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Archaeoastronomy in the Roman World

Springer

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ISSN 2509-310X ISSN 2509-3118 (electronic)
Historical & Cultural Astronomy
ISBN 978-3-319-97006-6 ISBN 978-3-319-97007-3 (eBook)
https://doi.org/10.1007/978-3-319-97007-3

Library of Congress Control Number: 2019930545

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

Past societies—not only during prehistory—made gods of celestial bodies and phenomena, including them in their mythological narratives and linking them not only to atmospheric events and seasonal cycles but also to important social institutions and the destiny of men.[1] Early on in the history of archaeology, some researchers, especially astronomers but also anthropologists and prehistorians, began suggesting that some archaeological remains (especially prehistoric ones) could be measured and examined in order to explore potential alignments with celestial phenomena. This, they claimed, would improve our understanding of the symbolic universe of the groups and societies that built these monuments. In time, this developed into an interdisciplinary subject of study, half way between astronomy and the social sciences.[2] Different terms have been put forward to refer to the discipline, including archaeoastronomy (E. Ch. Baity; M. Hoskin), astroarchaeology (Hawkins 1973), the history of astronomy and ethnoastronomy; more recently, S. Iwaniszewski (1997) and C. Ruggles (1999, 2001) proposed an all-embracing term, cultural astronomy (which can accommodate both the history of astronomy and ethnoastronomical traditions). This discipline examines how, throughout history, humans have oriented themselves in time and space through the observation of celestial bodies (Belmonte 2009: 58).

Within the field of cultural astronomy (Iwaniszewski 2009: 30), archaeoastronomy has been characterised by a lasting and intense debate around the discipline's very definition and methodological orientation. In recent decades, some degree of

[1]See, for instance, Lehoux (2007); Silva and Campion (2015). From prehistory until today (Chamberlain et al. 2005), groups and societies developed relatively advanced astronomical and calendrical knowledge, which served a variety of purposes. Calendars and programmed agricultural activities were made possible by the study of the position of celestial bodies (Antonello 2012).

[2]In general, this discipline analyses the alignment of monuments and buildings (menhirs, tombs, temples, etc.) and celestial phenomena (e.g. solar and lunar dawns and sunsets). The discipline also examines the iconographic representation of celestial bodies and phenomena and the reconstruction of astronomical events using the data gathered by modern astronomy (Krupp 1989, 1991).

agreement has been reached about the difficult question of definition. The discipline is thus described as an approach to the astronomical knowledge and beliefs of past societies (Belmonte 2000: 14) or, more restrictedly, to the astronomical practices of prehistoric societies (Esteban 2003a: 309). That is, the discipline examines astronomical, archaeological, historical, ethnographic and anthropological data in order to investigate the interaction of men and the cosmos from prehistory to the present day (Cerdeño et al. 2006: 14).

Methodological debates have also played a central role in the discipline during the final decades of the twentieth century. These debates revolved around the need to conciliate the methods followed by physicists and mathematicians (who can analyse the motion and position of celestial bodies) and those adopted by archaeologists, historians, ethnographers, etc., who can examine the cultural patterns of past societies and are in a position to ask the right questions (Silva and Campion 2015).[3] As such, the relationship between archaeology and astronomy relies on the ability of the former to provide data (gathered by means of methodologically precise astronomical calculations), the cultural analysis of which by the latter can contribute to the interpretation of the material record of past societies.[4] In addition to this, archaeology as a historical discipline has notably expanded its chronological boundaries over time, and multiple specialised period-specific archaeologies exist (Gutiérrez 1997: 25–88); it is worth emphasising that the data collected by physicists about a given period must be interpreted by archaeologists who specialise in that period.

Archaeoastronomy has a long tradition in some European countries, where there was an early interest in the interaction between past societies and the cosmos (Morellato 2011). The origins of the discipline go back to the late seventeenth century,[5] when a number of British antiquarians began to interpret megaliths as

[3]However, the twofold nature of the discipline has resulted in some degree of theoretical and methodological confusion and in the emergence of epistemologies in conflict (Iwaniszeski 1994: 5; 2003). For this reason, the interdisciplinary cooperation of physicists and archaeologists is essential for the appropriate data to be collected (Cerdeño and Rodríguez-Calderot 2009: 282–284; Esteban 2009: 69–77) and given a sound cultural interpretation. Some have even argued for the need to create a new professional category, that of the archaeoastronomer, in which the skills of both fields can meet (Antonello 2012; Belmonte 2009: 59); this is not impossible, but being proficient in the skills of both disciplines looks like a rather difficult task. Recent projects reflect the complexity of the issue, such as the *Journal of Skyscape Archaeology* (the publication of which began in 2015) (https://journals.equinoxpub.com/index.php/JSA), which aims to be a platform for the analysis of the archaeological record from the point of view of celestial phenomena, analysing the relationship between material culture, cosmos and society throughout history. The journal promotes a multidisciplinary perspective and encourages archaeologists to expand their horizons and include the sky in their cultural landscapes, while compelling archaeoastronomers to focus their study on the cultural interpretation of the material record.

[4]That is, archaeoastronomy would essentially be a technical discipline, a form of archaeometry, that is, a methodology which provides data to archaeologists for their subsequent interpretation (Cerdeño and Rodríguez-Calderot 2009: 279–286).

