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Representations of calendars and time at Göbekli Tepe and Karahan Tepe support an astronomical interpretation of their symbolism

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ABSTRACT
Göbekli Tepe, an archaeological site in southern Turkey, features several temple-like enclosures adorned with many intricately carved symbols. It is located centrally among a group of Taş Tepeler pre-pottery Neolithic sites which include Karahan Tepe and Sayburç. Here, an earlier astronomical interpretation for Gobekli Tepe's symbolism is supported and extended by showing how V-symbols on Pillar 43 in Enclosure D can be interpreted in terms of a lunisolar calendar system with 11 epagomenal days, which would make it the oldest known example of its type. Furthermore, it is shown how Göbekli Tepe's 11-pillar enclosures and a megalithic 11-pillar pool structure at nearby Karahan Tepe can also be interpreted in terms of the same lunisolar calendar system. Other V-symbols at Göbekli Tepe are also interpreted in astronomical terms, and it is shown how the Urfa Man statue, a wall carving at Sayburç and a statue at Karahan Tepe that display V-symbol necklaces can be interpreted as time-controlling or creator deities. Symbolic links with later cultures from the Fertile Crescent are explored. Throughout, links are made with the Younger Dryas impact and Cauvin's theory for the origin of the Neolithic revolution in the Fertile Crescent.

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1. Introduction

Humans have been carefully observing the stars for more than 50,000 years. Indeed, widespread myths involving the Pleiades are often so similar, typically involving stories of six or seven sisters or birds, it is suggested that they have a common origin in the middle Palaeolithic (d'Huy and Berezkin 2017; Norris and Norris 2021). It should be no surprise that astronomy was seen as important at such an early time. Until relatively recently, life depended on paying close

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attention to the seasons since all resources depended on them, at higher latitudes at least. As the seasons can be tracked easily by observing the solstices and equinoxes, we can expect many ancient cultures to have a significant interest in astronomy. It follows that they would also take a keen interest in the lunar cycle.

In more recent times, many Bronze and Iron Age cultures were known, or strongly suspected, to encode astronomical data in their megalithic monuments (Krupp 1983). For example, one of the most famous ancient megalithic sites of all, Stonehenge (UK, circa 2500 BCE), is thought to be arranged to celebrate either the summer or winter solstice or both (Hawkins 1962; Parker-Pearson 2013). Recent work suggests it also encodes a solar calendar (Darvill 2022). Meanwhile, many recumbent stone circles in North-East Scotland of a similar age to Stonehenge that typically feature 11 or 12 megaliths are also thought to relate to the lunar cycle (Henty 2014). An ancient temple in Malta, on the other hand, appears to be deliberately aligned with sunrise on the equinoxes (Cox and Lomsdalen 2010). Indeed, ancient temples and pyramids across the world are aligned so closely to the cardinal directions that it is clear that careful astronomical observations were being made routinely in early antiquity. Moreover, it is well known that many ancient cultures, including those from Egypt and Mesopotamia, practised religions with strong astronomical associations (Krupp 2000; North 2008). This includes conceptions of deities linked with constellations and zodiac-like animal symbols or with the planets (Kurtik 1999, 2019).

It is in this context that archaeoastronomy has become a popular way of understanding ancient megalithic constructions (Magli 2015). Decoding the astronomical alignments and symbolism of an ancient megalithic site can provide insight into the culture that built it and lived there. In eras before true writing, such insights can be especially important.

One such ancient archaeological site where archaeoastronomy has proven extremely useful is Göbekli Tepe. Situated in modern southern Turkey, it became famous for its extraordinary megalithic architecture consisting of multiple stone 'enclosures' (Dietrich et al. 2012; Schmidt 2000, 2010, 2011). Each enclosure (see Figure 1) consists of a sub-circular rough stone wall embedded with megalithic T-shaped pillars, many of which are adorned with a rich symbolism. It is worth noting that Enclosure D and the inner ring of Enclosure C are both formed by 11 T-shaped pillars. Each enclosure also contains a central pair of tall pillars consistent with a world-wide 'twin' sky-deity mythology (Coombs 2023).

Earlier work provided an astronomical interpretation for some of Göbekli Tepe's symbolism (Sweatman and Tsikritsis 2017b). Specifically, animal symbols on the broad sides of Göbekli Tepe's pillars were interpreted as constellations similar to some of those from ancient Greece. In addition, Pillar 43 from Enclosure D (see Figure 1) was suggested to use precession of the equinoxes to display a date around 10,950 ± 250 BCE and interpreted as a memorial to the Younger Dryas impact event (Firestone et al. 2007).

