presided over ceremonials, but also where they would have stood in full view at the point of entry to (or emergence from) the Temple itself. The archaeoastronomical evidence suggests that the entrance point was positioned so that, with appropriate timing, the Temple officials could have been seen with the sun (or other celestial body) setting behind them, thus providing a sort of “hierophany for the masses”.

The scatter of points marking the edge of the visibility envelope (points from which the entrance to the Temple of the Pillars is just visible) traces out a jagged profile formed by the sharp edges of the towers and the gaps between them moving in relation to the Temple and its entrance. The ‘shadow’ of the towers extends somewhat further (~10–15 m) eastwards than the boundary line generated by the ground survey. This is because the viewshed was based on the eye-height of an observer at the entrance of the Temple of the Pillars looking down over the plaza, whereas the ground survey was based on that of an observer on the plaza looking up at the Temple, which is more relevant here.

The saw-tooth shape of the boundary is most evident in the vicinity of the ‘shadow’ of the southernmost towers. It is also especially evident in this area that unexcavated features seem to avoid the area from which the Temple entrance was hidden by the ridge containing the towers. Possible structures, on the other hand, appear to be concentrated along the boundary and just outside it, especially in the vicinity of the ‘shadows’ of Towers 13 and 12. Regardless of the astronomical possibilities, this in itself suggests that it was important for such structures either to be within sight of the Temple entrance or to have the Temple entrance within view. The correlation is much sharper in relation to the surveyed points than to the viewshed boundary, suggesting that it was the view to, rather than from, the Temple entrance that was important.

As viewed from these points on the plaza, the Temple entrance, appearing just above and behind the towers, or in gaps between them, broadly coincided with the position of sunset at the June solstice. This is the part of the plaza where the entrance appears in, or above, the gap between Towers 9 and 8.

Finally, as noted by Ghezzi (2007), there is an intriguing correlation between the area of the plaza from which the Temple platform is visible and the area from which the geoglyphs to the SSW of the Fortified Temple are visible. The geoglyphs only seem to be visible from parts of the plaza from which the entrance to the Temple entrance is also visible. Furthermore, there is an additional ‘cut-off’ more or less exactly beyond the part from which the June solstice sun aligns with the Temple entrance. Whether this is significant or could cast light upon the purpose and possible meaning of the geoglyphs, it is impossible to say at this time.

4.3 Light and Shadow Hierophanies

The fact that the width of the bright stripes shrinks to zero more or less exactly at the time of the June solstice, and that the bright stripes align in the gaps between the pillars at the December solstice and equinoxes, considerably strengthens the idea that the light and shadow effects were intentional, and indeed purposefully orchestrated to span the entire year. The importance of the December solstice would have been enhanced by the appearance, about a month before the actual date, of the sets of three bright patches in each pillar shadow, widening to their maximum at the solstice itself. These hierophanies (of sacred significance) could have offered another type of calendrical indicator at Chankillo, accessible only to those permitted to enter the Temple. Sadly, these spectacular effects are not visible today, both because the temple space is no longer enclosed and because most of the pillars with their slits have been destroyed.

5 Conclusions

The Chankillo Solar Observatory is composed by the Thirteen Towers and two observing points to the West and East, from which the profile of the towers spanned the annual sunrise and sunset arcs, respectively. These are the leading elements that make Chankillo unique and outstanding globally. While its solar horizon calendar is not directly comparable with modern instruments, it can justifiably be termed an observatory because the position of the towers and observing points shows unequivocally that their primary end was to serve as a precise calendrical instrument. Solar horizon calendars require tracking accurately, from a single spot and using natural or artificial markers, the progress of sunrises or sunsets. Examples of true horizon calendars are extremely scarce. At Chankillo, seasonal observing activities appear to have been arranged from a restricted spot by (presumably) a privileged elite. Narrow gaps between a series of artificial markers defined time intervals of just a few days, so that by reference to the gaps and markers an observer could identify a date in the seasonal year to within a margin of, at most, 1 or 2 days.

There is extensive evidence of astronomical alignments within existing world heritage properties (Ghezzi, 2018). Solar alignments are common, because they are the simplest to recognize and show to have been intentional. Some of the alignments at Chankillo, such as the broadly solstitial orientation of the overall grid pattern of the buildings stretching over several plazas, are comparable with patterns of orientation and alignments found at many sites elsewhere. It shows that this built environment was planned relative to the sun. Various astronomically aligned architectural elements encapsulated sky events that were visible to all, while observations of sunrises against the towers from the West Observation Point could only be made by privileged individuals (presumably members of a chiefly or priestly elite) and (from the evidence of numerous votive offerings at this spot) accompanied by due ritual. In this respect, Chankillo belongs in the category of sites that represent the complexity and diversity of ways in which people rationalized the cosmos and framed their actions in accordance with that understanding.

However, the mere existence of solstitial or equinoctial alignments does not prove that a site was a calendrical instrument, not even that it was necessarily used specifically for observations of the sun. In this sense, the Thirteen Towers unquestionably did form an observing instrument. Unlike architectural alignments upon a single astronomical target found at many ancient sites around the world, they span the entire annual solar rising and setting arcs as seen from the two observing points, not only giving direct indications of all four solstitial rising and setting points but also the means to identify every other day in a year by observing sunrise or sunset against the intervening towers and gaps between them. Chankillo is unique worldwide as a functioning solar calendrical observation device and quite an extraordinary example of native landscape timekeeping.

Moreover, only Taosi, a 2300–1900 BC site of the Longshan culture in China, and Chankillo in Peru are known to have incorporated a complete solar horizon calendar, using markers to track the progressive passage of the sun along the horizon throughout the entire year. Chankillo is the only one where this was achieved on a monumental scale, and where all the component elements of this unique instrument are still extant and functional.

Chankillo also embodies an accumulation of knowledge about natural and astronomical processes and their connection to the solar cult, expressed masterfully in the integration of the skyscape to the natural and built environment. Besides the Solar Observatory, a wider set of monuments forming the ceremonial centre likewise took advantage of further solar and possibly lunar alignments upon both constructed and natural targets to define dates. It provides a prominent example of human interaction with a desert landscape.

