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Megalithic Astronomy? Where we are and where we're going to

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Abstract

The data collection and methodological analysis of megalithic monuments throughout Europe unequivocally demonstrated their astronomical orientation by the end of past century. The main result of these works, especially those of Michael Hoskin for Iberia, is clear: the megalithic monuments of a given area and epoch and of a given typology have a characteristic orientation pattern. In several cases, this pattern can be related to astronomical events such as the rising of the sun at certain times of the year. Over the past two decades, new contributions provided a more nuanced understanding of the builders of the megaliths and their conception of space and time. While they raise new questions, they also allow us to present a richer and more varied picture.

1 Introduction

The 80s and 90s of past century witnessed some works on the astronomical relevance of the orientation of megalithic monuments of the Iberian Peninsula and the Balearic Islands (see, e.g. [56]; [42]; [16]). However, Michael Hoskin and his collaborators endeavoured for almost two decades on a massive work of collection and methodical analysis of data, which was compiled in the book 'Tombs, Temples and their Orientation' [34]. His work establishes a definitive methodology for data collection and analysis. It also verifies the systematic effect on orientations in the different areas where the megalithic phenomenon appears in the Peninsula and the Balearic Islands. To sum up: the megalithic monuments in a specific area and of a specific type have characteristic orientation patterns. In most cases, these patterns can be related to astronomical events such as sunrise at certain times of the year. These two key contributions have formed the basis of subsequent work. On the one hand, various contributions and scopes have attempted to qualify, complement or even surpass the methodology. Work has also been done to complete the samples obtained by Hoskin. On the other hand, once the existence of intentionality has been demonstrated, an attempt has been made to reveal the intention behind such premeditation.

2 Methodology for data collection

The methodology employed by Michael Hoskin, described in his numerous works (e.g. [34]), includes the identification of a main line of orientation, usually from the monument itself (a taula, or a dolmen, for example) towards the horizon in that main direction (Fig. 1). In the case of megalithic tombs, such a direction is normally defined in the direction of the chamber towards the corridor, from the inside towards the outside (although it is recognised that it can be defined from the outside towards the inside as well). At other times, if such a direction does not exist or is difficult to establish, it is defined as perpendicular to the backstone (e.g.[36]).

Figure 1: Left, once the axis has been defined, this is marked with rods and it will be this line that will be measured. Right, the main line to be considered will be from the inside out. We will take into consideration the angle with respect to the north of that line, the azimuth, and the height of the horizon in that direction.

Thus, the azimuth of the principal direction and the altitude of the horizon in that direction are measured, and the location is also meticulously recorded. This allows the corresponding astronomical declination to be obtained, facilitating the identification of potential astronomical relationships. It should be noted that the accuracy of measurements taken from megalithic monuments is commonly limited by the condition of the remains and their dimensions, with an acceptable margin of error of only 2 or 3 degrees. While the use of a theodolite might be the optimal methodology, the use of a reliable compass is an acceptable alternative in the absence of significant magnetic disturbances, particularly given the anticipated uncertainty.

In his initial analysis, Michael Hoskin introduced orientation diagrams [33], which are circular diagrams that consistently display the relevant horizon sector and the azimuths of the measured monuments. Additionally, they indicate the sun rise at significant points in its annual movement on the horizon, such as the solstices. Furthermore, the use of histograms [37] enables the demonstration of the concentrations of orientations in specific directions. This is exemplified by the Antas of central Portugal (Antas Alentejanas; [35]), where all 177 measurements were found to be oriented towards sunrise at some point during the year. This may be the first instance where the astronomical relationship of a set of human-built structures has been proven beyond doubt [4], [5].

In the past two decades, geographic information system (GIS) methods have become increasingly relevant, including in the field of archaeoastronomy. In particular, the Google Earth (GE) application and its tool for measuring angles have been employed in certain instances for the collection of data. However, it is important to note that its primary function is to provide a means of contrasting or verifying other measurements obtained in the field (see, for example, [14] in relation to the tholos of Montelirio).

Although the GIS orthophotos are typically well referenced and corrected, this does not preclude the existence of minor distortion effects at the image edges, which could potentially lead to erroneous angle measurements. It is, however, not possible to guarantee this in GE satellite images. These images frequently exhibit a discernible parallax effect, whereby an entire side of a structure is visible when only the top should be visible. This introduces an estimated error of 2-3° when comparing measurements taken in GE with those taken in situ, particularly in clearly defined structures such as Roman cities [45]. The measurement of structures with smaller dimensions will inevitably result in a greater degree of uncertainty.