[5]During this period, archaeology was limited to the work of a number of antiquarians and their sponsors, while the earliest academies and museums began to open their doors; during this period, excavations were initiated in Pompeii and Herculaneum, and travellers began reporting discoveries

'astronomical observatories'.[6] Although the term 'archaeoastronomy' was used for the first time by Elizabeth Chesley Baity in 1973, the roots of the discipline are still a matter of debate. While such important physicists as Heinrich Nissen and Norman Lockyer (active in the late nineteenth and early twentieth centuries) could be considered as the fathers of modern archaeoastronomy, most agree that the discipline truly hatched in the United Kingdom, with Alexander Thom, a Scottish engineer who worked in England, especially at Stonehenge, from the interwar period to the 1970s.[7]

The 1980s witnessed the consolidation and growth of the discipline and the dispelling of numerous myths concerning various prehistoric 'observatories'. The discipline expanded into new geographical areas (the Balearic Islands, Sardinia, the Iberian Peninsula, America, Africa, etc.) and incorporated scholars from multiple countries (not only English-speaking), vindicating its multidisciplinary nature and demanding a space in the academic universe. In this context, the Leicester archaeologist Clive Ruggles, who re-examined Thom's data and arguments, and the Cambridge mathematician Michael Hoskin pushed for the creation, within the framework of the International Astronomical Union (IAU), of *The 'Oxford' International Symposia on Archaeoastronomy* in 1981.[8] Since its inception, this body has endeavoured to unify scientific and archaeological data and interpretations.

In the 1990s, the discipline underwent a phase of unprecedented growth, with the inclusion of yet more geographical regions and cultural horizons and with the publication of the earliest regional syntheses (Belmonte 1994; Romano 1992). This phase also witnessed the end of 'monumentalist' approaches,[9] and the

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in the Eastern Mediterranean; the earliest repertoires of antiquities were also published during this period, and J.J. Winckelmann outlined the principles of archaeological science as the history of Greek art; prehistory was barely defined as a discipline (Bianchi Bandinelli 1992[2]).

[6] John Aubrey (in 1678) and Henry Chauncy (in 1700) analysed some of the astronomical principles that governed the orientation of medieval Christian churches, while in 1740 the architect J. Wood and the antiquarian William Stukeley studied the astronomical orientation of the megalithic assemblages of Stonehenge's sarsen circle and Callanish, among others, presenting the idea of British (and later European) megaliths as astronomical observatories. Their ideas would remain virtually unchallenged until the 1980s. On the other hand, in the late nineteenth century, the astronomers Richard Proctor and Charles Piazzi Smyth examined the astronomical orientation of the pyramids of Giza, in Egypt, inaugurating the archaeoastronomical study of the major pyramid-building cultures, such as the Egyptian and the Maya (Aveni 1991; Bauer and Dearborn 1998; Galindo 1994; Šprajc 2001).

[7] The early scientific phase of the discipline, which focused on the measurement of astronomical orientations rather than on historical and cultural interpretation, led to the creation of the *Journal for the History of Astronomy* (1970) and later of its supplement, *Archeoastronomy* (1979). Although his work has been subject to a profound revision, Thom's influence persists, and his statistical analysis methodology remains part of the basic toolkit of the archaeoastronomer (Thom 1954: 396–404; 1967; 1984: 129–148).

[8] This body has celebrated a total of 11 symposia to date. The twelfth one is scheduled for celebration in La Plata, Argentina, in 2020; see https://www3.archaeoastronomy.org/index.php/oxford-conferences

[9] An approach that, to some extent, has also hampered Classical Graeco-Roman archaeology until recent times.

consolidation of stable avenues of cooperation between astronomers and archaeologists, as illustrated by the Stonehenge-centred project directed and published in 1997 by B. Cunliffe and C. Renfrew (1997). Another important milestone was the foundation of the *Société Européenne pour l'Astronomie dans la Culture* (SEAC) (Strasburg 1993), by the astronomer C. Jaschek.[10] This was followed in 1996 by the inception of the *International Society for Archeoastronomy and Astronomy in Culture* (ISAAC), created in the United States with the aim of developing the academic presence of archaeoastronomy and ethnoastronomy;[11] the *Sociedad Interamericana de Astronomía en la Cultura* (SIAC)[12] was founded in Santiago de Chile in 2003.[13] In recent decades, these three associations have worked ceaselessly for the promotion of archaeoastronomical studies (Belmonte 2016: 93–101).[14]

Archaeoastronomy is currently a mature discipline practised worldwide, with a place in the academic arena,[15] awake to theoretical and methodological concerns, and capable of producing rigorous results. This maturity is also reflected in the publication of synthetic works such as the monumental *Handbook of Archaeoastronomy and Ethnoastronomy*.[16] Another important outcome of the growth of the discipline is the cataloguing of 'astronomical' sites, their potential recognition as

[10]It has been pointed out that the work carried out within the framework of this body focuses excessively on technical astrophysical matters and lacks archaeological interpretation; see: http://www.archeoastronomy.org/

[11]https://www3.archaeoastronomy.org/

[12]Constituted by professionals working in the astronomical and cultural fields, from the point of view of archaeoastronomy, ethnoastronomy and the history of astronomy; see: http://eacultural.fcaglp.unlp.edu.ar/

[13]Within the framework of the *Simposio de Etno y Arqueoastronomía del Congreso Internacional de Americanistas*.