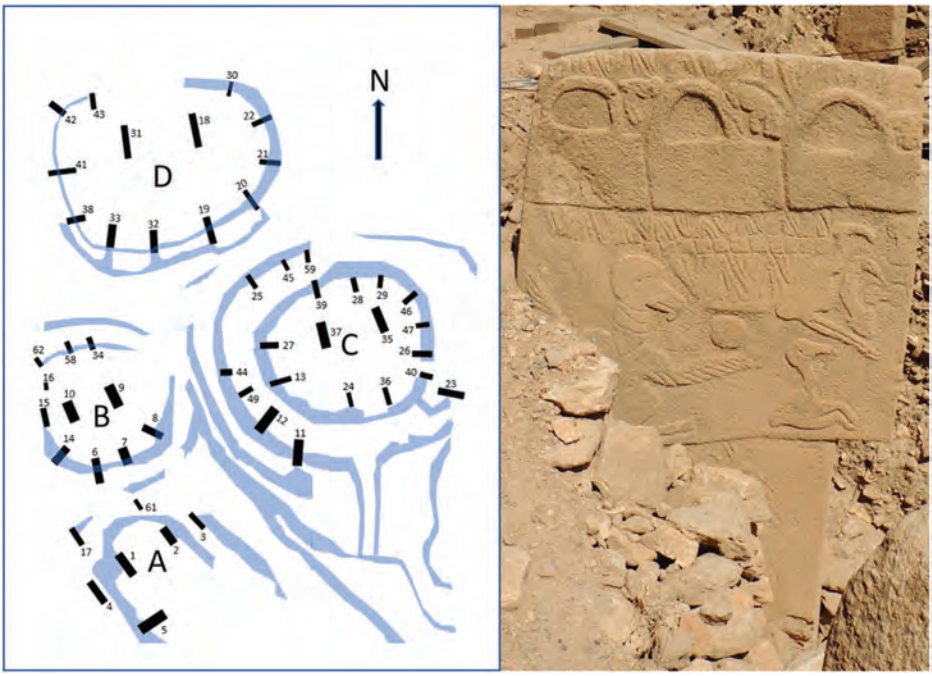

Figure 1. Left: Plan of Enclosures A–D at Göbekli Tepe. Right: Pillar 43 at Göbekli Tepe, Enclosure D. Image courtesy of Alistair Coombs.

This global-scale cosmic catastrophe dated to 10,835 ± 50 BCE (Kennett et al. 2015) is suggested to have triggered the rapid onset of Younger Dryas cooling, the extinction of many species of megafauna on several continents and the demise of the Clovis culture in North America. Furthermore, Pillars 2 and 38 at Göbekli Tepe were suggested to describe the path of the radiant of the Taurid meteor stream which is thought to have caused this impact event. Also, Pillar 18, one of the two central pillars from Enclosure D, was suggested to symbolize a comet related to the impact event.

If this interpretation is correct, it has profound consequences. Partly, this is because it implies that astronomical knowledge was far in advance of what is generally assumed for this time. Another reason is because of Göbekli Tepe's position in relation to the Palaeolithic–Neolithic transition in the Fertile crescent. Indeed, according to the site's excavators (Dietrich et al. 2012):

> Göbekli Tepe is one of the most important archaeological discoveries of modern times, pushing back the origins of monumentality beyond the emergence of agriculture. . . . At the dawn of the Neolithic, hunter-gatherers congregating at Göbekli Tepe created social and ideological cohesion through the carving of decorated pillars, dancing, feasting – and, almost certainly, the drinking of beer made from fermented wild crops.

In essence, their view is that Göbekli Tepe, for which the earliest date yet recorded is 9530 ± 215 BCE (Dietrich et al. 2013), played an important role in the Neolithic revolution that followed by creating the social conditions for large, settled communities to develop prior to the development of agriculture. This aligns well with Cauvin's theory for the origin of civilization in the Fertile Crescent, as he suggested it was triggered by a change in cognition related to religion and symbolism. With these views, the prime importance of agriculture in initiating this process is diminished. If it was confirmed that Göbekli Tepe's impressive symbolism and architecture were related to the Younger Dryas impact event, it would suggest that this cosmic event also played a pivotal role in the origin of civilization in the Fertile Crescent (Sweatman 2017, 2019).

Over the last decade, several other pre-pottery Neolithic (PPN) sites near Göbekli Tepe have been discovered, including Karahan Tepe, which suggest that Göbekli Tepe existed as part of an extended local culture. Due to similarities in their geographical location and age, these sites have been grouped under the Taş Tepeler archaeological project. Consequently, observations about the importance of Göbekli Tepe in relation to cultural changes after the Younger Dryas impact might also apply to these sites, although a detailed relative chronology for their occupation is not yet established.

However, many more symbols on Göbekli Tepe's pillars remain to be decoded. Probably, there remains much to be discovered from careful archaeoastronomical analysis of them and associated megalithic alignments. This work continues this investigation by decoding some of the more abstract symbols on Göbekli Tepe's pillars in terms of astronomical notation, particularly the many V-symbols found on them and on similar stone carvings found nearby at other Taş Tepeler sites.

2. Göbekli Tepe and other Taş Tepeler sites in the context of the Neolithic revolution

The Neolithic revolution in the Fertile Crescent, also known as the 'broad spectrum' transition, exhibits a complex pattern of development over many millennia. It is typically characterized in terms of changes in several key markers, such as settlement density and population, architecture, agriculture, lithics and art (Cauvin 2000; Watkins 2010). A few decades ago, most attention was focused on archaeological sites in the Levant and lower Mesopotamia as these showed signals of all these developments earlier than anywhere else in the world. The overall result of all this work was that a few signals of this transition could be observed before the Younger Dryas period (i.e. before 11,000 BCE) but a phase of rapid development took place after the Younger Dryas onset, i.e. within the Younger Dryas period and especially within the Holocene once climate had stabilized.

For example, the Natufian culture that occupied a region from the east coast of the Mediterranean through to Mesopotamia for several millennia until the end of the Younger Dryas period is credited with creating some of the world's first settlements with communal food storage (Bar-Yosef 1998). Those tribes that settled typically constructed circular houses with semi-subterranean walls built from large stone blocks, such as those found at Tell Qaramel (Mazurowski et al. 2009). Although it appears they cultivated some wild grains, they nevertheless remained hunter-gatherers. It is thought that settlement populations remained quite small at no more than a few hundred.

However, after the Younger Dryas period, within a span of a few thousand years, we see the rapid development of domesticated plants and animals, a larger number of settlements with higher populations, rectangular houses built entirely above ground from mud-brick and specialized buildings used for cultic purposes, more specialized use of stone tools and the emergence of a richer form of symbolic art (Watkins 2010).

Since it was often thought that these changes were all driven by developments in agriculture at the beginning of the Holocene period (Bar-Yosef 1998), the hunt for the origin of this Neolithic revolution tracked the earliest domestication of plants and animals to northern (upper) Mesopotamia close to the foothills of the Taurus Mountains (Watkins 2010). Well-known pre-pottery sites such as Çayönü, Nevali Çori, Hallan Çemi, Abu Hureyra and Jerf al Amar in this region (see Figure 2a) also display other features of this Neolithic transition at a very early time. Because the development in symbolic art appeared to have occurred millennia before clear and widespread signals of domesticated species of plant or animal, Cauvin (2000) proposed that this cultural transition was triggered by cognitive changes, especially the development of religion and associated symbolic artworks. In his view, agriculture developed later in response to the growth of settlements around cultic centres. However, more recent work suggests that changes in agriculture, symbolism and religion may have been more synchronous after the Younger Dryas onset (Moore et al. 2023).

