Mediterranean Archaeology and Archaeometry, Vol. 14, No 2, pp. 95-113

SACRED ARCHITECTURE ORIENTATION ACROSS THE MEDITERRANEAN: A COMPARATIVE STATISTICAL ANALYSIS

A. César González García[1] and Juan Antonio Belmonte[2]

[1]Heritage Sciences Institute, Incipit, Spanish National Research Council –CSIC, Rúa San Roque 2, Santiago, SPAIN
[2]Instituto de Astrofísica de Canarias and Astrophysics Department, University of La laguna, Calle Vía Láctea s/n, La Laguna, Tenerife, SPAIN

Received: 07/03/2014
Accepted: 16/05/2014
Corresponding author: A. César González-García
(a.cesar.gonzalez-garcia@incipit.csic.es)

ABSTRACT

The idea of temporality and how this concept is introduced in the ritual domain could be investigated in past cultures through measurements of the orientation of cultic buildings, provided that such orientations are linked with particular astronomical events. Hellenic societies, among those of the Mediterranean Iron Age, had a need to regulate time through a calendar. The orientation of Hellenic temples in present day Greece and the South of Italy have recently been shown to be somewhat dissimilar, despite the obvious cultural links. In the present paper we verify if the samples of orientations of Hellenic temples in five distinct geographic areas are consistent with each other from a statistical point of view. Then we compute the internal variability among these groups by comparing them with other samples of temples across the Mediterranean, both for the Iron and Bronze ages, in order also to find possible long duration effects on the orientation of temples. Despite apparent discrepancies when directly comparing the Hellenic samples, a clear similarity among these groups of temples appear when we compare them with temples from other societies. Such comparison links closer the temples in Greece with those in Lycia and perhaps Cyrene, and the ones in Sicily with those of Magna Graecia. As a by-product, we find other possible concordances among sacred building orientations across the Mediterranean that may deserve further exploration in the future.

KEYWORDS: Orientation, Greek temples, Mediterranean, Calendrical systems, Time and temporality, Statistical methods.

1. INTRODUCTION

Orientation studies, long neglected, have recently received considerable attention in the archaeological domain as a source of information that may shed light on a number of issues related to landscape and territory apprehension by past cultures (see Parker-Pearson 2008).

Divided for several decades among the practitioners of the so-called 'green' and 'brown' archaeoastronomies (meaning, the collection of statistical samples of data or the ethnographic and anthropologic research of particular cases, see Ruggles 2011 for a recent review), scholars working in Cultural Astronomy (CA hereafter) across the world today tend to apply a combination of the two above-mentioned approaches. Samples of orientation measurements are usually related, if possible, with ethnographic and anthropologic data, written records, etcetera.

In this sense, we must mention the valuable works by M. Hoskin (2001) and C. Ruggles (1999) on the megalithic phenomenon. Of particular interest are the results from a number of such studies on the orientation of temples and funerary structures in literate societies in the Old World, particularly in the shores of the Mediterranean (See Belmonte & Shaltaout 2009; Boutsikas 2008; Boutsikas & Ruggles 2011; Gonzalez-Garcia & Belmonte 2011; Belmonte, Gonzalez-Garcia & Polcaro 2013) as these results can be compared with the written record and help to clarify controversial issues regarding those societies.

In particular, the above-mentioned works on Megalithism (and others) indicate a purpose to dominate the ritual landscape through the need to control the correct time to perform rituals (Aveni 2000:325-339). At the same time, we might acknowledge that the Mediterranean Bronze and Iron Age societies, as early state societies had different calendric systems as a reflection of the various needs to regulate the experience of time. The distinct orientation patterns of their monuments might reflect precisely those differences in the calendric and/or belief systems.

The written records of some ancient Mediterranean cultures, such as the Egyptians, Greeks or Romans, do speak of the need to set temples with a correct orientation, whatever this might be, although it is often difficult to discern if this precept was actually followed. For instance, Vitruvius (De Architectura I, 6) and Higinus Gromatici (Constitutio, 1) tell us that Roman temples should be orientated in a particular way. However, Nissen (1869) showed early on that the orientation of such temples seemed not to follow what was presumably prescribed.

The roots of Archaeoastronomy and CA are deep in the study of the orientations of monuments, and these orientations are no more than measurements in space. Thus, when we measure an orientation we are measuring a dimension, a direction. This dimension is embedded in material objects as a formal constituent of them and so the cultural process that generated it could be studied and interpreted.

However, particular directions might have special meaning on temporality for a given society. Singular areas of a given landscape might be important on certain periods of the year. For example, a meadow might have special relevance in summer when the harvest time comes, and a given culture might impose a temporal significance to that meadow, which could be highlighted if particular rituals have to be performed at that place on that occasion precisely. So, material forms, social and ritual processes and cultural concepts are reciprocally engaged: the spatially important area of the landscape gains a temporal and ritual meaning (Gell, 1992:197-205).

At the same time, we must bear in mind that temporality introduces order in space. In this sense, it creates the Landscape, as the space thought and culturally built where not only the natural features such as springs, mountains or woods are present but also other artificial structures from the same or other societies which are though or reinterpreted by a different culture (García Quintela & González García 2009), 'Landscape is time materialized' (Bender 2002).

The practice of a society of going to a particular part of the territory at a given moment or performing a specific ritual at the correct epoch and place, orders the experience of time and space (Whitrow 1988; Ingold 1993). In this sense, orientations might not be just reflecting a social activity, but they are an active part of it.

The celestial phenomena provide a number of regularities that can be used to orientate in space and to define understandable time lapses. It is also important to note that the sky has been used as a repository of myth and metaphysical explanations in several societies. Following this reasoning, an assumption on the astronomical significance of the orientation of monuments may give us information on time or, to be more precise on the concept of temporality in a given society (see e.g. Magli 2005 and Ruggles 2014).

This is a complex subject. Not all societies need to have acknowledge the apparent flow of time, and those who did it might have done it in a wide variety of forms, from cyclic to linear or other concepts based on the ancestors cult, the naturalistic cults, etcetera (Gell 1992: 37-77). However, we might postulate that different orientations are perhaps reflecting a different conceptualization of time or, at least, of the way of understanding and ordering temporal experience and its incorporation towards the cultural discourse.

The concept of temporality we are using here might be related to the calendrical time, however it should not be understood as opposed or completely separated from other expressions of temporality, like the biographical, ritual or historical time (see e.g. Fabian 1983; Gell 1996; Ingold 1993). In this sense, we will use the term temporality as the concept of the understanding and apprehension of the flow of time. This is not a paper on the concept of temporality but rather on how this concept could be investigated in past cultures through CA measurements or orientation of cultic buildings, and thus how this concept is introduced in the ritual domain through the orientation of cultic buildings.

In this sense, the different attitudes and needs of a society would also be reflected on how they build their sacred buildings, how they integrate them in the landscape and, in this sense, in their orientation. It should be noted here that there is a fundamental difference between a purpose to control time and the need to regulate such time. The first indicates an interest towards knowing when a particular event should happen, while the second indicates a purpose to manage the flow of the events, an intention to adjust the time account in order to follow particular markers previously prescribed, like for instance Passover, which should be celebrated on a given Sunday after the first full moon of spring. Of course, the need to regulate or control time would be reflected on the different kind of rituals to be expected in one or the other instances, and would also talk to us of perhaps more complex beliefs. This would be ultimately reflected on different ways to orientate the monuments.

2. CULTURAL ASTRONOMY, ORIENTATIONS AND TIME

The Near East and Hellenic societies had a need to regulate time (Cohen 1993; Hannah 2003). They required a calendar, as it is understood today, as a system to compute and regulate time. Not only they had to regulate civil time, but also religious and ritual time, although these concepts must not be separated for most of those societies. This need is reflected in the different calendars that have reached to us which pay great interest to particular moments of the year and the necessity to accommodate ritual and natural (i.e. seasonal or astronomical) cycles. This might be reflected in the appearance of clearly solstitial or equinoctial related orientations (Gonzalez-Garcia & Belmonte 2011; Belmonte et al. 2013).