[14]This work includes promoting the field in universities; the development of interdisciplinary cultural astronomy studies; the creation of links between international, regional and national experts; and the organisation of symposia, workshops and field schools, which have channelled most of the scientific activity of the discipline and have become the main arenas for debate and the presentation of results. Since 1993, the SEAC has organised 25 conferences (apart from the foundational conference, celebrated in 1992 at Strasburg Observatory); the 26th Conference SEAC, in Graz (Austria), is scheduled for August–September 2018. The SIAC has organised six field schools and five workshops. The *VII Escuela* and *VI Jornadas Interamericanas de Astronomía Cultural*, titled *Agua y Cielo*, to be held in Samaipata (Bolivia), are scheduled for October 2018. The ISAAC, for its part, is in charge of organising the aforementioned *'Oxford' International Symposia* and the publication of *Archaeoastronomy. Journal of Astronomy in Culture* (https://escholarship.org/uc/jac); this journal, which is based in the University of California, is open access and is published twice a year, coinciding with the solstices.

[15]After being recognised as a scientific discipline, the next challenge is to have archaeoastronomy regularly incorporated into teaching plans, for instance in Spanish universities (Belmonte 2009: 65; Cerdeño et al. 2006: 25–26).

[16]Edited in three volumes by C.L.N. Ruggles (Heidelberg, 2014–2015), it presents an up-to-date theoretical and methodological perspective, as well as including thematic approaches centred on specific topics such as cosmologies, calendars, navigation, orientation and alignments and ancient perceptions of space and time; the work also includes ethnoastronomical studies which focus on current 'indigenous' groups and some wide-ranging geographical and chronological case studies.

World Heritage Sites[17] and their protection by international organisations such as UNESCO and ICOMOS.[18]

In this context, the 1990s also witnessed the emergence of veritable national schools of archaeoastronomy and cultural astronomy. I want to emphasise two of them, because of the prominence that their members have gained worldwide, and because of the relevant role that they play in this volume. Two milestones stress the interest for the discipline in Spain (Belmonte 2009: 55–67; Esteban 2003a: 309–322): M. Hoskin's study of the alignment of Iberian megaliths, from the 1980s onwards (Hoskin 2001),[19] and Jaschek's time in Salamanca (1993–1999), which was a boost for the discipline in Spain and led to the organisation of various seminars (e.g. *Astronomía y Ciencias Humanas*), among which the celebration of the 1996 SEAC annual meeting in Salamanca (1996) (Jaschek and Atrio Barandela 1997) may be highlighted. This favourable context also witnessed the formation of the first (and to date unparalleled) Spanish archaeoastronomy team[20] in the *Instituto de Astrofísica de Canarias* (IAC) and the University of La Laguna (Tenerife). This team was led by the astrophysicist J.A. Belmonte and included the physicists César Esteban and Antonio César González, among others.[21]

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[17]See, for instance, the volumes published by the *International Council on Monuments and Sites* [ICOMOS] and the *International Astronomical Union* [IAU]: Ruggles (2017) and Ruggles and Cotte (2010).

[18]Archaeoastronomy will be considered a thematic area in the forthcoming *ICOMOS International Scientific Committee for Archaeological Heritage Management 2018 Annual Meeting*, to be celebrated in October 2018 in Montalbano Elicona (Sicily, Italy), under the title *Discover Sicily's Argimusco. A Holistic Approach to Heritage Management* (http://icahm.icomos.org/2018-icahm-annual-meeting-sicily/).

[19]Hoskins established important links with local teams, such as those led by M.ª L. Cerdeño and G. Rodríguez Caderot (University Complutense de Madrid), and M. García Quintela and F. Criado (University of Santiago de Compostela), and those which focused on Islamic astronomy (Belmonte 2009: 63) and the Iberian world (Esteban 2002: 81–100; and Espinosa Ruiz 2018: 265–278). See Cerdeño and Rodríguez (2009), *Arqueoastronomía* (*Complutum*, 20, 2), and especially the synthetic, conceptual, epistemological and methodological works by G. Rodríguez Caderot and M.ª L. Cerdeño Serrano, Stanislaw Iwaniszewski, Marco V. García Quintela, A. César González García and Juan Antonio Belmonte Avilés. For the international projects undertaken by these teams, see Lull (2006).

[20]http://www.iac.es/proyecto/arqueoastronomia/

[21]This team, which from the 1990s onwards undertook several projects in cooperation with other European and American colleagues, also organised the *VI 'Oxford' Symposium* (1999) in La Laguna and convened the organisation of the research group *Arqueoastronomía* within the framework of the IAC (Esteban and Belmonte 2000), whose main aim is to assess the role of astronomy in the cultural milieu of past civilisations, from prehistory to our days. The interests of the group go beyond the local perspective (Aparicio and Esteban 2005; Belmonte et al. 1995: 133–156), largely focusing on Mediterranean societies, from the Atlantic façade to the Middle East (Belmonte and Shaltout 2009), and especially the Iberian Peninsula. They have also carried out some work concerning Mesoamerican and Polynesian (Easter Island) societies. The prestigious work undertaken by this research group at the international level is of enormous importance; the analysis of such a wide variety of cultural horizons from an astronomical perspective involves the participation of experts with an in-depth knowledge of historical and archaeological sources as well as of the