A relatively novel aspect of data collection is the 'window of observation' by Fabio Silva [50]. Although Hoskin makes reference to this concept on several occasions (e.g. [38] for the dolmens of Valencina de la Concepción, Seville), Silva exploits it in a comprehensive manner, combining it in a clever way for several dolmens in the area of central Portugal. This method considers the orientation of each corridor or chamber as determined by the horizon arc that is visible from the chamber. In principle, any point in such arc might be equally significant, thus defining an observation window. Consequently, when the windows for a number of cameras in the same area are superimposed, specific areas of the horizon and sky might be common to all (or a large majority) of them. Thus, [50] proposes that the monuments in the area of Carregal do Sal, near the Mondego river, may have a double topographical and astronomical relationship. The monuments would appear to be oriented towards the peaks of the Serra da Estrela. Furthermore, the consistency of the orientations would seem to be related to the star Aldebaran. This star could also be related to the name of this mountain range.

In recent years, the curvigram has emerged as a relevant analytical tool. The curvigram accounts for the inherent uncertainty associated with the data, as indicated by the estimation of error. To build the curvigram, each individual measurement is treated as a continuous distribution, with a maximum positioned at the value of the measurement and a dispersion determined by the error associated with that measurement. The distribution is based on a kernel function, with the Gaussian and the Epanechnikov kernel [20] are the most commonly used, with the dispersion value set at twice the measurement error. Consequently, the addition of the values for each azimuth (or declination) results in the generation of a probability distribution, which is the typical representation observed in a curvigram (Fig. 2).

The interpretation of the values displayed on the vertical axis of this diagram is challenging, as the probability in question is difficult to comprehend. This is why, in recent years, we have been developing a method for assigning significance to this axis. To achieve this, we employed the z-score. The value displayed on the y-axis indicates whether the concentration in question is one, two, or more than three times higher than what would be expected under the given circumstances [19], [20]; [52].

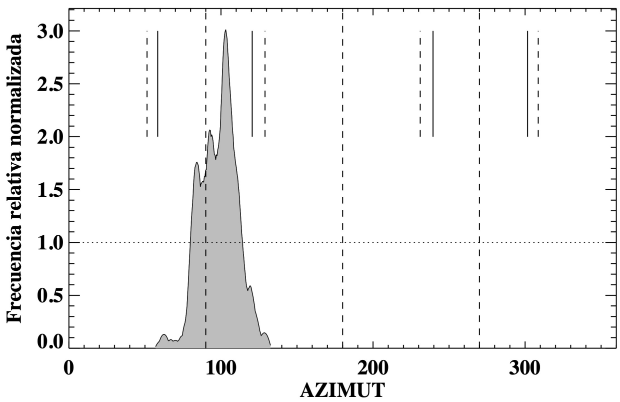

Figure 2: The curvigram of the Alentejo Antas. The long dashed lines indicate the cardinal directions. The short vertical solid lines indicate the points of sunrise and sunset for the solstices. The short dashed vertical lines indicate the extremes of moonrise and moonset. Note the concentration of orientations within the solar range.

3 Completing data collection in new and old areas

Although Hoskin's studies were exhaustive, there were areas that, for various reasons were not included in his initial exploration. Such areas included, for example, the central Pyrenees, Asturias or the central areas of the Iberian Peninsula. In other instances (for instance, the border region between Ourense and Portugal, as discussed by [55]), it appears that there were cases of monuments being subjected to duplicated measurements.

The relatively low density of megaliths in central Spain in comparison with other areas may be considered a justification for their initial omission from consideration. This was partially corrected by [30] and [24], who conducted measurements in Burgos, the north of Zamora, and several relatively isolated megaliths in present-day Castilla y León and Toledo. Furthermore, the scope of the study was expanded to encompass central Portugal ([48], [50]; Fig. 3). More recently, these samples were augmented with the inclusion of additional data collected in areas of La Rioja ([22]). Nevertheless, there are still regions that require further investigation, with the dolmens of Asturias representing a particularly intriguing case.

In general, these monuments demonstrate a pattern of orientations that is consistent with previous findings. For instance, Hoskin's study of Salamanca [33] revealed a similar pattern to those of Castilla y León, with orientations primarily aligned with winter solstice sunrise.

Another area of interest is that of the mountains of Huesca. The results of the 2012 study [2] and the more recent 2021 study [29] have revealed the existence of a pattern of orientations, which could prove to be highly significant in understanding the motivations behind the construction of these high mountain megaliths (Fig. 3).