Hellenic societies, among those of the Mediterranean Iron Age also had this need to regulate time through a calendar. Of course, each city-state had a different calendrical system, but festivals had to be celebrated at particular times of the year and in most occasions in accordance with the seasons (Hannah 2003). Salt & Boutsikas (2005) and Boutsikas & Ruggles (2011) have shown that the orientation of some temples might be associated with particular dates of those calendars, perhaps related to the sighting of specific astronomical events and festivals. There is somewhat of a controversy about the orientation of Greek temples. While Salt (2011) investigating the Greek temples in Sicily finds arguments to support that those temples are not orientated randomly, but mostly towards the eastern horizon, Boutsikas (2008), while investigating the temples in present day Greece finds that only 58% of the temples there are oriented towards the eastern half of the horizon. This would point towards clear differences in orientation between Greek temples in different areas of the Hellenic milieu.

Despite the possible presence of stellar based festivals (see e.g. Boutsikas & Salt 2005 or Boutsikas & Ruggles 2011) and that the start of the month and of the year might vary from one city to another (Hannah 2003), the basic calendric system seems to have been of luni-solar character. Such system was based on a count of days collected in lunar months, at first computed by observation, and latter on by the introduction of diverse ways of computus; and with the need to introduce intercalary months to accommodate the lunar cycles to the solar ones, in order to celebrate festivals at the correct time. If such a system was common to most of the Hellenic city states (albeit with differences, for example about the start of the year), and if the orientation of temples had a relation to their way of understanding time, we might expect that the orientations of temples at different Hellenic areas would be more similar to each other than to the orientation of temples in other societies, like for instance the Egyptian or the Etruscan ones, with presumably different concept of temporality. Besides, if this concept did not arise with the advent of the Hellenic classical city-states, we would expect it to be maintained over time and space.

This is the hypothesis we want to test in the present paper. The different calendars, religious belief systems and time conceptions should be reflected in different orientation patterns. Conversely, similar calendric and belief systems should be reflected in similar orientation patterns. Such patterns have eventually been directly compared with historic sources in many instances. In particular, we want to test that groups of monuments built by Hellenic societies at different areas of the Mediterranean share the orientation of their monuments as a common characteristic of their temples. This would be a reflection of a common form of the concept of time and shared religious background and its way to compute it in a calendar.

In order to achieve our purpose, we first concentrate on a particular set of monuments with obvious cultural links (Hellenic temples), then we compare with other sacred precincts across the Mediterranean for a similar time frame, and finally we compare with other sacred precincts from other epochs.

It should be stressed here that in order to perform this study we need extended statistical samples of sacred areas. A single orientation might be significant only if taken within its cultural context. In the case of multiple orientations, the possibility that a pattern on orientation arises provides a framework that is telling us something about the society who built those structures, and as a material record, it is also telling us something about its culture. It has been argued elsewhere (Boutsikas & Ruggles 2011) that pure statistical approaches, because they are decontextualized from other archaeological or literary material are susceptible to a number of limitations. To overcome these limitations, we propose to use an approach where the conclusions are dictated by the orientation data considered inside the culture that developed such orientations.

3. DATA SAMPLE

We begin this exercise by introducing the data for two groups of temples measured by the authors and presented here for the first time. These groups belong to Lycian and Hellenistic towns in southern Turkey and the Greek and Hellenistic temples of Cyrenaica.

Our knowledge of the Lycian society relies mostly on local inscriptions and the Greek accounts prior to the conquest of the area by Alexander. Bryce (1986) arguably connects the Lukka found in inscriptions of several sources as the likely predecessors of the Lycians in western Anatolia, with possible ties both with the Luwian speakers but also with Minoan and Mycenaean Greece. During the 6th to 4th centuries Lycia was shifting allegiances, and perhaps also cultural influences, from Persia to Greece, while after the conquest of Alexander it was clearly in the sphere of influence of the Hellenistic realms. The Greek influence seems wide, among other examples, in the characteristics of the temples, denoting a clear Greek flavour, and in the names of the principal deities worshiped there.

Cyrene, on the other hand, was directly founded as a Greek settlement on the 7th century BC, and remained as a Greek city, possibly one of the most important Greek enclaves in Africa (Austin 2006). Herodotus, describes the foundation by an expedition from Thera after an oracle from Delphi. It was a rather independent, although undoubtedly Greek city state, although with influences from nearby Egypt, as it is attested by the worship of Ammon in Cyrene and the political allegiances with their rulers, and the local Libyan population. After the dead of Alexander it became part of Ptolemaic Egypt, displaying a clear Hellenistic influence afterwards. It was Romanized in the 1st century BC, together with the cities of the Pentapolis.

Figure 1: Two examples of the temples measured in Lycia and Cyrene. (a) Apollo temple at Letoon. (b) Zeus temple at Cyrene. Images courtesy of A. C. Gonzalez-Garcia and J.A. Belmonte respectively.

Indeed, both regions share a somewhat loose link through the Greek cultural milieu (see Figure 1), but given the internal differences in geographic location, and the varying cultural substrata it is possible that the orientation of temples should not be similar.

Table 1 lists 56 temples and monumental tombs from the Lycian and Hellenistic towns in the southern coast of Turkey, collected in the summer of 2009. Table 2 includes the Greek and Hellenistic temples of Cyrenaica, measured in a campaign during the winter of 2006. Both tables include the location, given by the name of the city and the monument, the geographic coordinates and the epoch of construction. Finally, the orientation data are presented as the azimuth measured from inside the temple looking outward, and the angular height of the horizon in that direction. The next column provides the declination, while the last includes comments when particular orientations, such as the perpendicular to the main axis, have been considered.

To fairly compare the orientations of the cultic elements in different regions in a way that is independent of geographic coordinates, we have used the conversion of the orientations (azimuth) to declinations. Declination is a coordinate commonly used in astronomy and might be equated as a transposed version of the latitude for the celestial sphere. For a given location on the surface of the Earth, it relates the azimuth and the angular height of the horizon with a particular sector of the sky, independently of geographical location.

Figure 2 shows the orientation diagrams for these two regions. Diagram (a) shows the Lycian monuments, built from the VIth to the IIIrd centuries BC, with a clear concentration on the east-west line. This is clearer in panel (b), which shows the declination histogram.

In the following we will be using an appropriate smoothing of the declination histogram by a function called 'kernel' to produce the kernel density distribution (hereafter KDD). At each entry in declination, we multiply the value of the number of occurrences of a given declination by the kernel function with a given pass band or width. For this process, an Epanechnikov kernel is employed with a bandwidth of twice our estimated error in declination.

To be able to say whether a measurement is significant, we use a normalized relative frequency to scale our KDDs or histograms. To do so, we divide the number of occurrences of a given declination by the mean number of occurrences for that sample, this is equivalent to dividing or comparing with the results of a uniform distribution of the same size as our data sample, and with a value equal to the mean of our data.

A clear concentration of orientations appears around δ = 0°. This could easily be related to the equinoxes, a term used here in a broader sense (see Ruggles 1998). Panels (c) and (d) pertain to the temples in Cyrenaica.

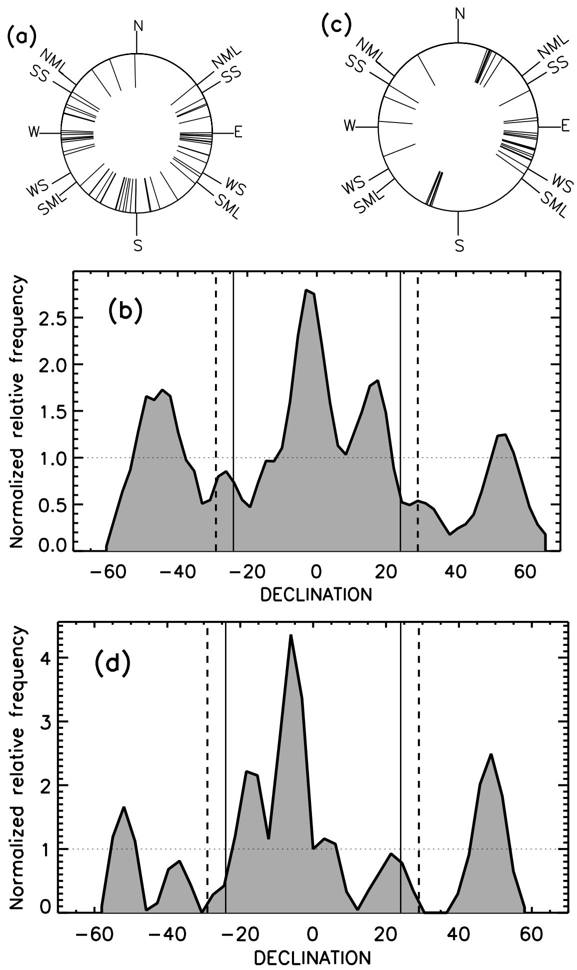

Figure 2: Orientation diagrams for the Lycian monuments and temples from the Cyrenaica listed in Tables 1 and 2, respectively. (a, c): azimuth plots showing the directions with respect to the local landscape. SS stands for Summer Solstice, WS for Winter Solstice, NML and SML stands for the northern and southern Major lunar Standstill, respectively. These are the northernmost and southernmost risings or settings of the Moon. (b, d): declination histograms showing the preferred directions with respect to a non-local coordinate system. The histogram is normalized by the mean, so values above 2.5 can be considered as 99% statistically significant. Vertical solid lines indicate the winter (left) and summer solstice (right) positions reached by the Sun, while dashed lines indicate the SML (left) and NML (right) for the lunar extremes. The interval between these lines indicates orientations compatible with the Sun or the Moon. See text for further details.