In Italy, the interest in Sardinian dolmens, popularised by Hoskin in the 1980s (Hoskin and Zedda 1997: 1–16; Magli et al. 2011), progressively expanded to other regions (Puglia, Lazio, Veneto and Valle d'Aosta) (Aveni and Romano 1986: 23–31; Romano 1992). After a series of meetings convened by the *Accademia Nazionale dei Lincei*, a group of archaeologists, astronomers and practitioners of associated disciplines[22] created the *Società Italiana di Archeoastronomia* (SIA) in Milan in 2000.[23]

This volume is the result of the collaboration between Spanish and Italian scholars, which began in earnest during the *16th Conference of the Italian Society for Archaeoastronomy*, titled *Quis dubitet hominem coniungere caelo?*[24] As in previous meetings, the conference was a forum in which to continue exploring the relationship between the cosmos and human societies, from prehistory to our days. In addition, the organisers had—in my opinion—the felicitous idea of convening, in parallel with the main meeting, the *1st International Workshop on Archaeoastronomy in the Roman World*,[25] in response to an increasing interest in Classical, especially Roman, archaeoastronomy, over the previous decade.

In general, the current concept of Classical archaeology has transcended the limits of the Graeco-Roman cultural milieu. In this new social and chronological dimension, the field is also interested in the study of cultures that co-existed with the Classical civilisations, such as the Italian protohistoric societies and the Germanic peoples (Gutiérrez 1997: 51–52). Within this expanded discipline, Roman archaeology is now divided into multiple specialised fields (the diachronic study of the polity of Rome, the Italian Peninsula, the Eastern and Western provinces, etc.). It is, therefore, not unreasonable to demand the configuration of a specialised field, the aim of which would be to analyse the way Romans (and the societies that preceded and followed what we understand as Ancient Rome) related to the cosmos and

operation of social processes (see, for instance, the following synthetic works: Belmonte 1999; Belmonte and Hoskin 2002; Belmonte and Sanz de Lara 2001).

[22]Including the archaeologist Gustavo Traversari and the astronomers Edoardo Proverbio, Giuliano Romano and Elio Antonello.

[23]The association is based in the Osservatorio Astronomico di Brera and was created with the aim of promoting archaeoastronomy, ancient astronomy, cultural astronomy and historical astronomy. These aims emphasise the inherently interdisciplinary nature of the field (Antonello 2003: 507–513); see http://www.brera.inaf.it/archeo/index.htm.

[24]The meeting was organised by the Department of Mathematics of the Politecnico di Milano (Italy) on 3–4 November 2016. The scientific committee was formed mainly from important members of the archaeastronomical communities in Italy and Spain and included E. Antonello, J.A. Belmonte, A.C. González-García, R. Hannah, M. Incerti, G. Magli, V.F. Polcaro and G. Rosada; see https://www.mate.polimi.it/sia2016/.

[25]Astrophysicists linked to important research institutions (concerning such fields as physics, astrophysics and heritage studies) are currently consolidating the field of archaeoastronomy in the European continent. Their work is analysing the relationship between architecture, landscape and mathematic-astronomical knowledge in ancient societies (especially concerning European megaliths, the prehistoric, protohistoric and Roman Mediterranean, Egypt and the Near East).

astronomical phenomena through the analysis of astronomical, archaeological and historical data.[26]

In a paper published in 2006, Cerdeño et al. (2006) carried out a bibliometric analysis of the papers published by the journal *Archaeoastronomy* between 1979 and 2002. They concluded that 31.8% of the papers dealt with European megaliths, and only 6.2% focused on the Classical period (Cerdeño et al. 2006: 20). These results are hardly representative, but reflect an emphasis—from the beginning of the discipline—on megalithism, especially in Europe. In recent years, the situation has changed substantially; as previously noted, over the last two decades archaeoastronomical studies have become much more widespread, covering almost every past human society, including Roman civilisation.

This volume, edited by Giulio Magli, A. César González-García, Juan Belmonte Aviles and Elio Antonello, follows a threefold diachronic, geographical and thematic structure. It is divided into several sections, dealing with Etruria—the earliest Italian culture during the Iron Age—and the Roman Empire (first to fourth centuries AD); special subsections address the *Urbs*, other Roman cities, the Eastern provinces and the application of computer methods to archaeoastronomy, which have led to the emergence of a new discipline: virtual archaeoastronomy.

We know that the Roman *libri vegoienses* contained instructions for the interpretation of electrical phenomena (the *libri fulgurales* and especially the *libri rituales*).[27] Antonio P. Pernigotti, an archaeologist at the Università degli studi di Milano, reassesses matters of orientation and ritual among Etruscan temples, which have been previously examined by different authors (e.g. Aveni and Romano 1994: 545–563; Prayon 1991: 1285–1295). Pernigotti aims to examine whether the orientation of Etruscan temples was random or whether they followed any rules regarding order and proportion. After measuring the azimuth and, whenever possible, the horizon height of major Etruscan sacred structures (28 temples in 10 different locations, 9 in Etruria and 1 in Tuscia)—and finding errors in previous measurements—Pernigotti relates the data with the chronology of, and the deity worshipped in, each temple, in order to determine possible patterns in the orientation of the temples. Based on his results, Pernigotti argues that Etruscan temples were oriented according to the Sun, rather than to the celestial dwellings of the deities (known after Martianus and the famous Bronze Liver of Piacenza). With some exceptions, temple facades were not oriented towards the dawn, and their *cellae* were not illuminated by solar rays; instead, there seems to have been a function between orientation and specific deities (Uni, Vea, Hercules . . .).