In addition, researchers have conducted research in a number of other locations. It is worth mentioning the research conducted by Benítez de Lugo Enrich et al. ([6]; Fig. 3) in the northern part of Andalusia and the study of the megalithic monuments of Montelirio [14].

Another interesting contribution is that carried out in Galicia [26]. This study expanded Hoskin's original sample of 32 monuments to over 70, demonstrating the persistence of the patterns identified in the original work. Additionally, it revealed a distinct pattern of orientations, with all monuments falling within the luni-solar range and exhibiting notable concentrations at the winter solstice (Fig. 3).

It is also noteworthy the research in the Balearic Islands. In particular, Michael Hoskin's studies have been extended in the Taulas of Menorca [54], the Mallorcan Talayots [1] and the dolmen of Formentera [23].

In summary, the majority of these studies demonstrate that the sample taken by Michael Hoskin remains pertinent, confirming that the vast majority of megalithic monuments in the Iberian Peninsula face east, while those in the Balearic Islands face west (Fig. 3 right).

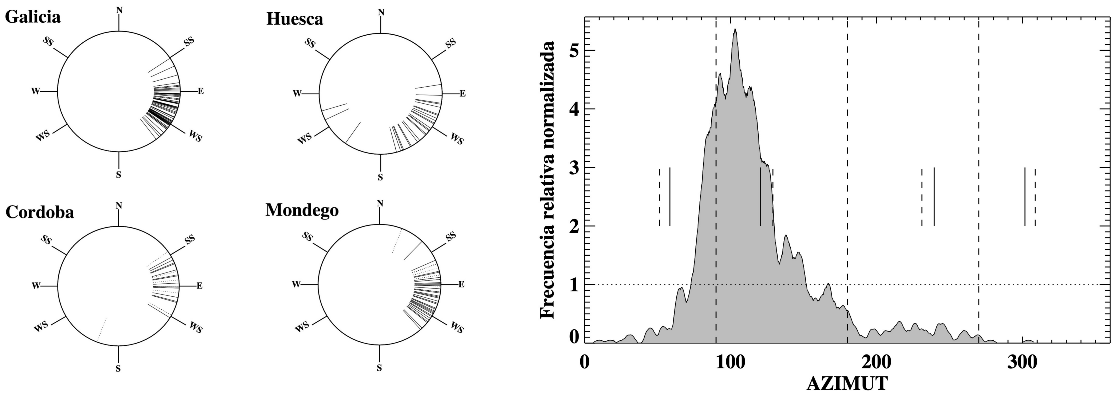

Figure 3: Left: Orientation diagrams for the new surveyed areas. The outer lines indicate the sunrise and sunset boundaries. Orientations are indicated by lines inside the circle. Right: Azimuth Curvigram of all measured megalithic monuments of the Peninsula and the Balearic Islands.

On a global scale, [18] and [24] employ a range of multivariate techniques on the orientation clusters examined by [34]. They identify the existence of supra-regional clusters of orientation coherence. For example, it is notable that the megalithic monuments of the Atlantic façade display considerable similarities with one another. This phenomenon is also observed in the monuments of southern France and the Balearic Islands, as well as those of Catalonia and the islands of Corsica and Sardinia (a finding that is further substantiated by [27], with the inclusion of additional data). Conversely, [24] conclude that lunar models are more effective at explaining the orientation patterns of monuments in Alentejo than solar models. This finding was later corroborated by [51] for other Portuguese groups.

Figure 4 presents an updated classification of orientation groups found in the Iberian Peninsula and surrounding areas, incorporating the new data indicated above (see Section 3). The groups previously described by [24] are now more clearly defined. Notably, the expansion of the Catalonian group toward the interior of the peninsula, following the Ebro Valley, stands out.