If we perform a Kolmogorov-Smirnoff Test (see e.g., Fletcher & Lock 2005), to check whether the two could be drawn from different populations, the distance and probability: D=0.18, p=0.38, tell us that we cannot exclude the null hypothesis that they are drawn from the same population.

We should include here a cautionary note. Such test does not tell us that they are correlated; it merely says that we cannot rule out the null hypothesis.

Given the abovementioned Greek sway we could compare the data samples from Lycia and Cyrenaica with those of ancient Greece in order to see if they all could be drawn from a common pool. To do so, we use the data from the Hellenic temples in Greece presented by Boutsikas (2008). These include 112 orientations of temples located across present day Greece and from the VIIIth to the IIIrd century BC.

We have performed two correlation tests:

i) The Pearson linear correlation index (R; Rodgers & Nicewanders 1988) shows if the two samples could be directly related by a linear combination. This index is calculated as the covariance of the two samples divided by the product of the individual standard deviation:

$$R_{X,Y} = \frac{\sigma_{XY}}{\sigma_X \sigma_Y}$$

If the index is close to one means a perfect correlation with very small (null) dispersion, a value close to zero means no correlation while values close to -1 mean anti-correlation. The comparison of the data Greece-Lycia and Greece-Cyrene show values of R equal to 0.76 and 0.71 respectively. Although the coefficient is not close to unity it is large enough to indicate that there could be a good linear correlation, with a given spread.

ii) A standard cross-correlation (Ljung 2003). Such exercise searches if two distributions (in our case, derived from two data samples) are similar in shape. Let us suppose we have two functions *f* and *g* identical in shape but differing by a shift along the x-axis. The cross-correlation will inform us of that shift. Basically, the cross-correlation is equivalent to the convolution of $f^*(-t)$ and $g(f)$:

$$(f * g)(t) = \int_{-\infty}^{\infty} f(\tau) g(t-\tau) d\tau.$$

In principle, if two distributions are identical the final value of the cross-correlation should be close to unity for an offset of zero. Cross-correlation can be calculated for different values of a given offset in the x-axis, the offset with the maximum value for the cross-correlation gives a measure of the offset applied to the distributions in order to match the shapes. If two completely different samples are compared, the cross-correlation will provide very small values.

After performing such cross-correlation for the distributions of Greek, Lycian and Cyrenaic temples we obtained values of 0.8 for the Greece-Lycia comparison and 0.72 for Greece-Cyrene, for values of the offset of 3° and -3° in declination. This means that, despite a small offset the three samples correlate quite well.

These tests show that the three samples of Hellenic temples in Greece, Lycia and Cyrene do seem to present reasonably similar orientation patterns. Given the cultural ties among them we could conclude that there possibly was a common practice in temple orientation among them, and thus our starting hypothesis seems robust.

In order to find if such consistency is shared by to other groups of Hellenic temples we further include temples from of other areas of Greek culture such as Sicily and Magna Graecia, obtained from Salt (2009) and Aveni & Romano (2000), respectively. The result of comparing the Greek temples with those measured in Magna Graecia and Sicily is similar to the results exposed above for the temples in Lycia and Cyrene. The K-S text shows that we cannot exclude that they are drawn from a common distribution (D and p), and when we calculate the Pearson correlation test with the results from Greece, both values (Magna Graecia vs. Greece P=0.76; Sicily vs. Greece P=0.68) indicate that there could be a good linear correlation, albeit with some scatter. The cross-correlation indicates that both have maximum values at a shift of −3° in declination with values 0.77 and 0.69 respectively.

These results seem to indicate that the customs for temple orientation were common to the different Hellenic groups. This does not mean that all temples should be oriented equally, but that in a statistical sense, the temples followed shared patters. Given the hypothesis stated above –that such orientations might have something to do with the calendar and/or ritual times–, such similarity comes to no surprise if the different groups shared a common way of counting time or orientated their monuments to similar astronomical targets.

However, to properly account for the degree of agreement between them we must test the internal variance among these groups. Comparing these groups with others supposedly not directly culturally connected with them is the best way to do so. First, we will compare with other groups of cultic monuments from the Iron Age to test whether such coherence is something internal of Hellenic temples. Finally, we will also compare with temples from the Bronze Age, to test if such consistency could be traced back to earlier times, and thus see possible long duration effects on the orientation customs.

4. A COMPARISON BETWEEN IRON AND BRONZE AGES

Data from the literature (including the authors' ones) for 24 areas have been collected. In total we have analysed above 2400 cultic structures in the Mediterranean and for different epochs, from Old Kingdom Egyptian shrines to North African Roman temples.

Data for the Egyptian temples were obtained from Belmonte, Shaltout & Fakri (2009) and Belmonte et al. (2010). These authors have analysed a sample of nearly 400 temples from the Early Dynastic to the Roman period and have confirmed that both astronomy and topography were important when laying out the orientation of the sacred structures. Kushite data include 50 temples and were taken from Belmonte et al. (2010). Hittite and Phrygian orientations were obtained from the survey performed by González-García & Belmonte (2011). Nabataean temples were measured in a recent campaign by Belmonte, Gonzalez-Garcia & Polcaro (2013). M. Blomberg and G. Henrikson measured Minoan temples in several campaigns and the data were kindly provided by the authors (see Henrikson & Blomberg 2008 for further details). Maltese megalithic temple data are from Fodera-Serio et al. (1992), while the Etruscan and Samnitte temples were measured by Aveni & Romano (1994) and Ruggieri & Pagano (2010), respectively. Taulas from Minorca were measured by Hoskin (2001), and Aramburu-Zabala & Belmonte (2002) collected the data for the square talayots from Majorca. Data for Sardinian nuraghe come from Zedda & Belmonte (2004). Esteban (2002) collected the data for the Iberian shrines while Esteban et al. (2001) and Belmonte et al. (2007) did the same for pre-Roman and Roman temples in North Africa. This cluster of temples has been divided into two groups, the first including pre-Roman sanctuaries, presumably showing Libyan-Phoenician ancestry (Esteban 2003) and the second including Roman temples founded *ex novo* (see Figure 3).

As a test group, we have included a number of funerary structures with possible cultic functions such as the Thracian megalithic monuments (González-García et al. 2009), Tunisian dolmens (Belmonte et al. 1998; Belmonte et al. 2003), Sardinian Tombe di Giganti (Zedda et al. 1996) and Punic hypogeal tombs (González-García et al. 2007).

Indeed, these groups include completely different societies that might not have any relation at all. We will be comparing both temples, and funerary monuments, beside other structures, but all of them have a clear sacred character. In any case, our intention is to use them as a test group for the internal variance of the orientations within the Hellenic group of cultic structures as compared with contemporary monuments of the similar kind. As a by-product, some of these groups could be a priori more closely linked in terms of their possible cultural connections, and one could expect that some similarities appear among them.

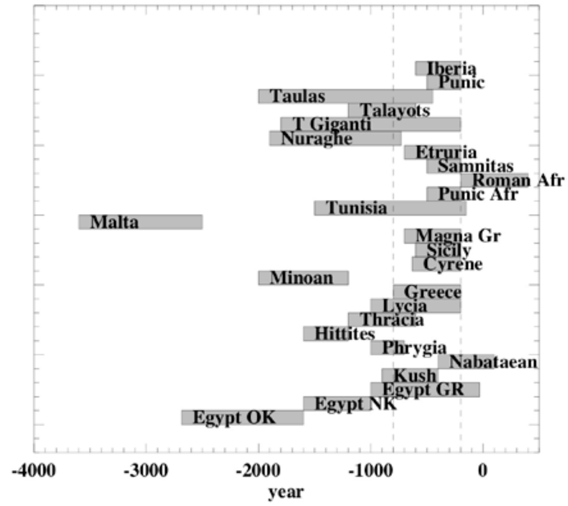

Figure 3: Time span of the different societies whose temples or funerary structures are considered in the text. Horizontal lines are indicative only of the criterion followed to include temples in the Iron Age or global group analysis.