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Cultural Heritage of Observatories in Context with the IAU–UNESCO Initiative: Highlights in the Development of Architecture

Gudrun Wolfschmidt

1 Introduction

The architecture of observatories has not been discussed much; there is practically only one publication which discusses not just one, but several observatories in Europe and in the world (Müller, 1975, 1978). The Greenwich list of astronomical observatories (Howse, 1986) presents mainly instruments and clocks of observatories from Baroque times to the middle of the nineteenth century. The emphasis of Krisciunas (1988b) is on "modern" observatories of the nineteenth and twentieth centuries, but not on architecture.

In this overview, I will not include the Islamic observatories like Samarkand and Beijing—important in the Middle Ages. I also have to skip here the five impressive Indian Observatories in Delhi, Ujjain, Mathura, Varanasi and Jaipur, erected from 1724 to 1734 during the rule of Maharaja Jai Singh II, already on the UNESCO World Heritage List since 2010. My contribution is focussed on occidental astronomical heritage, particularly observatories from Renaissance to the twentieth century.

Astronomy has always played an important role for time keeping and calendars. Since early Christian times, this has been true also for calculating the date for the celebration of Easter, resulting to the church having a great interest in astronomy. In this context, I would like to mention only shortly: in order to measure the length of the solar year in connection with the Gregorian Calendar Reform (1582), cathedrals were used as solar observatories—"beauty and utility" (Heilbron, 2001). *"Between*

Dedicated to Clive Ruggles.President of Commission C4 *World Heritage & Astronomy*.

G. Wolfschmidt (✉)
Center for History of Science and Technology, Hamburg Observatory,
University of Hamburg, Hamburg, Germany
e-mail: gudrun.wolfschmidt@uni-hamburg.de

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1650 and 1750, four Catholic churches were the best solar observatories in the world. Built to fix an unquestionable date for Easter, they also housed instruments that threw light on the disputed geometry of the solar system, and so, within sight of the altar, subverted Church doctrine about the order of the universe." (Heilbron, 2001).

The first meridian room was established by Ignazio Danti (1536–1586) in the Tower of the Winds in the Vatican (1578/1580), under the sponsorship of Pope Gregory XIII in connection with the calendar reform. The aim was to follow the path of the sun during the year, in order to check if the new calendar is correct and to show this to the public. Important examples for cathedrals with meridian lines are the 67-m-meridian line in San Petronio in Bologna, 1655, made by Jean Dominique Cassini (1625–1712); Santa Maria del Fiore in Florence; St. Sulpice in Paris; and Santa Maria degli Angeli in Rome. Meridian lines were also integrated in observatories in Italy, but rarely outside of Italy, such as for instance the Clementinum in Prague and the Mathematical Tower in Breslau (today Wrocław, Poland). Meridian lines combine many fields of science and cultural history like astronomy, mathematics, architecture, ecclesiastical and civil history.

In Europe, during the Renaissance and Baroque, no observatory buildings in the modern sense existed with fixed instruments and domes. Instead, city fortification bastions, city walls and church towers or even balconies of castles were used as observatories. The only examples of known actual observatories were Tycho's Uraniborg and Stjerneborg (Stellæburgum, Star Castle) on the Danish Island Hven (today Ven, Swedish) in Øresund in 1576/1580 and 1584.[1]

2 Baroque Observatories, Seventeenth/Eighteenth Century

2.1 Tower and Roof Observatories

The Round Tower (Rundetårn) in Copenhagen was erected in Flemish Renaissance style in 1642 by the architect Hans Steenwinkel the Younger (1587–1639), during the reign of King Christian IV (1588–1648). The 209-m long spiral ramp is unique in European architecture. The platform, 34.8–m above the street, offered excellent observation possibilities, an excellent view above the roofs of the city. The building was used not only as an astronomical observatory, but also as a university library and church, until 1861. Today, it is a public observatory and museum.

Many Baroque observatories used the city wall fortification, becoming thus tower observatories, such as the ones in Bologna (1725) and Padova (1761). The earliest university observatories were founded already in the seventeenth century: Leiden started in 1633 with a small observatory tower on the roof of the University. In 1861 (until 1974) the fortification Rapenburg was used as a new building for the Sterrenwacht (now public observatory). In 1642 a platform on the fortification tower

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[1] See for example, Wolfschmidt (2002).

Smeetoren served as Utrecht's observatory. In 1853 the Sterrenwacht Sonnenborgh was erected on the bastion Sonnenborgh (since 1987 astronomical museum). In Jena, an observatory was built in 1697 on top of the gatehouse of the university *"Collegium Jenense"*.[2] In Cambridge, in 1704, the first observatory was founded on top of the gatehouse of Trinity College.

In the Baltic region exist several old universities like Rostock (1419), Greifswald (1456) and Kiel (1665); they added observatories in the baroque era (Wolfschmidt, 2018a, 2018b). In Rostock, the tower of the waterworks was adapted for the observatory "Specula" (1662–1852) (Fig. 1), and subsequently, a new tower observatory was built together with the Physical Institute (1910).[3] In Greifswald, the "Fangenturm" of the city wall served first as an observatory (1775–1826) and the first astronomer Andreas Mayer (1716–1782) used his private house with a roof top observatory. In 1891 a tower observatory was erected on the new Physical Institute of Greifswald University (still existing). In Kiel, one tower of the castle was converted into an observatory (1769–1820).

In Mannheim the Jesuit tower observatory, constructed in Baroque style (1772–1774), was used for astronomy and meteorology. In 1779 the "Societas Meteorologica Palatina" was founded, an international network with 39 stations

Fig. 1 Model of the "Specula" in Rostock (1662), former water tower (photo: G. Wolfschmidt)

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[2] The ducal observatory erected under Goethe's overall supervision in 1813 eventually developed into the astronomical institute of today.

[3] For more details see Pfitzner (2015).

from Eastern America to the Ural mountains, using standard instruments, standard procedures and observations at fixed local times, the so-called “Mannheim hours”. Very famous is also the “Astronomical Tower” of the Jesuit College “Clementinum” in Prague (1725), which was crowned with a statue of an Atlas (2.4-m high) carrying the celestial sphere on his shoulders with a golden Sun in the middle.[4] In 1753, the architect Martin Knackfuss (1740–1821) erected Vilnius Observatory, Lithuania, (Fig. 2), with two towers and a platform on the top of the three-storey university building. The front wall of the observatory had the meridian slits and was decorated with the signs of the zodiac and the motto *“Sic itur ad astra”*.[5]

A small tower observatory was built on the roof of the buildings of the palace Bellevue in Kassel (1714), the University building in Altdorf near Nuremberg (1711–1803), and the Royal Academy in St. Petersburg (1725). For the observatory of Palermo (1791), astronomers used the Norman tower of the Royal Palace.