Following this interest in upper Mesopotamia, Göbekli Tepe was discovered towards the end of the last century in the hills overlooking the Harran Plain (see Figure 2b). It is situated between the upper reaches of the Euphrates and Tigris rivers, around 12 km north-east of the modern city of Şanliurfa, which was ancient Urfa and said to be the birthplace of Biblical Abraham.

Excavations of the tell (mound) at Göbekli Tepe began in 1994 (Schmidt 2000). They revealed four large sub-circular enclosures (labelled A–D, see Figure 1) and many other rectangular buildings which are generally smaller. Each rounded enclosure, as already mentioned, consists of a rough stone wall embedded with megalithic T-shaped pillars surrounding a pair of taller, centrally located T-shaped pillars which are typically grounded within stone sockets. Although Schmidt originally thought Göbekli Tepe was a cultic centre only (Schmidt 2010), more recent excavations indicate that Göbekli Tepe was also

Figure 2. (a) Selection of archaeological sites around Göbekli Tepe in upper Mesopotamia (from Siddiq et al. 2021). (b) Selection of contemporaneous sites around Göbekli Tepe and the Harran plain (from Ayaz 2023).

a settlement with the rectangular buildings thought now to be houses (Clare 2020). While the large enclosures are still considered 'special' buildings, it is debated whether they had a specific cultic purpose or whether they were the larger homes of important families (Kinzel and Clare 2020). In the context of this debate, it is argued whether the largest pillars could represent deities or perhaps revered ancestors. In either case, it is generally thought these large enclosures were roofed, although firm evidence is elusive.

The largest complete enclosure so far uncovered, Enclosure D at 30 m across, generated the oldest radiocarbon date yet measured for the site at 9530 ± 215 BCE (Dietrich et al. 2013). This date corresponds approximately to the end of the Younger Dryas period at the Epipaleolithic–Neolithic boundary when the northern-hemisphere climate rocketed upwards after more than 1200 years of near ice-age Younger Dryas climate. However, the earliest occupation date of Göbekli Tepe is unknown. Ground-penetrating radar scans suggest several other large structures situated towards the centre of the main tell also exist, waiting to be uncovered. In fact, given that only a small fraction of the site's surface (which covers around 7 hectares) has been excavated, with an even smaller area excavated down to bedrock, it is possible that Göbekli Tepe's origin will eventually be found to date closer to the onset of the Younger Dryas around 10,800 BCE. In fact, Schmidt (2010) suggested it could have a Palaeolithic origin.

Indeed, the scale and precision of Enclosure D clearly indicate that it was unlikely the first construction of its type. Kinzel and Clare (2020) show that, actually, Enclosure D's construction involved several phases of building and reconstruction. Moreover, the oldest part of the enclosure is older than the part that has been radiocarbon dated. Therefore, the age of the earliest version of Enclosure D is unknown, but Kinzel and Clare (2020) do not rule out a Palaeolithic origin. As we can expect at least one, and possibly several, earlier stages of design and construction preceded Enclosure D by many hundreds of years, although it is not known whether these occurred at Göbekli Tepe itself, its design template is surely Palaeolithic. Possibly, a fifth sub-circular feature at Göbekli Tepe called Enclosure E situated just outside the main tell might represent an earlier phase of construction. This view is supported by the fact that its pillars and walls are missing and thus might have been removed and re-used within the other enclosures. Only its smoothed bedrock floor, which appears smaller and more primitive than that of Enclosure D, remains, complete with a pair of centrally located stone sockets presumably designed to hold another central pair of tall pillars.

Over the last few decades, several more ancient archaeological sites with some similar features have been discovered in the local region surrounding Göbekli Tepe. These include Karahan Tepe, Sayburç and Balikligöl Höyük (within ancient Urfa), where the Urfa Man statue was found. Given their proximity to each other and their apparently similar symbolism, they are considered together to define the Taş Tepeler project or region. Although these Taş Tepeler sites are thought to be roughly contemporaneous, not all of them have been radiocarbon dated. They form a smaller region of focused activity within the broader context of the sites mentioned earlier (see Figure 2b).

Göbekli Tepe's architecture and symbolism are extraordinary for its age. No other site constructed before it, or for millennia after, is known to display such a grand architectural vision and such skilful artistry. However, elements of its design are seen elsewhere within the Taş Tepeler region, and beyond, which suggests Göbekli Tepe played an important role in establishing the local culture of this region. For example, Nevali Çori has rectangular communal buildings with T-shaped pillars. Most notably, Karahan Tepe in the east of the Taş Tepeler region about 45 km from

Göbekli Tepe shows most similarities with Göbekli Tepe in that it also features large sub-circular enclosures with T-shaped pillars and zoomorphic carvings. It is also known to be a large site, perhaps even larger than Göbekli Tepe (Karul 2020). Nevertheless, even Karahan Tepe does not yet display the same level of grandeur or artistry as Göbekli Tepe, although excavations there began only in the last few years. It is worth noting that as yet there are no reports of domesticated species of plant or animal at Göbekli Tepe or Karahan Tepe.

Clearly, to understand the sequence of events that lead to Göbekli Tepe's construction, which will likely hold clues to the motivation for the cultural transition at the onset of the Neolithic period in this region, it will be important to decode the rich symbolism covering many of its pillars.

To this end, first consider Pillar 18, one of the tall pair of pillars at the centre of Enclosure D with an anthropomorphic form consisting of a horizontal 'head' on top of a vertical 'body'. The 'necklace' symbol underneath the head of Pillar 18 (see Figure 3a) can intuitively be interpreted as a moon and sun symbol below an abstract H-symbol. The sun-disc and H-symbols are obscured by dimples.