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[26]The inclusion of several Roman-centred case studies in the *Handbook of Archaeoastronomy and Ethnoastronomy* (e.g. González-García and Magli 2014: 1643–1650) demonstrates the consolidation of this discipline, which is also illustrated by this volume.

[27]According to Festus, these were "Etruscan books which prescribe rituals for the foundation of cities and the consecration of altars and temples, the blessing of walls and the norms to distribute city gates and organise tribes, curiae, and centuriae; to organise armies and all else that pertains to war and peace." (Festo, *Rituals*). See Bagnasco et al. (2013) for a recent account on how these texts might be related to the orientation of the sanctuary of Tarquinia.

G. Bagnasco Gianni (specialist in Etruscan epigraphy in Università degli studi di Milano) combines Etruscan and Roman rituals related to the foundation of cities (Briquel 2008: 27–47; Rykwert 1988) and some cosmological principles of the Etruscan religion to re-examine (Bagnasco Gianni and Facchetti 2015: 27–56; Bagnasco Gianni et al. 2016: 253–302) the Tumulus of the Crosses, in Cerveteri, in whose corridor an Orientalising inscription containing the names of various divinities inside a celestial quadrant and a *siglum* formed by a cross inside a circle was found. The pictogram is divided into 16 regions, one for each deity, as also reflected in the previously noted Liver from Piacenza. Based on the differences and similarities between the information conveyed by the Liver and other written sources (especially Pliny and Martianus), Bagnasco Gianni concludes that the north-western orientation of the wall associated with the access ramp, where the inscription was found, allows for the beginning of the sequence of divinities mentioned in the Liver (and Martianus) to be established in the north-eastern quadrant. As such, the division of the Liver which contains the expression *Tin Ciles*, to the east of the division which contains the expression *Ciles* alone, could signal the increase in sunlight (*Tin*) that follows the sunrise at the summer solstice.

Concerning the Early Imperial period, some attention has been paid over the last decade—by Magli, Belmonte and González-García, among others—to the astronomical orientation of cities and buildings, especially in Italy and the western provinces, in relation to rituals and government propaganda.[28] Deliberate sunlight effects, as a way to stress hierophanies, most prominently found in the northern sector of the *Campus Martius* and in the triangle formed by the *Ara Pacis*, the *Horologium* and Augustus' Mausoleum (Buchner 1976; Hasalberger, 2014; Rehak 2006), can be attested in many more constructions in both Rome[29] and other regions.[30] Three case studies are analysed in this volume—specifically, in the sections dedicated to the *Urbs*, virtual archaeology and archaeoastronomy. A team integrated by V.F. Polcaro, S. Sclavi, S. Gaudenzi, L. Labianca and M. Ranieri (from the Universities of Ferrara and Roma La Sapienza and the Soprintendenza Archeologica di Roma) reassess (Labianca et al. 2008) the study of the so-called Neo-Pythagorean basilica of Porta Maggiore, an underground complex dated to the first century AD and located in the city suburbs. The complex has been interpreted as being related to Neo-Pythagorean cults, or otherwise as the funerary mausoleum of the consul *T. Statilius Taurus*. The evening sunlight penetrated the complex through a skylight in the vault of the vestibule (this was especially intense around the summer solstice) and, less directly, through a window in the main nave, projecting a point of light upon an altar. The authors argue that, by placing a light-reflecting surface on the

[28]Bertarione and Magli (2015); Esteban (2003b); Espinosa-Espinosa and González-García (2017); Ferro and Magli (2012); García Quintela and González-García (2014: 157–177); González-García and García Quintela (2014); Magli (2008: 63–71); Magli et al. (2014); Rodríguez-Antón (2017).

[29]For instance, in the Neo-Pythagorean basilica in Porta Maggiore, the Mausoleo degli Equinozi in the Via Appia (De Franceschini 2012), the Pantheon (Hannah and Magli 2011) and Adrian's mausoleum (De Franceschini and Veneziano 2015).

[30]For an illustrative example from Spain, see the studies about the orientation of the sanctuary of Torreparadones (Córdoba) (Abril Hernández and Morena-López 2018: in press).

altar, this point of light would fall upon a painting interpreted (not without some doubt) as the ‘Rape of Ganymede’. According to the authors, this hierophany would be at the centre of the rituals celebrated in the complex.

Based on an allegorical interpretation of a text by the Neo-platonic philosopher Porphyry, who—inspired by the Mithraic mysteries—assimilated the nymphs’ cavern described by Homer (Od. 13.102–112) to the cosmos, R. Hannah (University of Otago, New Zealand) suggests that solar equinoxes were points of balance in which gods and (deified) emperors were enthroned and that northern and southern solstices opened ‘passages’ for the transit of souls. According to Hannah, these ideas found reflection in public architecture, in which domes were used to represent the cosmos. The Pantheon, rebuilt in the centre of the *Campus Martius* during Hadrian’s reign, was originally an *augusteum* and a temple consecrated to the divine pantheon, but later it was also used to determine the agricultural cycle, and its interior operated as a giant sundial (*hemiciclum*); on the equinoxes, at noon, the Sun entered the building and fell above the entrance, and this also happened on anniversaries meaningful to Imperial propaganda (e.g. 21 April, the day of the foundation of Rome). This use of light can also be attested in Nero’s *Domus Aurea*; several poetic and historical sources recount that the entrance to the Octagonal Room was hit by sunlight on the equinoxes, also at noon (Hannah et al. 2016). Some evidence suggests that these effects were similarly used in Domitian’s palace, in the Palatine. Finally, Hannah tries to picture the celebration of these hierophanies, based on the analysis of a number of Eastern Byzantine churches; in these churches, geometry, light and cosmology were used to provide light effects for solemn parades and processions, as a symbol of the divine will. According to Hannah, these light-infused rituals could be inspired by, and provide evidence for, Imperial ceremonies, also known to have taken place in Villa Adriana (De Franceschini and Veneziano 2013).