Fig. 2 Vilnius Observatory (1753) (photo: G. Wolfschmidt)

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[4] See e.g. Udías Vallina (2003) or Šima (2001).

[5] See Wolfschmidt (2018a, 2018b).

The most impressive building, a fully freestanding nine-storey tower, the "sky scraper" of the eighteenth century, is the "Specula Cremifanensis", in the Benediktine monastery Kremsmünster, Austria (1758).[6] Its name, the "Mathematical Tower", points out the strong link between astronomy and mathematics. In addition, there is a cabinet of rarities, organised into the main categories *"naturalia"* and *"artificialia"*. This "universal" comprehensive exhibition of the collection in Kremsmünster guide the visitor—from inanimate nature (minerals and fossils on the second floor) to lower living nature (zoology and botanic, plants and animals), then to the human sciences and arts (art chamber and picture gallery on the third and fourth floor), further to the cosmos (the large observatory hall on the sixth floor)—and finally to the reflection of God (the chapel on the seventh floor).

2.2 Observatories with Platforms

The first "modern" observatories, after the invention of the telescope, were established in the seventeenth century in places like Paris (1667) and Greenwich (1675). They have been extensively discussed elsewhere (e.g. Müller, 1992). The French architect Claude Perrault (1613–1688) and the astronomer Giovanni Domenico Cassini (1625–1712) wanted to make Paris observatory an outstanding instrument of astronomy, each in his own way. The result was an impressive palace building with an assembly hall for the Academy of Sciences. For observation purposes, a platform was provided for the long telescopes on the roof of the building.

Johannes Hevelius (1611–1687),[7] beer brewer and lord mayor of the Free and Hanseatic City of Danzig (today Gdańsk, Poland), built his private observatory in 1649, enlarged on a platform above the roofs of his three burger houses (Stellaeburgum, 1650–1679) (Fig. 3). Here, he observed and produced high precision star catalogues together with his wife Elisabetha Catherina Hevelius, born Koopmann (1647–1693). It was the largest observatory of the time and was destroyed by fire in 1679.[8]

Very similar was Eimmart's Observatory (1677–1757) in the Free Imperial City of Nuremberg, Franconia, established on the Vestnertor bastion of the fortification of Nuremberg castle. Georg Christoph Eimmart (1638–1705) built this observatory in 1677 for research and particularly for training astronomers. It was one of the major observatories of Europe's Baroque period with a large collection of instruments and telescopes, but this open-air observatory survived only until 1757.[9]

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[6] See Klamt (1999).

[7] Hewelcke or Polish Jan Heweliusz.

[8] For more details about the observatory and its instruments, see Kampa (2018).

[9] See Wolfschmidt (2010).

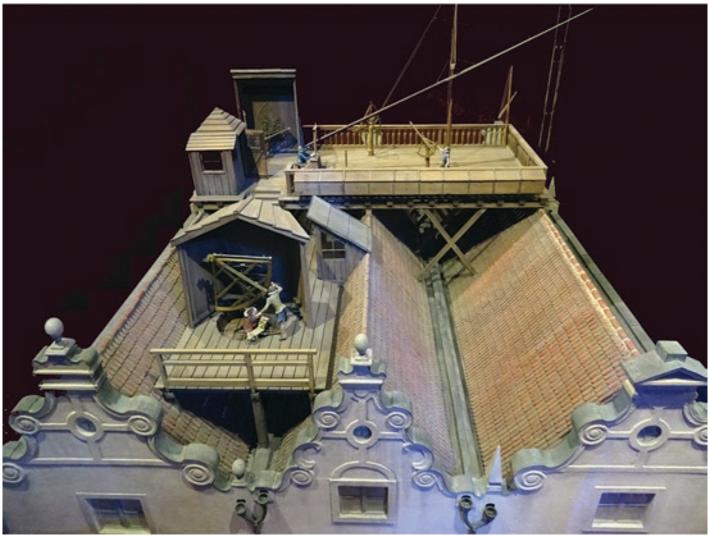

Fig. 3 Hevelius Observatory Danzig/Gdańsk, Poland (1649), model in the "Deutsches Museum" Munich (photo: G. Wolfschmidt)

2.3 Octagonal Shape: Inspired by the Tower of the Winds *in Athens*

The architect Sir Christopher Wren (1632–1723) constructed the Royal Greenwich Observatory (1675) for the first Astronomer Royal John Flamsteed (1646–1719). We find here an interesting feature, inspired by Antiquity, the octagonal observing room in the centre, in order to have observation possibilities in all cardinal directions. This can be found relatively often in observatories until around 1800 and first emerges in Antiquity. Such an example is this famous building in the Roman Agora in Athens, the *Tower of the Winds*, with wind deities (Greek: Ἄνεμοι) carved on each of their respective eight cardinal directions, as well as sun dials on the walls. Andronikos of Kyrrhos, ca. 100 BC, built this 14-m-high tower with a conical roof and a weather vane (in the shape of a blowing Triton). It is mentioned in Vitruvius (*De architectura* libri decem I.6, 4–5) as *"*turris marmorea octagonos*"* and Varro (*De re rustica* III.5, 17) calls it "Horologium". A round annex in the South contained a water tank and tubes. Kienast (2014) presented a new interesting interpretation of the tower not only as clock tower with water meter (*clepsydra*), but also as a *planetarium*, a symbol of the cosmic order. The "dome" inside is interpreted as a representation of the starry sky, decorated with golden stars, whilst the water mechanism drives a large bronze armillary sphere with the orbits of the planets.

The best example, copying the *Tower of the Winds* in Athens, is Radcliffe Observatory of Oxford University (Fig. 4). In 1772 the octagonal *Tower of the Winds* (decorated with eight wind gods and zodiac signs), was placed above a

Fig. 4 Octagonal Tower of the Winds of Radcliffe Observatory in Oxford (1772) (photo: G. Wolfschmidt)

semi-circular Neoclassical central building. After having observed the Venus transit in 1769 from a room in the Radcliffe Infirmary, Thomas Hornsby (1733–1810), Savilian Chair of Astronomy, suggested the construction of this observatory. It was started by Henry Keene (1772–1776) and completed by James Wyatt (1746–1813) in 1794, who was impressed by the octagonal Tower of the Winds in Athens. The telescopes could be used in the octagonal observing room with large windows or on the balcony surrounding the tower.[10] The old Radcliffe Observatory building has been used by Green Templeton College since 1979. It is in good condition and its original instruments are now displayed in the Museum of the History of Science at Oxford.