The Sun and Moon were viewed as deities by many ancient cultures, including several from the Near East. Consequently, solar discs and lunar crescents are common cultic and religious symbols. Indeed, the ancient Egyptians used these symbols specifically to denote the Sun and Moon in their hieroglyphic writing. Moreover, the symbols found on Pillar 18 bear strong resemblance to those found on the Nebra sky-disc, an artefact discovered in modern Germany thought to date to the second millennium BCE (see Figure 3d and Goral 2020). On the sky-disc we see the Moon, Sun and, probably, the Pleiades. The two opposing arcs along the edges of the disc are thought to measure the angle between the rising and setting points of the sun on the summer and winter solstices. The identity of the final feature at the bottom of the disc, the long, curved shape incised with parallel lines, is contentious, but one possibility is that it is a comet.

Next, note the row of seven small bird symbols along the base of the carved stone socket for Pillar 18 (see Figure 3b). Given their number and form and the astronomical theme indicated by the necklace above, these birds might also represent the Pleiades which are often described in worldwide myths in terms of a group of six or seven birds or sisters (d'Huy and Berezkin 2017). Additionally, on the front of the pillar below a pair of hands is a geometric belt buckle and fox-pelt loin cloth that can be viewed as representing the head and tail of a comet, respectively (see Figure 3c). Thus, it appears that the Nebra sky-disc and the narrow face of Pillar 18 display very similar information.

Given that the Nebra sky-disc is generally thought to depict astronomical data, its similarity to the front face of one of the largest pillars within a 'special' structure at Göbekli Tepe suggests we should immediately consider the possibility that much of the symbolism at Göbekli Tepe is astronomical.

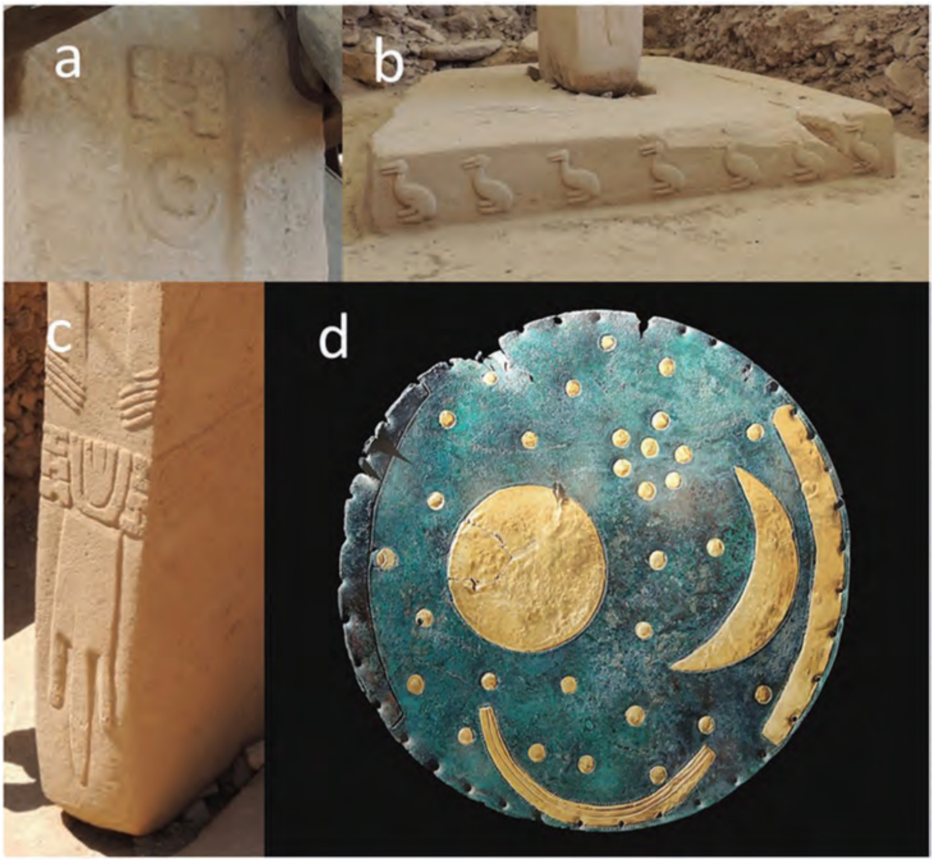

Figure 3. (a) Likely moon and sun symbols below an 'H-symbol' underneath the 'head' of Pillar 18. (b) Seven birds possibly symbolizing the Pleiades on the base of Pillar 18. (c) Belt buckle and fox-pelt loincloth, both reminiscent of a comet, on the narrow, inner face of Pillar 18. (d) The Nebra sky-disc, displaying symbols for the sun, moon, Pleiades and, possibly, a comet (image from Wikipedia, CC-by-4.0). Images a, b and c courtesy of Alistair Coombs.

The H-symbol is relatively common at Göbekli Tepe, although until now the example near the head of Pillar 18 is the only one carrying a dimple, which suggests the dimple has a special astronomical meaning. However, the circular disc symbol, likely representing the sun, is currently relatively rare. The only other example uncovered so far at Göbekli Tepe is on Pillar 43, which is embedded in the north-west portion of Enclosure D's wall (see Figure 1).

Pillar 43 is split into two sections by rows of V-symbols and small box-symbols (see Figure 4). The lower, main portion has a circular disc symbol supported above the wing of a bird of prey. Below this bird symbol is a scorpion symbol. If the circular disc represents the sun, as expected, then the animal symbols probably represent constellations. In particular, the scorpion reminds us of the Greek Scorpius constellation. Its position relative to a circular disc clearly points to an astronomical interpretation.