Methods

Each group of monuments provides a set of orientation data potentially comparable to other groups. Most works listed above provide enough data as to compute the declination for their measurement. In those very few cases where only azimuth data are given, we have assumed a constant horizon altitude (h=0º), and a mean latitude, to calculate the declination for the group under investigation.

We have used two different statistical methods based on cluster analysis to discriminate in our data set those groups that could be more closely related according to their orientation patterns.

On the one hand, the first approach is hierarchical clustering. This procedure, based on cluster analysis, identifies groupings of *m* items, on the basis of their distance in a given *n*-dimensional parameter space (see Tan, Steinbach & Kumar 2006).

To use this method, each group of monuments was characterized by a set of statistical parameters. Among the different possibilities, González-García & Belmonte (2010) came to the conclusion that the kernel density distributions of each group are well represented by seven common statistical parameters, or 'genetic markers', as listed in Table 3: the mean declination, the median declination, the standard deviation of the distribution, the maximum and minimum declination of the group, and finally the declination of the first and second maxima in the KDD.

We have used these data to calculate the statistical distances between the different groups of monuments. Finally, the data arranged according to these statistical distances can be presented in a dendrogram. We have used IDL software first to produce the cluster analysis data and then the distances among groups, using a weighted pairwise average algorithm already implemented in the software. In this algorithm the distance between two clusters is defined as the average distance for all pairs of objects between each cluster, weighted by the number of objects in each cluster.

Figures 3 and 5 show the corresponding dendrograms for the Iron Age only groups and for the total groups constructed using Ward's method. The relative distance is given on the left side of the diagram. This magnitude, which in itself has no physical meaning, can be used to find correlations between the different groups.

On the other hand, the second method uses the *k*-means clustering (Everitt 1995). In this case, the statistical approach links the groups of monuments into clusters by comparing the shape of the KDD of each data group with a given seed. In each step, the method computes the distance of each distribution to the seeds and then performs the grouping. In this algorithm the distance is defined as an Euclidean distance. The method tries to find by an iterative process, the optimal clustering which minimizes the distances within each cluster, defined as the sum-of-squares. To do so, at each step of the iteration, the groups define a new seed by calculating the one in that cluster that is closer to the mean of the cluster. The process is iterated until it reaches convergence, i.e. until further iterations result in finally obtaining the same groups.

We have initially used four seeds for the first test with Iron Age sacred areas and then six for the total groups (including Bronze Age temples). It is important to stress that, at the end of the process, the groups used as seeds do not need to be in the cluster they initially defined as they may happen to be closer to other groups once the iterative process has started. In order to verify the robustness of the four/six groups, we have performed tests changing the initial seeds that resulted in very minor differences.

Figure 3 shows the chronographic schedule of the societies involved in our investigation. For the first comparison with the Hellenic temples we consider those temples and funerary structures of societies commonly accepted to be of the first or second Iron Age or with chronologies mainly later than 1000 BC. This include: the five Hellenic groups treated so far (Greece, Magna Graecia, Sicily, Lycia and Cyrene), the temples of the Late and Graeco-Roman periods in Egypt, the temples from the Kushite kingdom, Phrygian temples, Samnite and Etruscan temples in Italy, Nabataean temples, Lybic-Phoenician temples and Roman temples in North Africa, Punic hypogean tombs in western Mediterranean and Iberian temples. In total this amount for 15 groups of monuments. The indices used for the cluster analysis are given in the upper section of Table 3.

Figure 4 shows two dendrograms for these groups of monuments. The second maximum of the distribution in two of the groups of monuments (Nabataean and Cyrene) is difficult to determine. Two maxima in each distribution have similar values of the relative frequency, and thus we have opted by including both in the analysis. The two values produce different links with other clusters and this explains the differences in the two diagrams shown in figure 4.

Looking at the disposition of the Hellenic temples in the upper diagram, the first outcome is that the temples from Cyrene seem to be located away from the other four Hellenic groups and closer to the Egyptian late period temples. This should be no surprise, given that the ruling elites in both geographic areas shared close ties (see e.g., Dodson & Hilton 2004). However in the alternative dendrogram of the figure including different second maxima, Cyrene temples are closer to the other Hellenic groups. Further, independently of the diagram, the other Hellenic temples are always clustered in similar positions. These latter groups seem to divide themselves into two further clusters, one relating closely the monuments of Magna Graecia with those of Sicily, and then a second one relates the temples in Greece with those in Lycia.

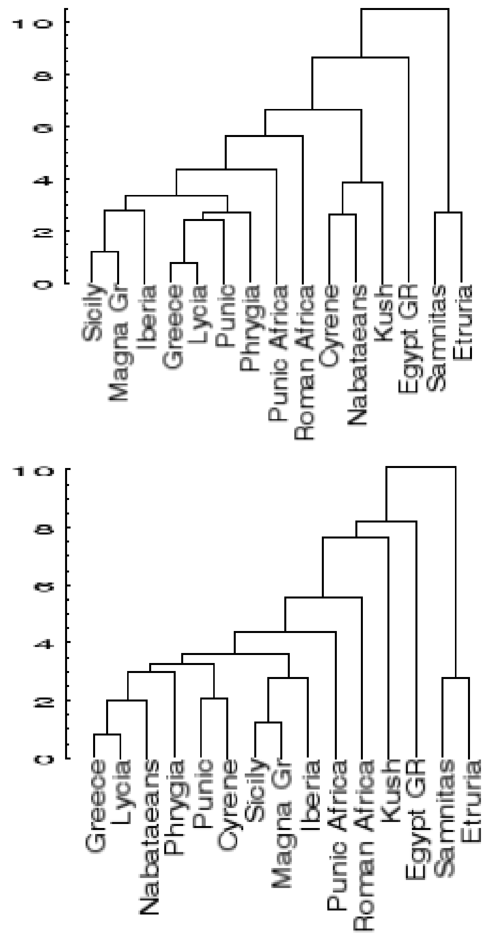

Figure 4: Dendrograms of the 15 groups of monuments of the Mediterranean Iron Age, considering two different possibilities for the secondary maxima of Cyrene and the Nabataeans. Upper diagram is for the values 50° for Cyrene and 61° for the Nabataeans, bottom if for −15° and 21°, respectively. The different groups are arranged according to a weighted pairwise average algorithm. The magnitude on the y-axis gives a sense of such distance. Note the consistency of the Hellenic group, irrespective of the Cyrene result.

These results are corroborated by the k-means analysis, as shown in Figure 5. Small variations are present, with perhaps a closer relationship between the Cyrene temples with those in Lycia and Greece. The Ionian temples (Aegean coast of Turkey) would be an ideal test bed for these results. In principle, our hypothesis would predict that their orientations should be closer to those found in Greece and Lycia, than to other Hellenic temples.

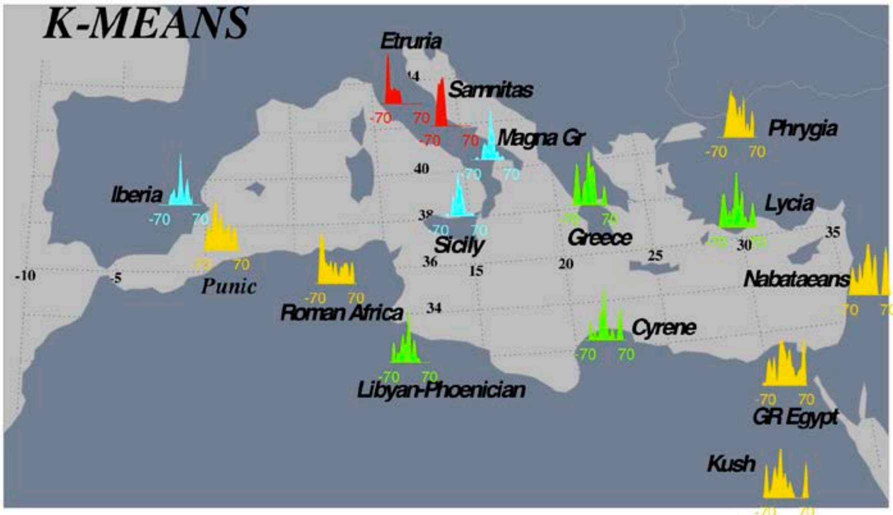

Figure 5: Map showing the results of the k-means algorithm, representing each group by its corresponding declination histogram. As shown here, the algorithm was run with four seeds and provides four groups, very similar to the ones obtained from the dendrogram, thus showing the robustness of the result.