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[10] Already in 1934, the Radcliffe Trustees sold it and erected a new observatory in Pretoria, South Africa, where the atmosphere was less polluted. Later, in 1970, it was merged with Cape Observatory (Cape Town) and Republic Observatory (Johannesburg) to the South African Astronomical Observatory (SAAO) at Sutherland in the Karoo, and had its headquarters in Cape Town (cf. Glass, 2009: 211–215).

One more interesting example of such a structure is the *Tower of the Winds* (73 m) in the Vatican (with a meridian line), which served as a first Vatican Observatory "*Specola Vaticana*" (1576). Other examples for octagonal observatories were the original buildings of Rapenburg Observatory Leiden (1633) with an octogonal-rotating turret, and Sonnenborgh Observatory Utrecht (1642), adorned with a platform with an octagonal tower at the top of the structure. Furthermore, one should mention the old university observatory in the botanic garden in Halle/Saale (1788), also an octagonal building in Neoclassical style by Carl Gotthard Langhans (1732–1808), who is famous for the Brandenburg Gate in Berlin. The octagonal structure of Santa Fé Observatory de Bogotá, Columbia (1802/1803), was used as the first observatory in South America.

The Stockholm Observatory (1753) is a prestigious building. "It is not unusual that an observatory would be included as a prominent feature on cityscapes or be represented as one of the most important buildings in the city. As such the observatory became a symbol of a learned society and its representative function had as a consequence that large sums were invested and prominent architects commissioned." (Elmqvist Söderlund, 2009: 235). Like in Greenwich, a central room with eight large "windows" in the ground floor—not a tower—served for observations, and especially for the measurements of the positions of the stars. It was not until 1877 that a tower was established on the top of the building to house the main refractor, with the mounting made by A. Repsold & Söhne of Hamburg and optics by Merz of Munich.

3 Observatories in Neoclassical Style Around 1800: Shape of the Greek Cross

The shape of the Greek cross (four wings of equal length) was distinctive for the architecture of observatories around 1800; they were constructed in Neoclassical style.[11] Examples are:

- Real Observatorio Astronómico in Madrid, Spain (1790)—architect: Juan de Villanueva (1739–1811);
- Astronomical Observatory of Capodimonte, Naples, Italy (1819)—architects: Luigi Gasse (1778–1833) and Stefano Gasse (1778–1840);

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[11] I would like to clarify the Neoclassical style, because it is very confusing in different publications – and the architecture is essential for the UNESCO application: In the first half of the eighteenth century, it was often called Neoclassicism, starting in Italy. Since the 1750s the architecture is called Neoclassical, e.g. in England. In France, there was the "Louis XVI style" before the Revolution, then "Napoleonic Empire style". In Germany, "Klassizismus" was used for architecture (Empire, later Biedermeier for decorative arts). In Sweden, during the reign of King Gustav III (1771–1792), Neoclassical buildings were referred to Gustavian architecture. In the USA, Greek Revival architecture is used in the nineteenth century. Victorian style refers to the reign of Queen Victoria (1837–1901).

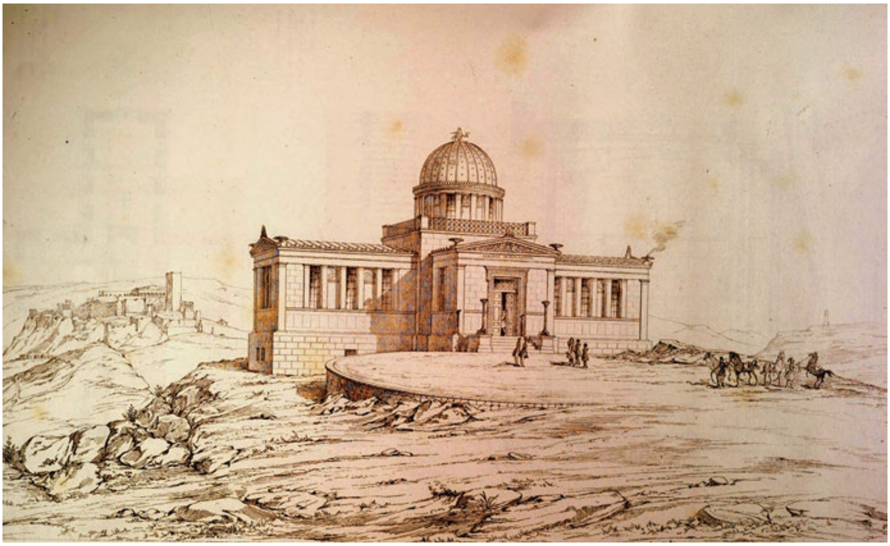

Fig. 5 Observatory in Athens (1846) (Hansen, Theophil (1846) Die Freiherr v. Sina'ische Sternwarte zu Athen, Allgemeine Bauzeitung Wien 11, pp. 126–131, T. 29)

- Cape of Good Hope, Royal Observatory, since 1972 South African Astronomical Observatory (SAAO) together with the Republic Observatory Johannesburg, Cape Town (Afrikaans Kaapstad), South Africa (1820)[12];
- Christiania/Oslo Observatory, Norway[13] (1831)—architect Christian Heinrich Grosch (1801–1865);
- Berlin (1835, dismantled in 1915)—architect Karl Friedrich Schinkel (1781–1841);
- Bonn (1844)—architect Karl Friedrich Schinkel (1781–1841);
- Athens, Greece (1846) (Fig. 5)—architect Theophil Hansen (1813–1891)[14];

Later the ETH Solar Observatory Zürich (1861–1864), architect Gottfried Semper (1803–1879), was established.[15]

In Turku/Åbo, Finland[16] (1818), the architect Carl Ludwig Engel (1778–1840), used a Latin cross for the floor plan. After the Great Fire in 1827, the university and

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[12] See Glass (2015).

[13] The name of the city and the political structure has changed over the time: Christiania (1624–1877, Kristiania 1877–1924) and Oslo (around 1000 and since 1925). Since 1536, Norway was in personal union with Denmark until 1814, then with Sweden until 1905—that means it was built as a Danish observatory and now it belongs to Norway.