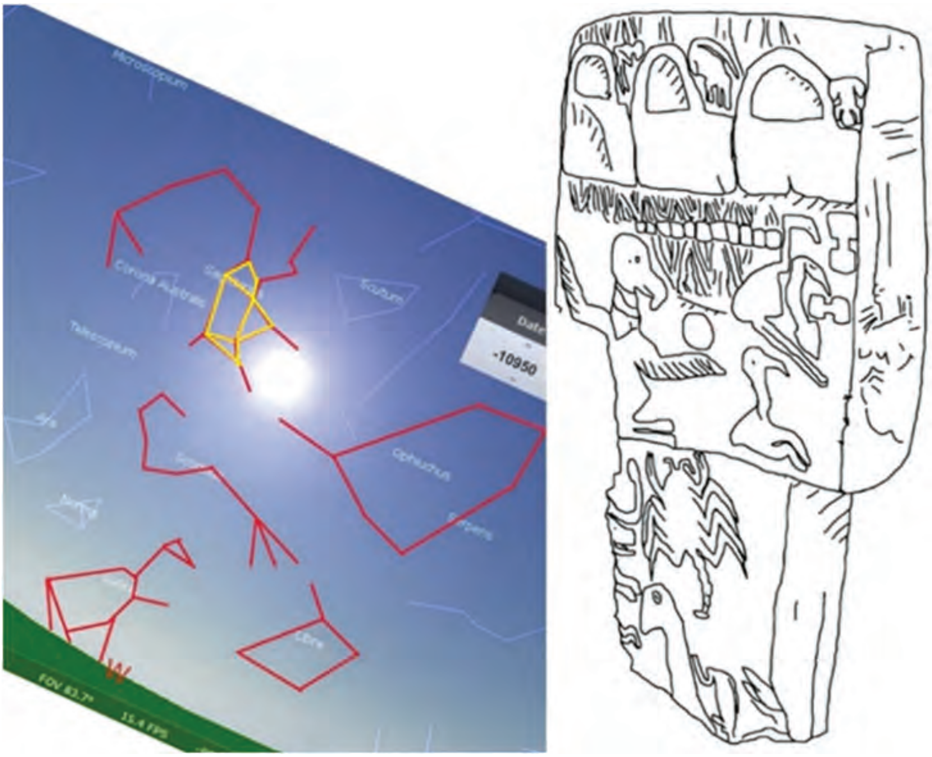

Figure 4. Left: a scene around Scorpius from Stellarium. The teapot asterism of the Sagittarius constellation is highlighted in yellow. Right: a sketch of Pillar 43.

Despite these rather obvious astronomical clues, other than in the work of Sweatman and Tsikritsis (2017b) interpretation of these symbols is generally quite cautious and vague. Peters and Schmidt (2004) favoured the possibility that the symbols indicated shamanistic practices and especially a 'cult of the deceased', that is, that ancestor worship was important. Although they found some correspondence between the animals depicted on the pillars and animal remains excavated from the enclosures, they viewed the animals depicted as mythological creatures rather than direct representations of wild animals and food sources. Essentially, Göbekli Tepe's enclosures were viewed as temple-like constructions for the performance of rituals, and the animal symbols were thought likely to be totems associated with shamanism.

Hodder and Meskell (2011) compared the symbolism found at Göbekli Tepe with that at Çatalhöyük. They found that although Çatalhöyük is around 450 km to the east of Göbekli Tepe and separated from it by around one millennium, a clear similarity is the focus on wild rather domestic animals, even though Çatalhöyük is agricultural. They note some continuity in terms of animal species between the two sites, like the aurochs, but there are also some clear differences; that is, foxes, snakes, spiders and scorpions are much more common at Göbekli Tepe. They also highlight the concept of 'history houses' developed at

Çatalhöyük and associated with human burials interred with animal parts, and a possible skull cult associated with de-fleshing by raptors. Regarding the latter, they point out that images of headless men and vultures are common to both sites. Especially, they suggest that the circular disc above the raptor's wing on Pillar 43 (see Figure 4) could symbolize a decapitated head. They conclude:

> The similarities between Çatalhöyük and Göbekli and in material culture we have drawn with other sites suggest a very long-term and very far-flung set of myths, ideas, and orientations, even if there were many local variations. (Hodder and Meskell 2011)

Regarding the similarities in material culture with other sites, burials of humans with the remains of specific species of animals, such as fox and aurochs, are documented at several PPN sites in the Levant (Horwitz and Goring-Morris 2004; Maher et al. 2011; Reshef et al. 2019). Such practices are often linked with shamanism (Dietrich 2023; Kolankaya-Bostanci 2014). In addition, images of snakes, scorpions and ibex are documented at Kortiktepe on stoneware and bone plaques (Siddiq, Sahin, and Ozkaya 2021). Note that the oldest layers of Kortiktepe date to just after the Younger Dryas onset. Images of snakes or serpents are common across a wide range of pre-pottery Neolithic sites (Çelik 2016).

While some later work takes a utilitarian view of the animal symbols as representing predators and/or food sources (Fagan 2017), a more frequent direction for research into the site's symbolism has tended to focus on emphasizing the role of shamanistic practices, in line with Schmidt's initial views (for example, see Benz and Bauer 2015). In the most recent contribution of this kind, Dietrich (2023) concludes:

> The present contribution has tried to refine already established criteria for the identification of shamanism, to add new ones, and to test them for materials from Göbekli Tepe and contemporary sites. The results are positive for a sufficient number of criteria . . . in order to identify Göbekli Tepe's (and PPN) material culture and imagery with an animistic ontology and shamanism.

Nevertheless, Dietrich (2023) and others avoid any astronomical interpretation of Göbekli Tepe's symbolism, other than acknowledging that the disc on Pillar 43 could represent the sun. Instead, the animals and other symbols are sometimes viewed mythologically and at other times as real-world creatures and objects. However, human burials appear to be mostly absent at Göbekli Tepe, and given the artistic talent displayed on Pillar 43 it is evident that if the circular disc was meant to symbolize a decapitated head it would probably have been carved to look a lot more like a head than a featureless disc.