Finally, the effect of sunlight on the Mausoleum of Santa Constanza, dated to the second half of the fourth century AD and located in the archaeological complex of Sant’Agnese fuori le Mura in Rome (Rasch and Arbeiter 2007), is examined for the first time, in this volume. Based on the Mausoleum’s azimuth, calculated with satellite technology, Flavio Carnevale and Marzia Monaco, from the Università degli studi di Roma La Sapienza—who have also made interesting contributions to the study of the orientation of Greek theatres, Etruscan funerary *tholoi*, the *Portunnus* temple in the Forum Boarium of Rome and the Mithraea of Ostia Antica—have attested two phenomena: (1) after the construction of the skylight (late fourth century), the Sun illuminated the interior between 8 and 25 February, during the festival of the *Parentalia*; this heliophany was similar in character to that attested in the Pantheon every 21 April; and (2) the sunlight would hit directly the centre of the Mausoleum, where the porphyry sarcophagus of Costanza was originally located.

The foundation of Roman cities and buildings was rooted in mythology, and religious formulae were essential for the projection of the celestial order upon the landscape and the spaces ritually arranged by the magistrates (Rykwert 1988). Various research projects, especially in the western provinces, have analysed the orientation of cities (an issue already mentioned by various classical authors such as

Hyginus Gromaticus [*Constitutio*, I] and Frontinus (*De Agrimensura*, 27]), the methods used to calculate these orientations and their symbolic meaning. This method, along with other similar practices, became especially popular during Augustus' reign and has been thoroughly studied in Hispania and the western provinces by the members of the archaeoastronomy team of the IAC (Belmonte et al. 2016: 65–77; González-García 2015: 141–162; González-García, et al. 2014: 107–119). Several members of this team (A.C. González-García, A. Rodríguez-Antón, and J.A. Belmonte), in cooperation with D. Espinosa-Espinosa and M.V. García, analyse the landscape of western Augustan cities (measurements have been taken in 64 of these cities, in Hispania, Gaul, Germania, Italy and North Africa). These measurements are compared with the celestial landscape, and increasingly clear orientation patterns have begun to emerge. The evidence suggests a preference for orienting cities towards dawn on the winter solstice and, to a lesser extent, on the equinoxes and the summer solstice. The study also aims to define with more precision than has been possible hitherto the 'solar model' that identified Augustus with the Sun and Apollo, a relationship that the *princeps* used regularly for propaganda purposes. Also in relation to this, several of these authors (A. Rodríguez-Antón, A.C. González-García and J.A. Belmonte), this time in cooperation with M. Orfila (archaeologist at the University of Granada), address the use of the geometric measurement technique known as *varatio* (Orfila et al. 2014). Based on measurements taken on 81 Iberian cities, it is concluded that this technique may have been used to calculate azimuths. However, the authors admit that, although it may be argued that *varatio* was used in order to organise urban and rural landscapes, which would indicate a direct link between technique and symbol when celestial phenomena were not available for direct observation, a larger sample of case studies is necessary.

The eastern provinces, which were thoroughly Hellenised and which maintained strong links with the Near East, have also been analysed from an archaeoastronomical perspective. These studies, which have been particularly intense in the Mediterranean Levant and Egypt, generally focus on the orientation of architectural features and the occupation of the landscape. Again, the team from the IAC, led by Belmonte, González-García and Rodríguez-Antón, analyse the so-called Khirbet et-Tannur Zodiac (Hurawa), which they suggest should be relabelled as an 'almanac' or 'parapegma'. This feature was found on the main altar of the sanctuary of Djebel Tannur (Jordan) (*Arabia Adquisita*) and depicts an impressive astral cycle dated to the Roman period. Despite the persistence of Nabatean traditions, Roman domination led to the adoption of the Julian calendar in the region, although the different months were still named after the lunisolar Nabatean calendar. This is the origin of the so-called *Era Provincia Arabia*. In this volume, the feature is interpreted as a calendric guide to the rituals celebrated in the sanctuary, and the measurements indicate that it was oriented towards dawn three days prior to the spring equinox, on 22 March, that is, day 1 of Nisan (New Year's Day in the Arabian Calendar). This could mean that the complex was regarded as a national sanctuary and the destination of the pilgrimage of Djebel Tannur. A small temple in Petra, erected between AD 106 and 114, and dedicated to the imperial cult, presents the same orientation (Belmonte and González-García 2017), suggesting the capacity of the Nabateans to adapt to the Roman domination.