Finally, we want to test if these relations hold when a much larger set monuments, is included: in this case from previous, i.e. Bronze Age, times. This will allow us to test the robustness of our result, and to find if there are persistence and long durations on these areas. The data for this analysis are the complete series included in Table 3.

Once more, figure 6 shows two dendrograms, with different final dispositions for the temples in Cyrene and the Nabataeans as explained above. In both, following the dendrogram from the furthest to the closest distance, the data are first divided into two main branches. The one on the left includes 16 groups of monuments, mostly from the eastern Mediterranean (Egypt, Kush, Hatti, Phrygia, Greece, Lycia, Cyrene, Minoan Crete, Nabataeans) or with well-known eastern Mediterranean cultural roots or influences (Sicily, Magna Graecia, Iberia). As in the previous case, the Nabataean and Cyrene temples change their position from one closely related to the Egyptian temples to one closer to the other Hellenic temples. This could perhaps be a reflection of the Hellenistic syncretism. Interestingly, the Hellenic groups are maintained and the group of sanctuaries from Minoan sites seems closely related to them.

The Libyan-Phoenician Africa and Punic tombs from the western Mediterranean appear as interlopers in this cluster (and subsequent divisions of it) if considered on geographic grounds, but not if we consider them on a cultural basis, as Punic civilization, although developed in the central and western Mediterranean, has a clear eastern Mediterranean cultural root.

It is of note that the three Egyptian groups are quite close together, a result that reinforces the idea of the continuity of orientation customs in this culture throughout three millennia of existence.

The second group can be found to the right sector of the dendrogram, mostly relating areas from the central and western Mediterranean. This group includes monuments with orientations mostly towards the southern half of the horizon, which in declination translates into large peaks in the negative extreme of the KDDs.

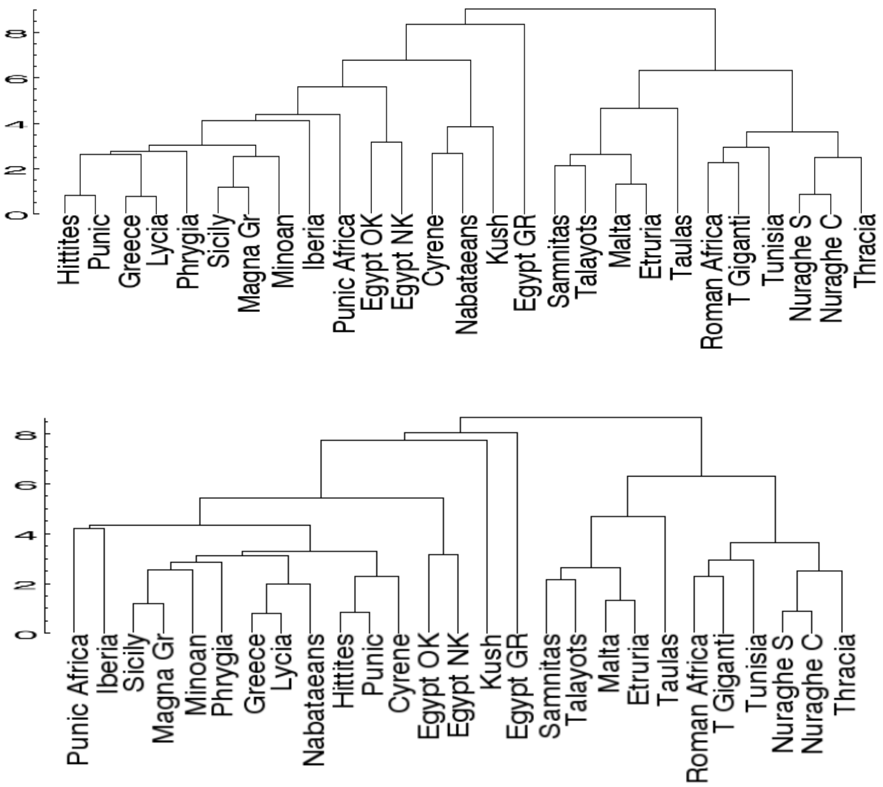

Figure 6: Dendrograms (again with two alternatives for Cyrene and the Nabataeans) showing the cluster analysis output from the data collected in Table 3. Note the geographic and cultural coherence of the groupings and differences between eastern and western Mediterranean cultures despite geographic information is not included in the analysis. See the text for further details.

Finally, it is worth mentioning that the Nuraghe, which appear separated into two groups in this analysis (simple and complex, Nuraghe S and Nuraghe C in Table 3 and Figure 6), are almost indistinguishable. This fact and the close link among the Egyptian monuments led us to consider these monuments as two independent groups (Egypt and Nuraghue) instead of five in the subsequent K-means analysis.

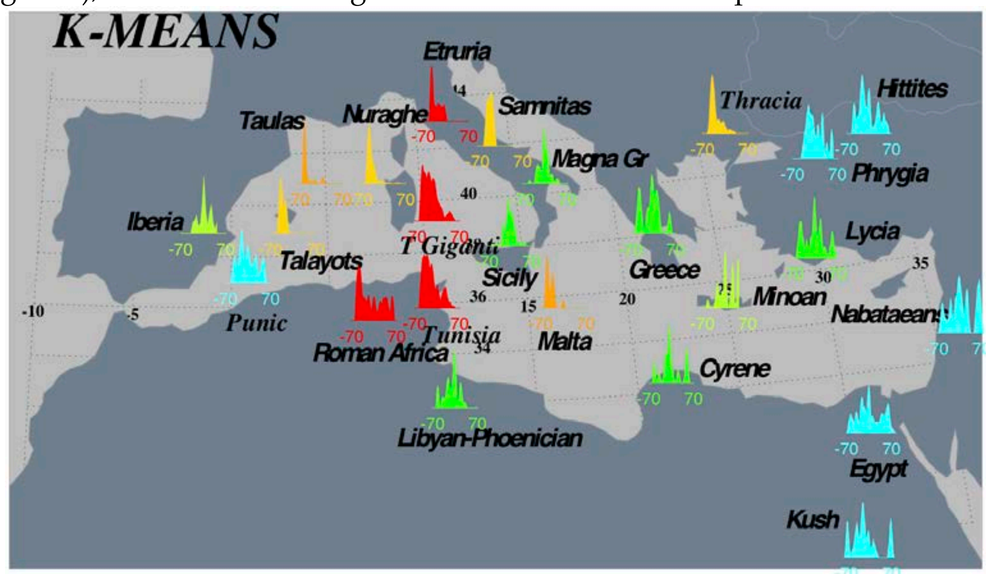

Figure 7: Map showing the results of the k-means algorithm, representing each group by its corresponding declination histogram. As presented here, the algorithm was run with six seeds and provides six groups, very similar to the ones obtained from the dendrogram, thus showing the robustness of the result.

Figure 7 shows the clusters obtained through the *k*-means method in a distribution map. We have included six seeds, rendering six groups identified by different colors. In blue are the members of the eastern Mediterranean cluster: Egypt, Kush, Hatti, Nabataea and Phrygia together, once more with the Punic tombs of the western Mediterranean. This result is very similar to that defined by the dendrogram analysis and also singularizes one of the abovementioned interlopers. The Greek-like temples define a second cluster: Greece, Lycia and Cyrene. A third cluster, very closely related to the previous one, is defined by what we may term as the eastern expansion through the central and western Mediterranean: Magna Graecia, Sicily, Libyan-Phoenician Africa and the Iberian temples, with the relative interloper of the Minoan temples, which could arguably be related to the common Greek milieu of this cluster. A fourth one includes the central Mediterranean monuments: Etruria, Tombe di Giganti, the Tunisian dolmens and the Roman Africa temples. The fifth includes the Talayots from Majorca, and Sardinian Nuraghe, together with Samnitte temples and an interloper, the Thracian dolmens. Finally a sixth cluster is defined, including Malta and Menorca, although it is very similar to the fifth one described above.