Sutliff (2012) rejected Hodder and Meskell's (2011) interpretation of the animal symbols as wild and dangerous animals capable of rendering flesh because this is not a consistent characteristic of the animals depicted. Instead, partly due to Göbekli Tepe's megalithic construction, Sutliff pointed

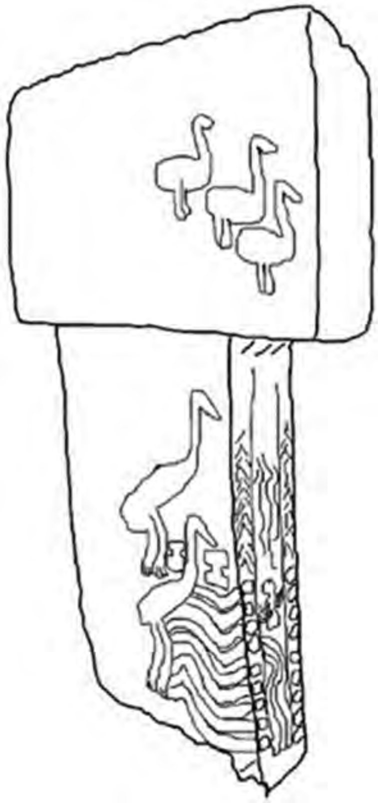

Figure 5. Sketch of Pillar 33 at Göbekli Tepe, enclosure D, showing the side with a pair of tall birds. The other side of the pillar shows a fox. Snake symbols emanate from these animal symbols, with their heads converging on the narrow inner pillar face.

to the sky and suggested the symbolism is largely astronomical. In fact, it is highly unlikely that the animal symbols at Göbekli Tepe represent actual animals since on the broad sides of Pillar 33, Enclosure D, we see bunches of snakes projecting from the legs and torsos of tall standing birds and leaping foxes (see Figure 5). Obviously, these images are much more likely to represent mythological or astronomical creatures. In the astronomical case, the scene on Pillar 33 has an immediate interpretation as meteors projecting from the direction of specific constellations, which provides further support to the link between Göbekli Tepe and the Younger Dryas impact for which the culprit is generally thought to be the Taurid meteor stream.

Having reviewed recent research into Göbekli Tepe's symbolism, one of the most notable aspects is its determination to avoid any astronomical interpretation for Göbekli Tepe's symbolism. This is despite some obvious clues and the well-known association between shamanism and astronomy across many widely dispersed cultures (Krupp 1999). In particular, neither Sweatman and Tsikritsis' (2017b) astronomical interpretation nor any research supportive of the

Younger Dryas impact are cited in the aforementioned research, despite the strong evidence in their favour and the clear possibility that the Younger Dryas impact motivated the rapid development in symbolism and cultic practices following the impact event, i.e. it is an explanation for Cauvin's (2000) observations.

Given this general hesitance to view Göbekli Tepe's symbolism astronomically, the remainder of this article describes evidence that supports an astronomical interpretation. This examination begins in the next section by reviewing the evidence for astronomy in the preceding Palaeolithic period.

3. European Upper Palaeolithic astronomy and Gurshtein's prediction

Any Palaeolithic hunter-gather tribe wishing to improve their lot would do well to study the motion of the sun and moon. Although weather varies dramatically on a daily basis, the seasons change slowly and predictably in time with the annual solar cycle. As all resources are seasonal, at least far away from the equator, family and tribal life can be planned and optimized by studying the sun's motion. Most easily, this is achieved by noting its rise and setting points on the horizon.

Any astute observer will soon recognize several interesting aspects of this motion. First, the limits of this motion define special days in the year; the solstices and equinoxes. These days will then likely take on important communal functions, such as social gatherings, and we can expect to encounter symbolism connected with them. Through noting these points on the horizon, true north can be defined. It will then be noticed that this direction correlates exactly with a stationary point in the night sky, which can be associated with a pole star. These connections indicate there is a deeper understanding of nature to be gained from astronomy and highlight the importance of the solstices and equinoxes.

A keen observer will also notice the regular motion of the stars at night, and how the sun and moon's rise and setting positions on the horizon can be recorded using the brightest stars. In turn, this will lead inevitably to the definition of constellations.

Any observant tribe that records the rise and setting point of the sun on the solstices and equinoxes against the constellations for several generations will notice a strange effect; the heavens appear to be shifting slowly. This is precession of the equinoxes. This motion is equivalent to a shift of about two moon-widths in a person's lifetime (~70 years) and is therefore relatively easily noticed once the solar cycle is known. Since we know that humans have been watching the skies carefully since the middle Palaeolithic, it is almost inevitable that this motion would have been noticed and recorded at a very early time. Hughes (2005) agrees that once observation of the solstices and equinoxes becomes established, the effects of precession would soon be noticed. Given the importance of such astronomical observations, Gurshtein

(2005) argued that a system of zodiacal dating using precession would likely have developed early in the Neolithic period to support a farming calendar. Specifically, he predicts the definition of sets of four zodiacal constellations corresponding to those behind the sun on the four solstices/equinoxes that can be used to define world ages, beginning with the age of Gemini around 6000 BCE. However, his arguments should apply equally to the Palaeolithic era since Palaeolithic hunter-gatherers would have been as dependent on the seasons as Neolithic farmers. Moreover, De Santillana and von Dechend (1969) claim that precession is encoded in many ancient worldwide myths, which also suggests it was known at a very early time.

Despite these arguments for very early discovery of precession, it is only known for certain that Hipparchus noticed precession in the second century BCE. But this should be considered the latest time by which precession was discovered, not the earliest. Magli (2004) discusses strong evidence for prior knowledge of precession, including in Bronze Age Egypt, Mesopotamia and the Indus Valley.

Although the constellations are human inventions, the brightest stars naturally form obvious patterns which are likely to be highly conserved across cultures. This led Frank and Bengoa (2001) and then D'Huy (2016) to suggest that some of our most noticeable modern-day constellations, like Ursa Major and Orion, might originate in the Palaeolithic period. They concluded this after comparing commonalities in associated myths from widely separated cultural groups.