In the following chapter, G. Magli undertakes the study of the orientation (which has not been measured to date) of the temple *podia* of the megalithic sanctuary of Jupiter in Heliopolis (Baalbek, Lebanon) (Kropp 2009; 2010; Segal 2013). The Sun aligns with the temple on 1 May and 12 August, dates with no special implications in the solar cycle, which could challenge the solar associations of the temple. However, Magli's results indicate that the temple was aligned with the Pleiades (the Seven Sisters) during the reign of Herod the Great, which could confirm the temple's association with Jupiter and the agricultural cycle. Magli also suggests that both *podia* may have been built at the same time, during the reign of Herod the Great.

C. Rossi and G. Magli undertake an analysis of Late Roman fortified settlements in Egypt's Western Desert (Rossi and Ikram 2018), which illustrate how Romans interacted with the landscape, following well-known precepts by such authors as Pliny and Vitruvius. These settlements seem to have been oriented towards the dominating winds, from the north-west, the azimuth of which was calculated by measuring the axial axles of the surrounding sand dunes. It is unclear whether this 'weathervane orientation' responds to pre-Roman traditions or whether it answers to astronomic concerns and the desire to adapt as much as possible to local environmental conditions (wind, topography, etc.).

Finally, two chapters analyse the use of computer applications and virtual archaeology, a useful combination for the analysis and dissemination of the historical and archaeological features of ancient buildings. The first of these chapters addresses the virtual reconstruction and archaeoastronomical analysis of the Mausoleum of Theoderic, in Ravenna, built during Theodric's reign and heavily transformed from the eighth century onwards. After examining the original elements, M. Incerti, G. Lavoratti and S. Iurilli (architects at the Università degli studi di Ferrara) explain the development of a 3D model of the exterior and interior of the building and use its astronomical orientation (measured in 1995 by G. Romano) to analyse the effects of sunlight at different times of the year. Specifically, light entered through some of the windows on the solstices, illuminating important elements in the interior, including the red porphyry sarcophagus. As noted in the introduction to R. Hannah's chapter, above, this kind of light effect was a common way to highlight special dates or times of the day. In addition, the geometrical study of the Mausoleum revealed that, rather than the mathematical calculations conveyed by *De Geometria*, attributed to Boethius, the architect of the Mausoleum used the geometrical tools contained in Euclid's *Elements.* The results also suggested that the builders of this monument occasionally used the Roman foot, although the standard measurement unit in the building was the Byzantine foot.

Finally, G. Zotti, B. Frischer, F. Schaukowitsch, M. Wimmer and W. Neubauer, who work on generating 3D models of archaeological buildings and features (Ludwig Boltzmann Institute for Archaeological Prospection and Virtual Archaeology de Vienna, Indiana University and the Institute of Computer Graphics and Algorithms of Vienna), are currently giving the final touches to the software *Stellarium*, which will present these buildings and features in relation to celestial bodies. The result of this project is the so-called *Skyscape Planetarium*, which presents the relationship between the Earth's landscape and the sky in an accessible way. The tool can simulate the astronomic relationships of buildings with total precision, showing orientation patterns and sunlight and moonlight effects (Zotti 2015).

These tools, which were publicly displayed with great success in the exhibit *Stonehenge. A Hidden Landscape*, celebrated in 2016–2017 in the MAMUZ Museum (Mistelbach, Austria), have also been applied in two 'Roman' projects: (1) the study of the astronomical orientation of the *Antinoieon*, in Villa Adriana (Frischer et al. 2016: 55–79), which has confirmed Mari's initial theses (Mari and Sgalambro 2007: 83–104) that the so-called Temple 1 is oriented towards dawn, on the summer solstice (festival of *Fors Fortuna*), and towards the constellation of Antinoo, the heliacal configuration of which occurs around the birthday of Hadrian's unfortunate lover, and (2) the analysis of the relationship between the *Ara Pacis* and the *Horologium* (Frischer et al. 2017: 18–119; Frischer 2017–18, 3–100), which has identified the mistakes upon which Buchner's (1976: 19–65) famous hypothesis was built, and has determined that the shadow of the obelisk did not run along the equinoctial line across the central area of the altar on Augustus' birthday; the emergence of the Sun over the top of the obelisk, on the other hand, has been confirmed, which reinforces the idea that the obelisk was dedicated to the Sun, already suggested by the epigraphic evidence.

There is little doubt that these works will notably contribute to the consolidation and dissemination of Roman archaeoastronomy, while highlighting the central role played by astronomical observation and celestial phenomena for the Romans, a key factor for the symbolic and mythical aspects of their society.

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15 June 2018

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Preface

In the last decade, there was increasing interest in the archaeoastronomy of the Roman epoch and many researches were carried out on this topic. Several studies have been devoted to the possible astronomical orientation of buildings—including the light effects with symbolic meaning—to the astronomical symbolism of the artefacts, and to the possible astronomical orientation of towns. Therefore, the time was more than ripe for a meeting dedicated specifically to ‘Roman’ archaeoastronomy. In 2016, the opportunity was offered by the Politecnico of Milan, Department of Mathematics, where the International Meeting on the Archaeoastronomy in the Roman World took place from 3 to 4 November. The meeting was followed by the Annual (XVIth) Conference of the Italian Society for Archaeoastronomy (SIA).