5. DISCUSSION: GENERAL RESULTS

The statistical approaches employed in the analysis: the Kolmogorov-Smirnoff test, the Pearson coefficient, the cross-correlation coefficient, the dendrogram and the *k*-means, are independent of each other and treat the data samples in completely different ways. However, especially the last two, provide similar trends, leading to similar conclusions since the groups are assembled in similar clusters whatever the method. The outcomes of the two methods are quite consistent, providing a test for the robustness of the results.

To this end we may safely argue, based on the statistical approaches, that the orientation of Hellenic temples across the Mediterranean are indeed remarkably similar among the different areas commonly related to classic Greek and Hellenistic cultures, and indeed quite different from the rest of orientations studied so far. Intra-group variability indicates that there might be two or perhaps three areas that are more closely related. On the one hand there would be the temples in Magna Graecia and those in Sicily, on the other there would be the rest, mainly Greece and Lycia with Cyrene, depending on the analysis. Finally, the consistency of the Minoan orientations with those of the Iron Age Hellenic group may be talking of a long-term tradition in temple orientation, which would deserve further exploration in the future.

On a general basis, for the whole group of Mediterranean cultic structures studied so far, we could safely speak of three main orientation clusters.

From east to west, a first cluster extending from Anatolia to the Nile may tell us of similar solutions found by different societies when facing similar problems. Written accounts from the Bronze Age cultures in these two areas, i.e. the Egyptians (see Belmonte & Shaltout 2009) and Hittites (González-García & Belmonte 2011) mentioned that the temples needed to be correctly orientated according to certain prescriptions. In various cases, these orientations were related to calendric issues, such as particular configurations of the wandering Egyptian civil calendar or the possible ritual orientation of certain Hittite structures, mainly in Hattusha, that may be linked to particular festivals. Although the two empires were in close contact for several generations, we do not claim any kind of mutual influence (although it may have existed). The later Iron Age successors of these two cultures –the Low Epoch Egyptians, the Kushite Kingdom and the Phrygians– seem to carry on with an ancient cultural tradition on the orientation of temples in the same areas, although subtly modified. Nabataeans seem to group in the same cluster but this and previous outcomes clearly demand further exploration of other sacred structures in the Levant for any statement to be made on firmer grounds.

A second cluster, which we could further subdivide into two, is related to the Greeks (maybe also to the Phoenicians) and their Mediterranean expansion during the first millennium BC. Despite of the distance, Greek, Lycian, Cyrenaic, Southern Italian, Libyan-Phoenician and Iberian temples share broad similarities of orientation. The oldest group in this cluster is the Minoan, and one might be tempted to claim this group as a prototype of the class. However, the uncertainties are large, and to be on firmer ground, new data on Mycenaean, Phoenician and other Bronze Age cultures in the Levant are highly desirable for verifying these trends. In this sense, the Punic tombs, more related to the first group than to the second, carry a distinct question mark to be addressed in the future. The Nabataeans, as for the Cyrene temples, could be a case of mixture between local traditions with those of the neighboring Egyptians and the ones of the Hellenistic milieu. As mentioned earlier, further studies on the area including other Levantine societies may shed light on these still controversial issues.

A third cluster, which again could be further subdivided, is formed by the central Mediterranean cultures. It seems that island cultures from the late Bronze Age and early Iron Age share similar orientation customs with respect to the southern sectors of the sky. It is interesting to observe that the orientation of these monuments, including both temples and funerary structures, are linked with prosaic maximization of the illumination of the interior, with an apotropaic meaning of certain parts of the horizon, or with particular groups of stars visible in the southern horizons of the epoch (Hoskin 2001). It would be important to incorporate into the discussion the now presented fact of a possible regional common pattern of orientation to try to shed light that would help ascertain the reasons for this custom.

6. CONCLUSIONS

Groups of Hellenic temples throughout the Mediterranean seem closely related in terms of orientations, especially when compared with other groups of sacred buildings. Although it is clear, from the works by Salt (2009) and Boutsikas (2008), that different orientation customs were present among the temples built in present day Greece and Sicily, it is interesting to see that such differences must be understood as local variations of a common pattern.

There might be intra-group differences, with Magna Graecia and Sicily being more similar to each other than to other groups, and with the temples in Greece presenting orientations more similar to those in Lycia than to those in Cyrene. It is also interesting that there might be a possible maintenance of the orientation with time, and in the line of our arguments above, perhaps extensible to the concept of time or temporality, given the similarities in the orientations of Minoan sanctuaries with those of later Hellenic temples.

Our initial hypothesis was that orientations could tell us something on temporality, provided that they could be related to particular sky events. It is interesting to note that, in order to obtain similar orientations for distant culturally linked groups of temples, the only possible means is the astronomical one. Although local topography, e.g. sacred mountains or water springs, could sometimes be linked to specific sanctuaries or temples, the common orientation pattern shared by some of these culturally related groups could only be achieved by pointing to a common celestial target observable at those different locations. So we could conclude, that Greek temples needed to be orientated astronomically to similar targets throughout the Mediterranean, albeit the specific targets could vary from site to site.

Indeed, Greek religion is too complicated and subject to local culturally dependent factors (Boutsikas & Ruggles 2011). However, it is also true that for most areas we know that, despite some possibly stellar-based festivities (Boustikas & Salt 2005; Boutsikas & Ruggles 2011), the calendric systems were luni-solar (Hannah 2003). Indeed, there could be subtle differences in the orientations if the target were the sun or the moon, but if the key element to understand orientations is that they are connected with the correct epoch to celebrate festivals (regardless of the astronomical target) such similarities arise in the orientations, specially when compared against other societies, with different calendrical systems and concepts of temporality.

In summary, culturally related groups of monuments tend to share orientation customs independently of their geographic location through the Mediterranean. This is clear in the Greek and Egyptian cases. However, similar orientation solutions are obtained even when starting from different cultural backgrounds (e.g. the case of the Hittites). In order to clarify and further explore some of the lines described here we stress the need to obtain further data in the unfortunately unstable area of the Levant.

In conclusion, similarly to other instances of the material record, orientations may give traces linking the builders of structures in different geographic areas to a common cultural milieu. In some cases, we could talk of the persistence of ancient traditions. In many other cases, when there is a common cultural background, the orientations may be linked to sharing aspect deities such as the astral ones. Finally, in others, different deities may share particular characteristics, such as the various solar or lunar deities, which could perhaps be related to particular events in the sky, thus explaining that different cultures, like the ancient Egyptians or the Hittites, may reach similar solutions to similar problems concerning temple orientation even when starting from different cultural viewpoints.

ACKNOWLEDGEMENTS

This work has been developed and partially financed within the framework of the projects P310793 ´Arqueoastronomía´ of the Instituto de Astrofísica de Canarias, and AYA2007-60213 and AYA2011-26759 of the Spanish Ministry of Science and Innovation. ACGG is a Ramón y Cajal Fellow of the Spanish MINECO.

Table 1: Orientation of 56 temples from Lycia, Panphylia and the Rough Cilician coast. Columns indicate the location, the identification of the temple (either the most common name, owner deity or builder), the epoch of construction, the latitude and longitude, azimuth (a) from inside looking out, the angular height of the horizon (h) in that direction (B and b stand for "blocked" view by a modern or ancient building, respectively) and the corresponding declination (δ). Finally, comments are added for some structures where other axes could be of importance. These secondary axes are not included in the analysis.