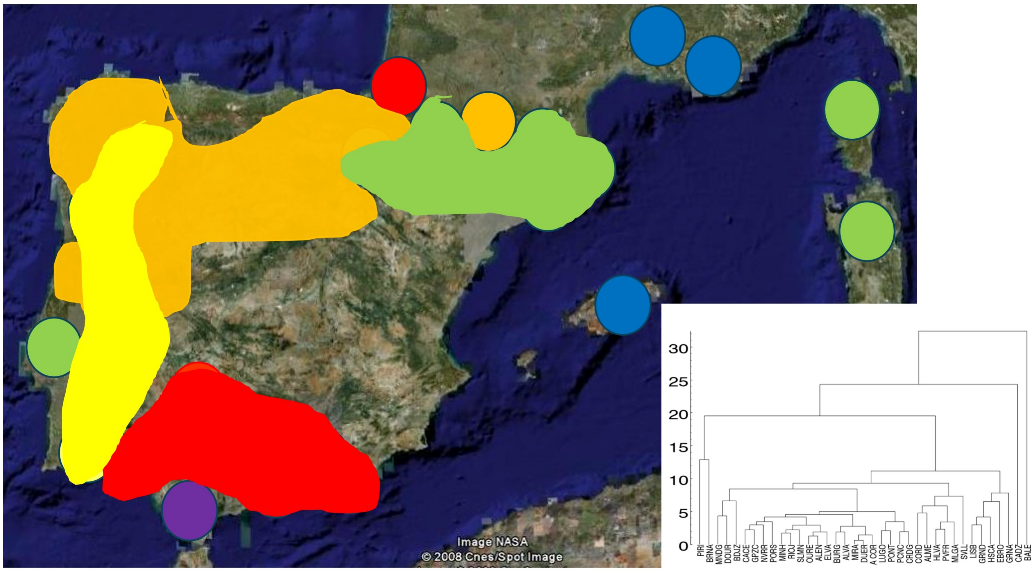

Figure 4: Cluster analysis for the orientation of dolmens in the Iberian Peninsula. The existence of the 'Atlantic' group (light yellow) with its possible extension towards NW and the centre of the Peninsula (gold) is confirmed. On the other hand, the Andalusian megaliths appear as another group. Another is formed by those in the area of the Ebro valley and the mountains. Finally, a fifth group would be formed by the megaliths of southern France and the Balearic Islands.

4 Towards models for intent

Michael Hoskin explicitly stated that the objective of his research was to ascertain whether a pattern exists that cannot be attributed to chance ([36]). After establishing intentionality, Hoskin proceeded to propose a model of motivation. In [37] he discarded the possibility that the monuments of Andalusia were built according to the lunastice, what led him to conclude that the sun must be the object of interest for such orientations, whether at the time of sunrise (SR) or slightly after (sun-climbing; SC). Accordingly, he formulated a model whereby the orientations were linked to the date construction started. The absence of orientations towards sectors north of 80° indicated that the tombs were constructed primarily during the winter months.

Nevertheless, The SR/SC scheme appears to be inadequate for accounting for all the diverse societies that inhabited the Peninsula over the course of several millennia during which megalithic practices flourished. Attempting to provide a unified explanation for these phenomena through a single, simplistic framework may appear overly reductionist and insufficient for comprehending the data within the specific cultural contexts of each case.

A number of alternative approaches have emerged since then that seek to adopt a more socio-cultural perspective. One is the above mentioned case of some stellar possiblitites in selected cases. Another, as in the case of the antas of central Portugal and Extremadura, [46] and especially [13] put forth the proposition that orientations could be explained if they were linked to the observation of the spring full moon. In particular, [13] proposes the 'cross-over' or the crossing of the full moon and the sun around spring as the relevant target. In light of the challenges associated with observing and determining the precise timing of the equinox (see [47]), as well as the prevalence of tombs with orientations aligned in such direction, it can be posited as a viable alternative. [53] subsequently proposed a generalisation based on these observations, which was applicable to other tombs and orientations. In light of the implications for the temporality of the pastoral societies that may have constructed and utilised these megalithic tombs, the lunar interpretation has the potential to offer a wealth of intriguing interpretative avenues ([25]).

The orientation of megaliths has also prompted scrutiny of the unconventional configuration of certain elements exposed during excavations. An example of this is the discovery of postholes predating the construction of the megalithic structure at Huerta Montero ([7]), which have been interpreted as potential markers used to determine the necessary orientation for the corridor of the megalithic structure. A similar case is found at the Rego de Murta dolmens in Portugal, where the unusual placement of certain quartzite stones has been interpreted in the same way ([15]).

A further area of investigation concerns the illumination of the internal structures of megalithic monuments ([21]). This light interaction can manifest in various forms. Direct illumination is where sunlight directly strikes specific elements of the architectural structure. A paradigmatic example is the dolmen of Dombate ([28]), where the winter solstice sun illuminates only the section painted with red and white geometric patterns on the backstone, which can be viewed from the anthropomorphic idols located at the entrance. Other notable examples include the dolmens in the northern part of Burgos ([31]), where the light also interacts with the carvings inside the chambers, and the tholos of Huerta Montero in Almendralejo, where the sun appears to emerge from the chamber, which is sunken into the ground, creating a particularly evocative play of light and shadow ([21]; [44]).