[14] See Kitmeridis (2020).

[15] See Wolfschmidt (2016a).

[16] The political structure has changed: Finland was part of Sweden until 1809; the University of Turku was founded in 1640 after Uppsala (1477) and Tartu (1632). In 1809, Finland became part of the Russian Empire until 1917.

the observatory were moved to Helsinki, the old observatory in Turku was reconstructed and used as a museum.

Particularly striking is the "Observatorio Astronomico" in Quito, Ecuador, (1873), the second oldest observatory in South America. It was built in Neoclassical style, and more particularly, Victorian style. The architect Juan Bautista Menten (1838–1900) chose a cross with six cylindrical "domes" for the front elevation and layout. This was inspired by the Bonn Observatory. These two observatories could be suitable for a cultural World Heritage "*serial transnational application*" with Quito as the leading observatory in a non-Western country—in the sense of "filling the gaps".[17]

4 Observatories in the Nineteenth Century: Three-Dome-Facade, a Recognizable Landmark

A new type of architecture started around 1800 involving observatories with a dome (first a cylindrical or conic shape), then a spherical dome, symbolizing the sky, atop of the main building, a feature that is nowadays seen as typical for observatories. Around 1800, Gotha was the leading observatory in Europe. It was built in 1788 and was the location chosen by Franz Xaver von Zach (1754–1832) to host the first international astronomical congress in 1798. In 1800 he initiated the "*Vereinigte Astronomische Gesellschaft*" (United Astronomical Society), founded in Lilienthal near Bremen. This is an early example of an international network in Europe, connected with the discovery of the first four asteroids (now dwarf planet): Ceres (1801), Pallas (1802), Juno (1804) and Vesta (1807). The Ducal Observatory, located on "Seeberg" hill, was a prototype building with strong fundaments for the instruments in the meridian hall (two mural quadrants and a passage (transit) instrument), and in the tower with the revolving dome (vertical circle made by Cary). The observatory was dismantled and closed in 1934 (only the pillars of the meridian circle exist).

Like Gotha Observatory, Göttingen Observatory (1816), where Carl Friedrich Gauß (1777–1855) acted as director, displays also this feature of an early rotating spherical dome. Other important examples of early one-dome observatories are Dunsink Observatory near Dublin, Ireland (1785), and Armagh Observatory, Northern Ireland (1790). Cylindrical domes are in Tartu Observatory, Estonia (1802), and Lisbon, Portugal (1861).

The old Hamburg Observatory, initiated by Johann Georg Repsold (1771–1830) and built by the architect Hinrich Anton Christian Koch (1758–1840) in 1825, had two cylindrical domes. This was an unusual feature, but the observatory was used

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[17] A serial property is a "property where two or more component parts are required to express the "Outstanding Universal Value". If more than one country is involved, then the phrase "transnational serial" is applied. See https://whc.unesco.org/archive/2009/whc09-33com-10Ae.pdf (Accessed: 20 June 2020).

for both—astronomy and navigation. It became a state institute in 1833. Similarly, two domes are also characteristic in the design of the Astronomical Observatory of the University of Warsaw, Poland (1825), by architects Chrystian Piotr Aigner (1756–1841), Michał Kado (1765–1824), and Hilary Szpilkowski (1753–1827), and for the old observatory in Brussels in Saint-Josse-ten-Noode (1826), initiated by Adolphe Quetelet (1796–1874).

The standard architecture for observatories of the nineteenth century became the Three-Dome-Facade since the 1830s, because of the increased number of instruments being used (refractors, heliometer, meridian circle or transit instrument). After the great fire in Turku in 1827, the new observatory was designed by Carl Ludwig Engel (1778–1840), a friend of Schinkel, in Helsingfors/Helsinki (1834), on the Tähtitorninmäki Hill (Lehti & Makkanen, 2013). This was the earliest example of the Three-Dome-Facade with wooden cylindrical domes. The middle tower had a time ball for navigational purposes as an addition. In 1890, a real rotating dome was constructed for astrophotography.

The old observatory in Kazan, Tartastan, Russia, (Fig. 6), was constructed by the architect Mikhail Petrovich Korinfsky (1788–1851) in Neoclassical style, in 1837. This remarkable curved building has a meridian line and offers the additional possibility to observe not only in the meridian, but also in the prime vertical.

Fig. 6 Old Observatory in Classicism Style in Kazan, Tartastan, Russia (1837) (photo: G. Wolfschmidt)

The innovative design principles of Helsinki and Kazan observatories were adopted in Russia for the design of the Pulkovo Central Observatory in St. Petersburg (1839) by the architect Alexander Brüllow (1798–1877). Much has been published about the Pulkovo Observatory (Abalakin, 2009; Krisciunas, 1988a: 99–119). Its architecture was especially formative for the nineteenth century: apart from the dominant central dome, it features also two smaller domes, for a refractor and a heliometer, and bears slits for the meridian circles in the interspaces. Five generations of the Struve family of astronomers, starting with Friedrich Georg Wilhelm Struve (1793–1864) and Otto Wilhelm von Struve (1819–1905), developed the Pulkovo Observatory in the nineteenth century to the leading institution in Europe.

The Pulkovo prototype of observatory architecture for the nineteenth century can be found for example in Observatório Astronómico de Lisboa (1861, architect Jean-François Colson); Yerkes Observatory, USA (1897, architect Henry Ives Cobb); Georgetown College Observatory, Washington, D.C., USA (1841–1844, Greek Revival style, architect and astronomer James Curley). Even for the Astrophysical Observatory (APO) Potsdam (1874/1879), as well as for the "Deutsches Museum" in Munich (1925) this characteristic front was chosen.

5 Modern Observatories, Twentieth Century

5.1 Modern Observatories in an Astronomy Park

In 1882 there existed 81 observatories (privately and publicly financed) in Europe, including 29 in Germany, 14 in England, 19 in Russia and, in addition, 28 in America. Nevertheless, around 1900 many new modern observatories were built and now are still constructed all around the world. In 1907, a publication of the Observatoire Royal de Belgique listed 467 sites—both public and private. Of these, 293 were in Europe, 113 in North America, 18 in Asia, 17 in Latin America, 15 in Oceania and 11 in Africa. Many are rather small, thus here I would like to discuss only the most significant examples.

Around 1900, a big change in astronomical research occurred. The transition from classical astronomy to the rise of modern astrophysics (Wolfschmidt, 1997), which became also apparent in the change of instrumentation, which caused a change in architecture.