Place	Monument	Epoch	φ (°/′)	λ (°/′)	a (°)	h (°)	δ (°)	Comments
Diocesarea	Zeus Temple	Hellenistic	36/35	33/55	63½	−0½	20¼	
	Zeus Temenos				68		16½	
	Tyche Temple				69	−0½	16	
	North Gate				339	3½	51½	
	Mausoleum 1		36/27	33/57	298¼	2	23½	
	Mausoleum 2A				180¾	−0½	−54½	
	Mausoleum 2B				169¾	−0½	−53½	
	Mausoleum 3				219¼	−0¾	−39½	
Arycanda	T1	Lycian	36/31	30/03	228½	9	−25½	
	T2				213	7	−36¾	
	Temple Stairs				92	15	7¼	
	Basilica				270½	7½	4¾	
	Basilica II				269	10	−2	
	Trajan				190½	7	−45½	
	Apollo				188½	5	−47¾	
	Helios				98	6	−3¼	
	Sebasteion				106	2	−11¾	
	Tiche				256½	10	−4¾	
	Stadium				162	2½	−47¾	
Pinara	Podium	Lycian	36/29	29/15	92¼	2½	−0¾	
	In Antis				91	3	0¾	

	In Podium				96	2	−3¾	
	Horn Tomb				52	2¼	31	
	Monumental Tomb				123¼	3	−24½	
Letoon	Apollo	Lycian	36/20	29/17	208¾	0	−45½	5½º W 25¾
	Artemis				209	0	−45¼	5¾º W 26½
	Leto				208¾	0	−45½	5½º W 25¾
Antiphellos	Helenistic Temple	Lycian	36/12	29/39	147	3	−40½	
	Helenistic Tomb				77½	11½	16½	
Xanthos	Xtian Basilica	Lycian	36/21	29/19	112	4¼	−15	
	Acropolis				219	1	−38½	
	Decumanus				284½	4½	14	5½º E −8
	Basilica				285	3½	13¾	
	Nereids (base)				291½	4	19¼	4º E −15¾
Patara	Heroon	Lycian	36/16	29/19	323½	2½	42	
	Main Street				1	1½	54½	
	Corintian				5	2	55	
	Gate				13½	10½	62	
	Monumental Tomb I				254	−1	−13¾	
	Monumental Tomb II				263½	0	−5½	
Phaselis	Temple	Lycian	36/31	30/33	89½	0B	0	
					266½	??	−3¼	
Perge	Tholos	Hellenistic	36/58	30/51	272	5½B	4¾	
Aspendos	Temple	Hellenistic	36/56	31/10	169	0	−52	2½º E 10
Side	Athena	Hellenistic	36/46	31/23	265½	0	−4	
	Apollo				265	0	−4¼	
	Men				289½	0	15	
	Dionysos				16½	2	51¾	
Termessos	Arte-	Lycian	36/59	30/28	94¼	4½	−0¾	
	mis/Hadrian				96½	21½	7½	
	Artemis A				16	−0½	49	
	Artemis B				121	−1½	−25½	
	Zeus				301½	11	31½	
	Zeus Herros				358½	4½	57¼	
	Corintian Temple				106¼	−0½	−13½	
	Alatas Tomb				129¼	−0¾	−31¼	

Table 2: Orientation of 45 temples from Cyrenaica. Columns as in Table 1.

Place	**Monument**	**Epoch**	**φ (º/′)**	**λ (º/′)**	**a (º)**	**h (º)**	**δ (º)**	**Comments**
Cyrene	Zeus		32/49	21/51	94¼	0	−4	
	Zeus Altar				291½	1	17½	
	Hill-top Temple				300	0	24½	
	Demeter out-walls				85½	1	4	
	Demeter Altar				83½	1	5¾	
	Isis and Serapis				64	−0½	22¼	
	Bacchus				111	4	−15¼	
	Venus				113	−0½	−18	
	Shrine 9b				97½	2b	−5¼	
	Shrine 9c				98½	2b	−6¼	
	Hermes				113½	2b	−18½	
	Hall of the Muses				203	0	−51¼	
	Great Hall				203	0	−51¼	
	Battus' Shrine				109½	1½	−15¾	
	Medusa				23	0½b	50¾	
	Capitolium				23½	0	50	
	Demeter				113	1½	−18	
	Core				329½	0b	46	
	Great Altar				199½	0b	−53	
	Agora NW				200½	0b	−52½	
	Aphrodite				274	?b	3	
	Strategheion				21½	2B	53	
	Hades				119	14	−15½	
	Proserpina ?				106	14	−5½	
	Dioscuri				204	15½	−36½	

	Artemis Altar				106	13½	−5¾	
	Apollo Altar				105	12	−5¾	
	Jason Magnus				24	−0½	49	
	A. Nymphagetes				25	−0½	48½	
	Isis				28½	−0½	46¾	
	Mithraeum				34	−1	42¾	
	Apollo				105	11¾	−6	
	Small Shrine				105	11¾	−6	
	Artemis				105¼	12	−6	
	Hecate				201	15	−38¼	
	Western Structure				249½	13	−9½	
	Theater Shrine				124	6	−24¼	
	Asclepius				7	17	73	
Al-Bayda	Asclepius		32/46	21/44	96	2	−4	
Apollonia	Western Church	Byzantine	32/53	21/58	77	1½	11	Not included
	Central Church	Byzantine			269½	1	0	Not included
	Eastern Church	Byzantine			269	0½	−0¾	Not included
Ptolemaida	Basilica	Roman	32/43	20/54	239	0	−26	Not included
	Forum				238½	0	−26½	Not included
	Mausoleum				146	4½	−41¼	Not included

Table 3. Input data used for the cluster analysis. The table presents the cluster name, the number of structures and the corresponding statistical data for every group. Note that the complete analysis includes data of a total of nearly 2400 cultic monuments. Groups of tomb monuments are shown in italics. The 16 groups of monuments above the horizontal gap are those used in the first cluster analysis. All groups are considered for the second one. See the text for further details.

Cluster	#	<δ>	med(δ)	σ(δ)	Max(δ)	Min(δ)	δ_{max1}	δ_{max2}
Egypt GR	119	-0.69	-4.00	38.23	64.00	-75.50	60	-11
Phrygia	40	1.69	-2.00	26.10	53.25	-38.50	-20	22
Greece	112	-4.61	-4.28	29.27	62.07	-53.41	-5	11
Iberia	15	4.40	2.00	20.29	42.00	-32.00	23.	0
Lycia	56	-2.15	-2.00	32.57	62.00	-54.50	-3	17
Punic	349	-2.59	-6.16	28.48	54.61	-52.24	-23	-2
Samnites	33	-31.60	-31.98	8.48	-17.01	-45.74	-28.4	-39
Etruria	26	-32.43	-37.83	15.12	-3.70	-48.06	-46	-27
R.N.A.	79	-8.90	-16.20	37.16	58.50	-54.45	-52.3	-40
Lybian-Ph	37	-8.03	-7.00	20.23	30.50	-54.50	-1.5	-22
Kush	55	-11.47	-18.75	42.37	72.75	-72.00	-18	63
Cyrene	39	-0.32	-5.75	31.41	52.00	-53.00	-7	(-15,52)
Sicily	41	1.19	0.00	15.82	47.00	-39.00	-4	10
Magna G.	49	-2.68	-3.10	16.45	40.90	-48.00	-3	8
Nabataea	50	8.32	3.72	37.63	71.12	-58.42	-0.6	(24,61)
Egypt OK	89	5.53	-0.50	29.53	79.25	-61.20	-1.5	-24
Egypt NK	129	-0.08	-10.10	38.58	71.10	-61.50	-24.75	-38
Hatti	63	-6.66	-11.50	28.40	57.75	-50.00	0	-24
Thracia	85	-29.87	-35.55	17.09	27.13	-50.66	-45	-37
Malta	15	-39.45	-43.80	14.18	0.000	-54.10	-50	-35
Nuraghe S	273	-36.60	-41.00	13.80	53.50	-51.00	-43	-31
Nuraghe C	180	-37.17	-42.00	16.16	45.50	-53.00	-43.1	-32
Taulas	27	-41.79	-49.00	16.43	8.400	-50.00	-47	8
T. Giganti	230	-20.13	-24.19	23.54	50.25	-50.86	-48	-25
Minoan	26	8.09	1.00	26.03	40.63	-54.00	0.	24
Tunisia	213	-18.86	-24.50	24.63	51.00	-51.50	-29.5	-41
S. Talaiots	28	-33.26	-35.75	8.28	-17.50	-44.50	-39.75	-22

REFERENCES

Akurgal, E. (1990) *Ancient civilizations and ruins of Turkey*. NET, Istambul, Turkey.

Aramburu-Zabala, X. and Belmonte, J.A. (2002) On the Astronomical Orientation of the Square Talayots of Mallorca, *Archaeoastronomy, Supplement of the Journal for the History of Astronomy* 27, 22, 67-74.

Austin, M. (2006) The Greeks in Lybia. In G.R. Tsetkhladze (ed.) *Greek colonisation: an account of Greek colonies and other settlements overseas, Vol. 2*. Brill, Leyden, The Netherlands. 187-218.

Aveni, A. (2000) *Empires of time. Calendars, clocks and cultures*. Tauris Parke, London, UK.