Hayden and Villeneuve (2011) argue that specialist astronomers in many Palaeolithic hunter-gather groups likely tracked the solstices and equinoxes. They came to this conclusion after reviewing the research literature for evidence of good naked-eye astronomy amongst Palaeolithic people, and performing an ethnographic review of extant hunter-gatherer groups from around the world. They found that most modern-day hunter-gatherer groups maintained important communal knowledge of astronomy and that a significant fraction carefully tracked the solstices and/or equinoxes. Moreover, they found that this custom was much more prevalent in what they called 'complex' hunter-gatherer groups.

Regarding evidence for good naked-eye astronomy amongst Upper Palaeolithic hunter-gatherer groups, Hayden and Villeneuve's reviewed the work of Marshack (1972), Rappenglück (2004) and Jegues-Wolkiewiez (2007). Marshack's early work focused on interpretation of repeated carved lines and marks on many artefacts from the Upper Palaeolithic era as lunar calendars (Marshack 1972). Probably the most relevant example is a carved bone from the Abri-Mège at Teyjat (see Figure 6) which was found in two fragments. Its upper

Figure 6. Sketch of a carved bone from Abri Mège at Tarjat (after Marshack 1972, 166–167).

fragment is carved with a row of four deer heads while its lower fragment has a series of V-shaped marks in two rows. The upper row appears to count 14 while the lower row appears to count 15. Together, these marks can be read as a complete synodic lunar month of either 29 or 30 days as follows. Counting left-to-right and back along the lower row gives 30 days, while counting left-to-right along the lower row and back along the upper row, on the other hand, gives 29 days. Of course, the synodic lunar month is very close to 29.5 days which means that counting the days of successive lunar months will usually give alternating counts of 29 or 30 days.

In Rappenglück's (2004) work, probably the strongest indication of an interest in astronomy in the Upper Palaeolithic are groups of painted dots found in well-known caves, such as Lascaux, that he interprets as representing the Pleiades star cluster (see Figure 7). While the positional correlation between these groups of dots and the brightest stars in the Pleiades cluster is not very strong, these groupings are similar to contemporary symbols found painted on a Navajo Tipi, within a Hopi Kiva and on a Chukchi shaman's cosmographical map which Rappenglück claims represent the Pleiades.

In each of these cases from Marshack and Rappenglück there are clear associations between the abstract markings and neighbouring animal symbols or paintings that led both authors to suggest the animal symbols might represent constellations. Indeed, Rappenglück suggests they might even represent constellations similar to those we know today, including the bull as Taurus. Using statistical analysis, Sauvet and Wlodarczyk (2008) find these Upper Palaeolithic animal paintings are correlated such that they often form clusters or groups with similar species of animal. For example, they note that paintings of horse, ibex and bison often appear together although this correlation is not perfect. Clearly, if these animal symbols do represent constellations, any correlations among them could help to identify the constellations they represent.

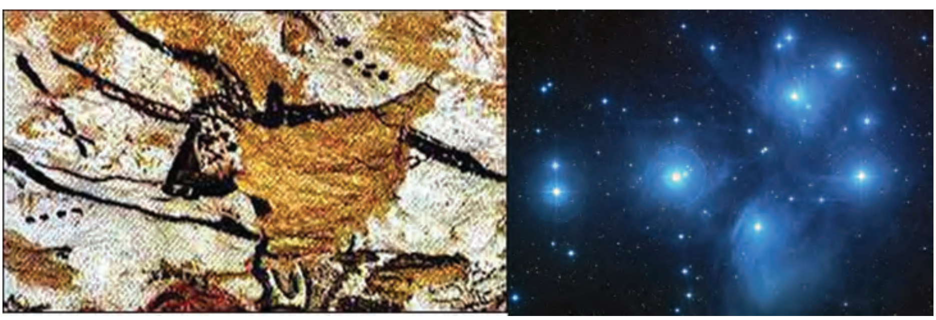

Figure 7. Left: Painting of a bull in the Lascaux cave, along with six painted dots (above the bull) that might represent the Pleiades star cluster. Right: The Pleaides star cluster (from NASA).

European Palaeolithic cave art is highly conserved and remained almost unchanged for 30,000 years in terms of subject matter and style. Clearly, it was an immensely important activity for Palaeolithic people. This suggests it was linked to a long-lasting mythology. As we also expect that some long-lasting myths are linked to constellations, we have a consistent set of assumptions; namely that Palaeolithic people studied the stars, associated them with myths and animals, and painted their constellation symbols on cave walls.

Jegues-Wolkiewiez (2007) examined the apparent direction of numerous Upper Palaeolithic painted cave entrances in western Europe and found a very strong tendency for these cave entrances to align, or point, towards the latitude of the rising or setting sun on one of the solstices or equinoxes. Although there remain some questions about her cave selection and measurement methodology, the strength of this correlation strongly suggests a special interest in the solstices and equinoxes.

Hayden and Villeneuve (2011) highlight the Lascaux cave entrance as an example. This cave entrance opens into the Hall of Bulls, so named for the series of paintings of bulls on its walls. It also happens that this cave entrance faces very closely towards the setting of the sun on the summer solstice such that the sun illuminates portions of these bull paintings on this event. Yet at the time it is thought these cave walls were painted, around 15,300 BCE, the summer solstice constellation is Capricornus, not Taurus. It is, therefore, unclear why the bull symbol was chosen specifically for this entrance chamber if it represents a constellation similar to Taurus as claimed by Rappenglück (2004).

This mystery is very likely solved by Sweatman and colleagues (Sweatman and Coombs 2019; Sweatman and Tsikritsis 2017b). Based on deductions made from analysis of Göbekli Tepe and Çatalhöyük in Neolithic Anatolia and the Lascaux Shaft Scene, which is a specific painting within the Lascaux cave system, they derived an ancient zodiac where the bull symbol represents a constellation similar to Capricornus instead of Taurus. We can now understand why the bull symbol might have been chosen for the Hall of Bulls at Lascaux; it is perhaps so that the summer solstice constellation symbol, that is, the bull symbolizing pseudo-Capricornus, is illuminated as the sun sets on the summer solstice around 15,300 BCE.