For example, old instruments included the meridian circle, refractor, heliometer and time keeping instruments (like in Pulkovo, St. Petersburg, and other observatories in the nineteenth century). The new era of instruments since the 1860s or since 1900 with the beginning of observational astrophysics for photometry, photography and spectroscopy/spectral analysis (also solar physics) involved tools like astrograph, portrait camera, reflecting telescope, Schmidt telescope, photometer, spectrograph, and several astrophysical laboratory instruments. They are important in the context of the application of an observatory for the UNESCO World Heritage

List, and in addition, accompanied by impressive architecture (well preserved and renovated).

The important feature connected to this change of research, architecture and instrumentation is the invention of the observatory park. Instead of one building with domes on the top, allowing only poor observation possibilities (because the heating of the building causes air turbulence in the observing dome), the new characteristic feature is the ensemble of buildings in an "astronomy park" with strict separation of buildings for observation and on the other hand offices, library, administration and residential buildings. This new idea, a revolution in observatory architecture, started with Strasbourg Observatory (1881), realised by the architect Hermann Eggert (1844–1920), who was a specialist in prestigious buildings. Three parts are separated in the Botanical Garden: first, the main building with workspaces and the library but still with the dome containing the large refractor; second, the two domes with smaller instruments; and third, the residential building (Wolfschmidt, 2005b). The buildings are connected by sheltered corridors. In addition, Strasbourg Observatory is an excellent example of the integration of observatory buildings with other university buildings in urban planning. This feature, the separation between the main building and the two domes and the meridian hall, can also be found in the Dr. Karl Remeis Observatory in Bamberg (1889).[18] The next example is "Observatoire de la Côte d'Azur", Nice, 1879–1888, which was established as a modern park observatory, a group of buildings in a park (Le Guet Tully & Sadsaoud, 2009).

In addition, the "Observatorio Astronómico de La Plata", Argentina (1881/1883), designed by Pedro Benoit (1836–1897), has very similar in structure: the main building and all the domes are spread in an astronomy park. Built on a hill at the border of the city, the new Hamburg Observatory (Wolfschmidt, 2014) fulfils also the conditions of modern observatory architecture. It was embellished as an ensemble in the astronomy park with a good view of all domes to the south, essential for astronomical observation. Albert Erbe (1868–1922) built this new observatory in Hamburg–Bergedorf in Neobaroque style between 1906 and 1912. The main building has a library and offices, a residential building, director's villa, facility manager building, five domes, the meridian circle and the solar physics building. Richard Schorr (1867–1951), director of the observatory, succeeded in obtaining an impressive instrumentation, classical refractors, an equatorial and meridian circles, but also modern astrophysical instruments like astrographs, 1-m-reflecting telescope (Fig. 7) and the Schmidt telescope, with cameras, spectrographs and photometers. It was one of the most modern observatories in Europe of its time. The observatories of Hamburg and La Plata are currently preparing a serial transnational application for UNESCO. I have discussed this in detail in the Thematic Study 0: "Astronomical Observatories: From Classical Astronomy to Modern Astrophysics" (Wolfschmidt, 2009). Observatories are presented in 40 articles. The following 12 observatories were recommended for a "*serial transnational application*": Argentina, La Plata

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[18] See Wolfschmidt (2015).

Fig. 7 1-m-Reflecting telescope of Hamburg Observatory, Carl Zeiss of Jena, 1911 (photo: G. Wolfschmidt)

(Fig. 8); Brazil, Rio de Janeiro; UK, Greenwich; Estonia, Tartu; France, Paris-Meudon; France, Nice; Germany, Hamburg-Bergedorf; India, Kodaikanal; Portugal, Lisbon; Russia, Pulkovo, St. Petersburg; USA, Naval Observatory Washington D.C. In the meantime, I would like to add to this list of typical observatories of around 1900 with the mentioned features the old and new observatory in Kazan, Russia, and the Dominion Observatory, Ottawa, Ontario, Canada (1902–1970), together with the Dominion Astrophysical Observatory (DAO), Victoria, British Columbia, Canada (1918) with the 1.8-m Plaskett telescope for spectroscopy.

5.2 International Cooperation and Instruments

I would like to present two more examples for "*serial transnational applications*".

"Large meridian instruments not only tell us a lot about basics of the motion of heavenly bodies, but because of their size and proximity to different types of powers, they are also deeply connected to their cultural and historical context." (Benoist, Le Guet Tully, & Davoigneau, 2016: 164). Around 1800 meridian circles, associated to precise clocks, superseded the large mural quadrants (made by Sisson, Bird) or large circles (made by Cary) like in Palermo, in providing the most precise measurements of

Fig. 8 80-cm-Reflecting telescope, Gautier of Paris, now Cassegrain with Zeiss mirrors (1:20), La Plata Observatory, Argentina (photo: G. Wolfschmidt)

stellar coordinates. Especially the French observatories like Paris, Marseilles, Bordeaux, Besançon, Nice, together with Algiers-Bouzaréah, Algeria, offer a homogeneous group of meridian circles (Gautier, Eichens and Brunner). German meridian circles like Ertel & Sohn of Munich, Pistor & Martins of Berlin and Repsold of Hamburg, can be found also in central Europe, Russia, Washington D.C./USA, Argentina and Brazil.

In 1887, the French Academy of Sciences invited astronomers from all over the world to attend an "*International Congress of Astronomical Photography*" in Paris, organized by Ernest Mouchez (1821–1892) (Gingerich, 1984: 16–39). Eighteen observatories in the Northern and Southern hemispheres[19] launched the photographic catalogue and a photographic mapping of the sky, using the same standard instrument, the 34 cm-astrographic refractor (focal length 3.4-m), developed by the

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[19] Eighteen observatories were involved, four were later exchanged: Greenwich, Vatican, Catania/Sicily, Helsinki, Potsdam & Uccle Observatory/Bruxelles, Oxford, Paris, Bordeaux, Algiers, San Fernando, Tacubaya/Mexico, Santiago de Chile & Hyderabad/Egypt, La Plata & Cordoba/Argentina, Rio de Janeiro/Brazil & Edinburgh, Cape, Sydney, Melbourne & Sydney, Paris. See Wolfschmidt (2020): 77–79.