Aveni, A. and Romano, G. (1994) Orientation and Etruscan ritual. *Antiquity* 68, 545-63.
Aveni, A. and Romano, G. (2000) Temple orientations in Magna Grecia and Sicily. *Archaeoastronomy, Supplement of the Journal for the History of Astronomy* 25, S51-S57.
Belmonte, J.A., Esteban, C. and Jimenez, J.J. (1998) Mediterranean archaeoastronomy and archaeotopography: Pre-Roman tombs of Africa Proconsularis. *Archaeoastronomy*, 23, S7-24.
Belmonte, J.A., Perera Betancort, M.A., Marrero, R. and Tejera Gaspar A.(2003) The dolmens and 'Hawanat' of Africa Proconsularis revisited. *Journal for the History of Astronomy*, 34: 305-320.
Belmonte, J.A., Tejera Gaspar, A., Perera Betancont M.A. and Marrero R. (2007) On the orientation of pre-Islamic temples of north Africa: a re-appraisal (new data in Africa proconsilaris). *Mediterranean Archaeology and Archaeometry, Special Issue* 6, 3, 73-81.
Belmonte, J.A. and Shaltout, M. (2009) *In Search of Cosmic Order: Selected essays on Egyptian Archaeoastronomy*. Supreme Council of Antiquities Press, Cairo, Egypt.
Belmonte, J.A., Shaltout M. and Fekri M. (2009) Astronomy, landscape and symbolism: a study on the orientations of ancient Egyptian temples. In J.A. Belmonte and M. Shaltout (eds.), *In search of cosmic order, selected essays on Egyptian archaeoastronomy*. Supreme Council of Antiquities Press, Cairo, Egypt. 213-84.
Belmonte, J.A., Fekri, M., Abdel-Hadi, Y.A., Shaltout, M. & González-García, A.C. (2010) On the orientation of ancient Egyptian temples: (5) testing the theory in Middle Egypt and Sudan. *Journal for the History of Astronomy* 41, 65-93.
Belmonte, J.A., Gonzalez-Garcia, A.C. and Polcaro, A. (2013) Light and Shadows over Petra: Astronomy and Landscape in the Nabataean Lands. *Nexus Network Journal* 15, 497-502.
Boutsikas, E. (2008) Placing Greek Temples: An Archaeoastronomical Study of the Orientation of Ancient Greek Religious Structures. *Archaeoastronomy, Journal of Astronomy in Culture* 21, 4-19.
Boutsikas, E. and Ruggles, C.L.N. (2011) Temples, Stars, and Ritual Landscapes: the Potential for Archaeoastronomy in Ancient Greece. *American Journal of Archaeology* 115.1, 55-68.
Bryce, T. R. (1986) *The Lycians, Vol I.* Museum Tusculanum Press, Copenhagen, Denmark.
Cohen, M.E. (1993) *The Cultic Calendars of the Middle East*. CDL Press, Bethesda, US.
Dodson, A. and Hilton, D. (2004) *The complete royal families of ancient Egypt*. American University of Cairo Press, Cairo, Egypt.
Esteban, C., Belmonte, J.A., Perera Betancort, M.A., Marrero, R. and Jimenez Gonzalez, J.J. (2001) Orientations of pre-Islamic temples of Northwest Africa. *Archaeoastronomy, Supplement of the Journal for the History of Astronomy* 26, S65-S84.
Esteban, C. (2002) Elementos astronómicos en el mundo religioso y funerario ibérico. *Trabajos de Prehistoria* 59(2), 81-100.
Esteban, C. (2003) Temples and Astronomy in Carthage. *Uppsala Astronomical Observatory Report* 59, 135-42.
Everitt, B.S. (1995) *Cluster Analysis*. Arnold, London, UK.
Fabian, J. (1983) *Time and the Other.* Columbia University Press, New York, US.
Fodera Serio, G., Hoskin, M. and Ventura, F. (1992) The orientations of the temples of Malta. *Journal for the History of Astronomy* 22, 107-119.
Fletcher, M. and Lock, G.R. (2005) *Digging numbers*. Anthony Rowe Ltd, Chippenham, UK.
Gell, A. (1992) The anthropology of time. Berg, London, UK.
García Quintela, M. and González-García, A.C. (2009) Arqueoastronomía, antropología y paisaje. *Complutum* 20 (2), 39-54.

González-García, A.C., Costa-Ferrer, L., Zedda, M.P. and Belmonte, J.A. (2007) The orientation of the Punic tombs of Ibiza and Sardinia, in M.P. Zedda and J.A. Belmonte (eds.) *Light and Shadows in Cultural Astronomy*. 47-57

González-García, A.C., Kolev, D.Z. , Belmonte, J.A., Koleva, V.P. and Tsonev, L.V. (2009) On the orientation of Thracian Dolmens. *Archaeoastronomy, The Journal of Astronomy in Culture* 22, 21-33.

González-García, A.C. and Belmonte, J.A. (2010) Statistical analysis of megalithic toms orientations in the Iberian Peninsula and neighbouring regions. *Journal for the History of Astronomy* 41, 225-38.

González-García, A.C. and Belmonte, J.A. (2011) Thinking Hattusha: Astronomy and Landscape in the Hittite Lands. *Journal for the History of Astronomy* 42, 461-494.

Hannah, R. (2005) *Greek and Roman Calendars*. Duckworth, London, UK.

Henriksson, G. and Blomberg, M. (2008) Orientations at the Minoan peak sanctuary on Philioremos near Gonies (Maleviziou), Crete. *Archaeologia Baltica 10*, 125-30.

Hoskin, M. (2001) *Tombs, temples and their orientations*. Ocarina Books, Bognor Regis, UK.

Ingold, T. (1993) The temporality of the Landscape. *World Archaeology*, 25, 2, 152-174.

Laronde, A. and Golvin, J.-C. (2001) *L'Afrique antique: histoire et monuments*. Talandier, Paris France.

Ljung, L. (2003) *System identification: Theory for the users, 2nd edition*. The Mathwork, Inc, Natic.

Nissen, H. (1869) *Das Templum*. Weidmannsche, Berlin, Germany.

Parker Pearson, M. (2008) *New discoveries at Stonehenge*. Mart Spruijt, Amsterdam, The Netherlands.

Rodgers, J.L. and Nicewander, W.A. (1988) Thirteen ways to look at the Correlation Coefficient. *The American Statistician*, 42, 1, 59-66.

Ruggieri, F. and Pagano, M. (2010) Il tempio e le stele. Analisi dell'orientamento di temple e santuari delle popolazioni parlanti la lingua osca, in M. Incerti (ed.) *Mensura Caeli, Territorio, Citta, Architetture, Strumenti*. 229-39

Ruggles, C. (1998) Whose equinox?. *Archaeoastronomy* 22, S45-50.

Ruggles, C. (1999) *Astronomy in Prehistoric Britain and Ireland*. Yale University Press, Yale, US.

Ruggles, C. (2011) Pushing back the frontiers or still running around the same circles? 'interpreting archaeoastronomy' thirty years on. In: Clive L.N. Ruggles (ed.), *Archaeoastronomy and Ethnoastronomy: building bridges across cultures*. IAU Symposium 178. Cambridge: Cambridge University Press, 1-18.

Ruggles, C. (2014) (Ed.) *Handbook of Archaeoastronomy and Ethnoastronomy*. Springer-Verlag, New York, US.

Salt, A.M. (2009) The astronomical orientation of ancient Greek temples. *Plos ONE* 4, 11. Doi:10.1371/journal.pone.0007903.

Salt, A. and Boutsikas, E. (2005) Knowing when to consult the oracle at Delphi. *Antiquity*, 79, 305, 564-572.

Tan, P.-N., Steinbach, M. and Kumar, V. (2006) *Introduction to data mining*. Pearson Addison Wesley, Wilminton, US.

Whitrow, G.J. (1988) *Time in History. The evolution of our general awareness of time and temporal perspective*. Oxford University Press, Oxford, UK.

Zedda, M., Hoskin, M., Gralewski, R. and Manca, G. (1996) Orientations of 230 Sardinian Tombe di Giganti. *Journal for the History of Astronomy* 21, S33-54.

Zedda, M. and Belmonte, J.A. (2004) On the orientations of Sardinian nuraghes: some clues to their interpretation. *Archaeoastronomy, Supplement of the Journal for the History of Astronomy* 35, 85-107.