Worth mentioning are also the cases of the Alberite and Soto dolmens ([41]), where the internal structures, especially the pillars and orthostats located in the chamber and corridor, act as collimators, allowing sunlight to directly illuminate the back of the megalithic monument only during periods close to the summer solstice (Alberite) or the equinox (Pozuelo 4 or partially in the case of Soto).

Another form of illumination is indirect lighting, in which sunlight enters the back of the chamber after reflecting off other structures, as observed during the summer solstice at Menga ([43]; [41]) or after reflecting off the paved floor of the Cueva del Romeral in Antequera ([43]).

Additionally, the interaction between illuminated (directly or indirectly) and non-illuminated areas deserves attention. Various researchers have emphasized the differences between these two zones, whether due to the presence or absence of decorative elements —as seen in Dombate, where the illuminated areas feature paintings while engravings remain in shadow or semi-darkness ([28])— or due to constructive differences between the illuminated and non-illuminated elements, such as the north (illuminated) and south (in shadow) sides in Menga ([41]).

The way monuments are located in the landscape is another form of interaction between megalithic monuments and the sky. Numerous studies have highlighted that megalithic monuments are located in specific areas due to visibility, transit routes or physiographic elements ([9] [11] [58] see [8] for a recent summary). While it is highly probable that these factors often intersect ([10]), one further contribution from the perspective of archaeoastronomy is that megaliths often appear in areas with particular observational characteristics ([12]).

The relationship between megalithic monuments and landscape features was first emphasized by Michael Hoskin, notably at Menga ([34]) and later with Belmonte at Los Millares. The researchers observed that while some graves exhibited astronomical patterns, others were aligned with the peaks of Sierra Nevada ([3]). A similar observation has been made for the Chabola de la Hechicera dolmen ([22]) and at two megalithic necropolises in Galicia. There, [55] and [26] have shown how the arrangement of the megalithic monuments not only aligns with transit routes ([11]; [40]), but also positions them in areas of particular astronomical relevance. The Leboreiro necropolis is located on the border between the Spanish province of Ourense and the Portuguese region of Trás-os-Montes. The majority of the monuments are oriented eastwards or south-eastwards, while a prominent tumulus is seen westwards or north-westwards from most of them. This mound aligns with the sunset during the summer months, when it would have been seasonally occupied. People and their animals came to this area between April and late August to use the summer pastures. Consequently, the dates in question may have been marked in the landscape by the positions of the tumuli and the orientations of the megalithic monuments, possibly relating to the moon. These interactions between orientations and the landscape are further being investigated in the Costa da Morte ([32]) indicating that the monuments are located in areas deliberately selected to present an eastern horizon, in the direction where the chambers open, lower than expected for the area.

5 Conclusions

Michael Hoskin's work over nearly two decades established, among the community of researchers studying megalithic monuments, the idea that their orientations provide relevant data for interpreting the spatial, temporal, and ritual dimensions of these structures. When placed in context and integrated with other information from material culture studies, art, and spatial analysis, these data enable us to develop richer interpretations of the past.

As this brief overview suggests, in addition to orientations, other elements—such as the location of megalithic monuments—indicate that the sky and its cycles were incorporated into the mindset of their builders. As Felipe Criado [10] states, "Megalithic architecture constructs a way of thinking about the world that is also a way of inhabiting it, of being in it." In this model, light (from the sun, moon, or stars) and spatial arrangement (orientation, location, and their relationships with the environment and landscape) play a significant role.

The image emerging now is that the orientation of megalithic monuments may offer valuable insights into the social interpretation of dolmens. Some appear to display evidence of planning, or at the very least, observations made prior to the erection of the monuments to verify the correct orientation. Prior to this, there is an increasing body of evidence indicating that the selection of sites was based on a number of factors, including the scrutiny of astronomical events from the chosen location. The chamber in which the ancestors were buried was particularly illuminated at specific epochs, either by the sun or the moon, which may have been related to rituals performed in the immediate surroundings at chosen times. These findings suggest that these monuments were designed with a high degree of sophistication, reflecting a complex understanding of the relationship between the heavens and the worldview of their builders.

Finally, these studies have led to the recognition that the orientation of megalithic monuments has become an additional heritage resource. Notably, this aspect was one of the motivations for the recognition of the Antequera Dolmens or Talayotic Minorca as a UNESCO World Heritage Sites ([57]) and is also featured in other proposals currently being developed.

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