Henry Brothers (optics) and Paul Gautier (mechanics) in Paris. But this well prepared and excellent project was never completed after nearly 100 years.[20]

5.3 *Solar Observatories and Contemporary Observatories*

I would like to mention also remarkable solar observatories, which I have studied in detail, the early solar observatories from Renaissance to nineteenth century (Wolfschmidt, 2016a) like Ingolstadt, Germany (1611), Kew, UK (1769); Dessau, Germany (1829); Collegio Romano in Rome, Italy (1852); Zürich, Switzerland (1864); Astrophysical Observatory Potsdam, Germany (1874/1879); Meudon, France (1876); Kalocsa, Hungary (1878).

Especially important is the invention and development of the solar tower in the twentieth century (Wittmann, Wolfschmidt, & Duerbeck, 2005; Wolfschmidt, 2016b). Early such examples are the Mt. Wilson Observatory, USA (1904) with the 60 and 150 foot tower (1904/1908) (Wolfschmidt & Ruggles, 2011) and Pic du Midi, France (1878–1882), an example of a high-mountain observatory.

In addition, Erich Mendelsohn (1887–1953) in close cooperation with his friend Erwin Finlay-Freundlich (1885–1964) designed the impressive Einstein Tower in Potsdam (Wolfschmidt & Cotte, 2011), (Fig. 9), in the style of Expressionism between 1920 and 1922. The optical design, made by Carl Zeiss of Jena, surpassed the Mt. Wilson solar tower in respect to light intensity. Freundlich characterized the building as follows: "*The design of the telescope as a tower telescope gave the Einstein Tower its special character and allowed the architect to allocate the building the character of a monument due to the epochal significance of the theory of relativity in the development of physics.*" (Finlay-Freundlich, 1969: 541).

The later development started in the 1960s with the vacuum tower telescope; the result of the evacuation are images without distortions. Examples for the famous modern buildings are[21]: Kitt Peak's Solar Telescopes (McMath-Pierce Telescope 1960, KPVT 1973, SOLIS 2004), Sacramento Peak, New Mexico (Richard B. Dunn Solar Telescope, DST, 1969) and High Altitude Observatory (HAO), Boulder—Mauna Loa Solar Observatory, Hawaii (1965). In addition to these, we have also the European solar observatories (1979), the Observatorio de Teïde, Tenerife, and the Observatorio del Roque de los Muchachos (ORM), La Palma. The next generation of solar telescopes for the twenty-first century is designed as compact Gregory-type reflector,[22] similar to other astronomical telescopes, with 4-m-aperture. The DKIST will be the world's largest solar telescope. It is still difficult to include such leading

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[20] For the catalogue and the sky chart, 22,054 photographic plates were exposed but the plan was 88,216 plates. Only the catalogue was published in 1964. See Wolfschmidt (2020): 77–79.

[21] See Wolfschmidt (2005a) and (2016b).

[22] 1.5-m GREGOR, Tenerife, 2006, and the Advanced Technology Solar Telescope (ATST), since 2013 renamed as Daniel K. Inouye Solar Telescope (DKIST), Haleakala, Hawaii, USA National Science Foundation, 2020.

Fig. 9 Einstein Tower in Potsdam (photo: G. Wolfschmidt)

solar observatories or the contemporary optical observatories like La Silla and Paranal of ESO in Chile, the AURA Observatory in Chile, the Observatories on the Canary Islands in Spain, and the Mauna Kea Observatory, Hawaii, USA, on the UNESCO list, because they do not have an outstanding architecture, but they are more technical constructions.

6 Filling the Gaps: Success in UNESCO Applications

The IAU‘s Commission 41 Working Group on *Astronomy and World Heritage*, founded in 2009, with Clive Ruggles as chair (2009–2015), was subsequently renamed IAU Commission C4 on *World Heritage & Astronomy*, with Clive Ruggles as president (2015–2018), and has worked closely with UNESCO and ICOMOS to develop the initiative. An ICOMOS publication (Wolfschmidt, 2009) and two ICOMOS–IAU Thematic Studies on the Heritage Sites of Astronomy (Ruggles & Cotte, 2011, 2017) have been published. The success of the work in respect to UNESCO applications is described in the following paragraph.

In 2019, UNESCO listed 1121 World Heritage Sites of which 869 were cultural, 213 natural and 39 mixed properties. However, very few of these are connected to astronomy. Science heritage, especially astronomical heritage, is poorly represented on the World Heritage List (e.g. Jokilehto, 2005, e.g. also sacred sites). There are some archaeological and cultural sites, which have an established or postulated connection with astronomy such as Newgrange in Ireland, Stonehenge in the UK, the Great Pyramids of Giza in Egypt, and some Mesoamerican ceremonial centres in Guatemala and Mexico (e.g. El Caracol at Chichén Itzá, part of Pre-Hispanic City of Chichén Itzá). Some more archaeoastronomical sites should be mentioned here, recently named for the WH List: Cheomseongdae observatory, Gyeongju, Republic of Korea (WHL since 2000); Astronomical timing of Aflaj Irrigation Systems of Oman (WHL 1207); Dengfeng observatory, Henan, China (Historic Monuments of Dengfeng; "The Centre of Heaven and Earth" (WHL 1305). In 2019, two additional sites were included in the UNESCO World Heritage List: the Chankillo pre-Classic archaeological astronomical complex in Peru, referred as the first observatory of the Americas (WHL 5792), and Risco Caído and the sacred mountains of Gran Canaria Cultural Landscape in Spain (WHL 1578)—the land- and skyscape interaction in the different components of the property was a must for the success. The Talayotic Culture of Minorca in Spain will be the Spanish candidate for WHC in 2021 (WH Tentative List 3433).

The following sites are related to astronomy, but the UNESCO emphasis is different (they are not on the list as observatories, but as part of something else): Ulugh Beg's observatory in Uzbekistan (part of the historic city of Samarkand—Crossroad of Cultures, WHL 603), Pulkovo Observatory of St. Petersburg (WHL 540 "Historic Centre of Saint Petersburg and Related Groups of Monuments"), the Royal Observatory at Greenwich (WHL 795 "Maritime Greenwich"), and Strasbourg (Grande-Île, inscribed in 1988, and Neustadt, new town, extension 2017, WHL 495). Buenos Aires and La Plata (including La Plata Observatory) with a geometric city layout were included in the Tentative List (6296) in 2018 by Argentina.