This volume includes a selection of the papers presented in that event organised into parts and chapters. Part I is devoted to the Etruscan Civilisation, from which Romans took several ideas. This includes two chapters that centre on an analysis of temples and on how the cosmology of the Etruscans was related to their funerary customs. In Part II, the orientation and solar light effects at given dates are considered for the Imperial buildings in Rome. One paper deals with the motivations of the symbolic use of equinoxes and solstices during the Imperial period, and two chapters illustrate the possible light effects in two monuments: the Basilica of Porta Maggiore and the Mausoleum of Santa Costanza. Part III is dedicated to the orientation of Roman towns, with a paper on a statistical analysis of a large set of sites, from central Europe to northern Africa, while another paper describes the possible use of a practical geometrical tool for planning the orientation of an urban grid. Two chapters in Part IV illustrate the astronomy in the provinces of the Empire under the influence of Roman rule. The first chapter proposes a new interpretation of the Tannur Zodiac (Nabataea) as a ‘parapegma’, and the second one discusses the chronology of the complex realisation of the Temple of Jupiter at Baalbek. The case of the Kharga oasis in Egypt is discussed in the third chapter, where the importance of the wind direction for the settlement is pointed out, while, in Part V, the first chapter is dedicated to the architectural and geometrical analysis of the Mausoleum of Theodoric. Finally, the second chapter in Part V describes the capabilities of the open source system Virtual Archaeoastronomy within the Stellarium software, intended for research and outreach, and shows some examples of its application to Roman monuments.

Etruscans, people who '... excelled everyone in religious observance ...' (Livy 5.1.6), had a strong influence on political ideology and related rituals in the Roman world. The *Libri Rituales* of the *Etrusca Disciplina* also included the *Libri Fatales,* which probably contained the Etruscan founding rituals of cities and temples adopted by the Romans. The Etruscans gave great importance to the exact location of the cardinal points. According to Hyginus Gromaticus (first to second century CE), those points were the paradigm also for Romans, as regards at least (theoretical) land division. In the practical realisation, however, the Romans quite often adopted other criteria. For example, they usually took into account the physical characteristics of the places (e.g. rivers), or they used a simplified procedure to determine the East direction (and Hyginus showed why it could be erroneous). Vitruvius (first century BC), on the other hand, suggested a practical criterion for the town orientation based on the wind direction, since he was concerned mainly with the healthiness of the inhabitants, while he maintained the cardinal orientation for temples, when possible.

Things probably changed in part when Augustus introduced the (solar) cult of the Emperor. One may note in passing that he began this process with the divinisation of Julius Caesar in 44 BC by exploiting also an astronomical phenomenon, a comet that happened to appear during the period of the obsequy. It may be possible that astronomical criteria based on the sunrise at *specific* dates were then adopted for towns, temples and buildings. Many towns may be considered in this respect, since, as declared in the *Res Gestae*, Augustus settled colonies in Africa, Sicily, Macedonia, Spain, Achaea, Asia, Syria, Gallia Narbonensis and Pisidia, while Italy had 28 colonies founded under his auspices. Unfortunately, Augustus did not include the list, and historians tried several times to identify them (see e.g. Mommsen). As shown by inscriptions (e.g. OGIS 458), Oriental populations of the Roman Empire were keen to worship the Emperor (*Sebastos*). The positive attitude towards his divinity increased during the first centuries CE; for example, there are Roman coins with the representation of the Emperor as *sol invictus*. Several researchers have pointed out the light effects corresponding to solstice and equinox dates in Roman buildings of this epoch and connected in some way with the Emperor. Light effects based on specific astronomical orientations probably also were adopted later, but of course with a different meaning, for the Christian buildings.

A subtitle of the 'Joint 16th Conference of SIA and 1st International Workshop on Archaeoastronomy in the Roman World' was a quotation from Manilius' poem *Astronomica* (II.105)

> Quis dubitet [post haec] hominem coniungere caelo?,

that is, who can doubt that a link exists between heaven and man? Manilius was contemporaneous with Augustus and Ovid. In his poem, he described celestial phenomena, the zodiac and the related astrology. He and presumably many other people thought about cosmic harmony and the immanent divinity of nature. He wrote that into the soul of man God descends and seeks Himself and that the love of heaven makes us heavenly. Given that strong belief, it is therefore reasonable, not to say obvious, that present-day researchers would attempt to detect the expressions of such an astronomical link in ancient Roman artefacts and architecture, putting their results in archaeological and historical context. One can expect therefore further progress in this field.

Sadly, during the editing of these proceedings, we got the dismaying news that our colleague and friend Vito Francesco Polcaro passed away. Francesco was a polymath. He got three degrees, in mechanical engineering, aerospace engineering and mathematics; his scientific researches were mostly in high-energy astrophysics and technology, and in the astrophysics of the highest mass stars, but he also had deep interest in cultural astronomy, archaeoastronomy and archaeology. He collaborated with many professional and amateur archaeologists in the study of the astronomical content of ancient sites and artefacts, particularly in Rome and in Southern Italy. He regularly attended SIA and SEAC meetings, and he contributed actively to the organisation of several of our conferences. He was an enthusiastic man who believed passionately in science-led regulation and in the importance of the social aspects of science. Many people in primary and secondary schools and in cultural associations enjoyed his brilliant outreach talks. This volume on archaeostronomy in the Roman World is dedicated to the memory of Francesco.

As a final acknowledgement, we warmly thank the Politecnico of Milan for their hospitality and help with the organisation of the conference.

Milan, Italy Elio Antonello

Contents