The first property, to have been explicitly inscribed because of its astronomical significance along with its importance for the history of earth sciences and topographic mapping, is the *"Struve Geodetic Arc"* (WHL 1187, inscribed in 2005). Wilhelm von Struve (1793–1864) organized the triangulation project between 1816 and 1855, stretching from Hammerfest to the Black Sea—over 2820 km. Ten countries were involved: Norway, Sweden, Finland, Russia, Estonia, Latvia, Lithuania, Belarus, Ukraine, Republic of Moldova (265 main surveying points). Although developing ideas for cooperation for a "*serial transnational application"* is not onerous, the realization is particularly challenging. Suitable ideas could be for example, a group of solar physics observatories or observatories, which cooperate in projects like star catalogues, or a group of observatories equipped with the same

Fig. 10 76-m-Lovell Telescope, Jodrell Bank Observatory, UK (photo: G. Wolfschmidt)

kind of instruments (e.g. meridian circles) or made by the same firm like Repsold, Merz, Steinheil, Grubb, Zeiss or French instruments.

Of great importance is also contemporary astronomy (e.g. radio astronomy, new wavelength astronomy and new technology telescopes or space heritage), which ought to be discussed in more detail. The Jodrell Bank Observatory in Manchester, UK (UNESCO WHL 1594, 2019) (Fig. 10), is the earliest radio astronomy observatory in the world still in operation and is a key representative site for astronomical heritage. The Lovell Telescope (76-m/250 foot paraboloid reflector dish), previously known as Mark Telescope, was conceived by Sir Bernard Lovell (1913–2012) in 1948, as along with the Mark II with an elliptical reflector (38-m × 25-m) and both were designed by Charles Husband (1908–1983). The observatory's still operational 76-m fully steerable radio telescope completed in 1957, was the largest in the world and is now the third largest on Earth. The Jodrell Bank Observatory is an international icon of science and engineering, and a working research instrument that inspired the construction of others around the world. The 100-m Effelsberg Radio Observatory in Germany (1971) should be the next aim for a UNESCO application (Wielebinski & Wilson, 2011). It had the largest steerable radio telescope in the world until 2000, when the slightly larger 100-m × 110-m offset paraboloid reflector Green Bank Telescope (GBT) was constructed in the USA.

7 IAU List of "*Outstanding Astronomical Heritage*" (OAH)

The web-based "*Portal to the Heritage of Astronomy*" (www.astronomicalheritage.net) introduced by Clive Ruggles, includes case studies and tools vital for State Parties (national governments) developing nomination dossiers, but also provides public dissemination of this information.

It is sometimes difficult for observatories from Renaissance to the twentieth century to be included in the UNESCO World Heritage list, as their architecture cannot claim to be of "Outstanding Universal Value" (OUV). The guidelines require such structures to be *"an outstanding example of a type of building, architectural or technological ensemble which illustrates (a) significant stage(s) in human history"*.

The first important condition for UNESCO nomination is the site, the observatory building and the fixed instruments (fixed tangible heritage). All the moveable instruments and their scientific uses and results (intangible heritage) can then be included as an additional issue. However, there exist observatories, in which the building is severely damaged, destroyed or it does not fulfil the "authenticity" and "integrity" standards, the instruments no longer exist *in situ*, but which as institutions have played a significant role in the history of astronomy regarding scientific output, having carried out cutting-edge research in astronomy and astrophysics. For such cases, the idea has been discussed to create an IAU List of "*Outstanding Astronomical Heritage*" (OAH).[23] This contains astronomical heritage sites of the utmost importance, regardless of whether they are recognized as World Heritage Sites by UNESCO. The OAH list was launched at the IAU's 2018 General Assembly in Vienna.

For example, I would like to propose the inclusion of observatories like the Potsdam Astrophysical Observatory, where astronomers are no longer working (they moved to Potsdam-Babelsberg Observatory), or even observatories like Gotha or Göttingen, international centres of astronomy around 1800. In Gotha, only the basis of the meridian circle is still present, but its instruments are all displayed in museums and a large quantity of archive material exists. The best example is Tycho Brahe's observatory at Uraniborg, now completely destroyed, but a few of its instruments have been reconstructed. In addition, we can add to the OAH Hevelius observatory in Danzig (Gdańsk), the Jesuit colonial observatories, and many more like the recent modern observatories. The OAH list was presented by me in the IAU GA in Vienna (2018) and it will be enlarged in the next few years.

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[23] OAH: https://www.astronomicalheritage.net/index.php/heritage/outstanding-astronomical-heritage. (Accessed 1 January 2020).

8 Conclusion

First, I have presented some early observatories from the time of Renaissance, Baroque, Neoclassicism, up to the modern observatories of the twentieth century, which should be studied in more detail. Many are no longer used for astronomical purposes or the buildings no longer exist. Nevertheless, they were very important in their time and carried out innovative and cutting-edge research, so they are included in the "*Outstanding Astronomical Heritage*" (OAH).

In this contribution, I discussed only 'tangible immoveable' heritage, observatory buildings and fixed instruments. I have not included heritage sites of archaeoastronomy, archaeological monuments, 'tangible moveable' and 'intangible' heritage of astronomy and heritage in danger, or the Dark Skies initiative.

Modern observatories offer good potential for *serial transnational applications* to UNESCO and to select partner observatories, which form a consistent group, due to the date of their construction, to their architectural features, instrumentation (same instrument makers), or their scientific programmes (e.g. international cooperation projects). One example which I have presented is the shift from classical astronomy to modern astrophysics, which can be easily recorded in several observatories of around 1900, especially in Hamburg, Kazan and La Plata. These examples may concern the choice of instruments, the architecture and the idea of the astronomy park. All this is important cultural heritage connected with observatories of that time.

The observatory buildings and their architecture including their layout (e.g. in a Botanical Garden or astronomy park), the quality of instruments, the scientific archives (collections of photographic plates, observation journals, correspondence, star charts, catalogues, etc.), as well as the scientific/intellectual achievements, inventions and discoveries made by scholars related to the individual observatory, are all to be understood as categories of the cultural heritage (also in terms of scientific heritage). This corresponds to the main categories according to which the "*Outstanding Universal Value*" (OUV) of the observatories will have to be evaluated (UNESCO criteria ii, iv and vi): historic, scientific, and aesthetic. These observatories contributed remarkably to the cultural heritage of mankind, to astronomical science, and thus to modern worldviews. As such, they should be present in the UNESCO list.

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