However, Sweatman and Coombs (2019) go much further than this. They find an extremely strong correlation between the radiocarbon dates of well-dated animal paintings in European Palaeolithic caves and their corresponding 'zodiacal date'. The zodiacal date is the date range expected for an animal symbol if it was painted when its respective constellation corresponds to one of the solsticial or equinoctial constellations. Considering it is already suspected that these symbols might represent constellations, the strength of this correlation suggests we can be almost certain that this hypothesis is correct.

Presumably, Palaeolithic hunter-gatherers simply painted many of the respective animal symbols for the solsticial and equinoctial constellations at the time on the cave walls. This also helps to explain the strong correlation among the groups of painted animal species observed by Sauvet and Wlodarczyk (2008); these groups are likely related to the solstices and equinoxes. This adds further support to the view that Gurshtein's (2005) prediction of a Neolithic zodiacal dating system using the solsticial and equinoctial constellations should be extended backwards to the Upper Palaeolithic.

In summary, we can expect that many Upper Palaeolithic hunter-gatherer groups, especially 'complex' ones, were keen naked-eye astronomers focused on observation of the solstices and equinoxes mainly for calendrical purposes.

4. Origin of the Ancient Greek constellations

Considering the work by Sweatman and Tsikritsis (2017b) regarding an astronomical interpretation for Göbekli Tepe relies on identifying some of Göbekli Tepe's animal symbols as precursors to the Greek constellations, it is worth first reviewing the current understanding regarding their origin.

The modern set of Western constellations is based substantially on the ancient Greek constellations, described in detail by Ptolemy in the second century CE (Toomer 1984). The Farnese Atlas (also second century CE) and other ancient globes provide useful hints about how these constellation patterns were viewed. In turn, these constellations can be traced back, via Hipparchus and Aratus (Kidd 1997), to earlier work by the Greek astronomer Eudoxus in the early fourth century BCE.

Going backwards in time, we find earlier references to some of the non-zodiacal constellations in ancient works by Homer and Hesiod (Evelyn-White 1936; Lattimore 1951, 1991). Although the earliest surviving manuscripts of these epics date to the eighth century BCE, they are thought to describe events from the preceding millennium. In particular they allude to Orion, Bootes, Ursa Major and the Pleiades and Hyades, as well as specific stars.

As for the ancient Greek zodiacal constellations, they are also listed in the Babylonian MUL.APIN text, also from the mid-first millennium BCE (Krupp 2000), although they are not described with the same level of detail as in Ptolemy's Almagest. However, it is thought by some scholars that these surviving cuneiform texts are probably copies of older ones from the end of the second millennium BCE. It is, therefore, often suggested that the Greeks combined the Babylonian zodiacal constellations with disparate non-zodiacal constellations to create the complete set described by Ptolemy (Rogers 1998a, 1998b).

While this is an attractive story for the origin of the Greek constellations, there is no clear evidence it is correct. In fact, it is obviously contradicted by Pseudo-Eratosthenes, who recounts a myth recorded in a now-lost work by Hesiod (which therefore might date to the second millennium BCE) about the deity Orion (Condos 1997):

> Orion went away to Crete and spent his time hunting in company with Artemis and Leto. It seems that he threatened to kill every beast there was on earth; whereupon, in her anger, Earth sent up against him a scorpion of very great size by which he was stung and so perished. After this Zeus, at one prayer of Artemis and Leto, put him among the stars, because of his manliness, and the scorpion also as a memorial of him and of what had occurred.

Thus, it appears the Greeks might have known of at least some of their zodiacal constellations by the second millennium BCE. Recent reviews emphasize this uncertainty. For example, Kechagias and Hoffmann (2022) state:

> . . . the origin of the 48 ancient constellations of the Almagest remain largely enigmatic in contrast to the modern southern constellations . . . There has been much speculation about possible origins in ancient Mesopotamia and ancient Egypt (Boll 1903) with the first hypothesis being more popular due to the panbabylonism in the first half of the 20th century . . . Nevertheless, evidence for the conjectures about the constellations is hardly to be found.

Nevertheless, evidence for much earlier knowledge of some constellations is found in Mesopotamia. For example, Kurtik (2021) states that:

> In the Old Babylonian period (19th–16th centuries BC) the system of Mesopotamian constellations already existed, apparently in almost complete form . . . On the whole, we can find at least 46 constellation names in these sources. Most of them are written in Sumerian (with sumerograms) and only 10 (less than a quarter) in Akkadian (syllabically).

Unfortunately, Kurtik does not reveal exactly which constellations are referenced, or whether any of them are similar to the 48 Greek constellations. Nevertheless, he does highlight once again the link between constellations, animal symbols and religion in Mesopotamia. For example, Kurtik (2019) writes:

> Already in the Old Babylonian period (probably even earlier) the constellations in Mesopotamia were worshipped as deities . . . Names of stars, for example, in-zu-um (= ^{mul}uz3), in the Old Babylonian period were also the names of gods.

These associations between constellations and deities are explicit in the Mul. Apin text, which possibly dates to the late second millennium BCE. Kurtik (2019) discusses two specific early examples from the Old Babylonian period:

> This article is devoted to cuneiform sources shedding light on history of Mesopotamian constellations ^{mul}uz3 ('The Goat') located in the area of modern Lyra,^{mul} ^{d}Gula, a goddess connected with ^{mul}uz3, and ^{mul}ur.gi7 ('The Dog') located in Hercules.

As many Old Babylonian period star and constellation names are Sumerian, it is likely that the association of animal symbols, constellations and deities is a prehistoric tradition. As we already expect that some very ancient and widely dispersed myths, perhaps from the middle Palaeolithic, are also linked with constellations and specific animal symbols (D'Huy 2016; Norris and Norris 2021), we can expect that this practice is quite common throughout history. Given

Göbekli Tepe's location in upper Mesopotamia and its suspected role in the Neolithic revolution, along with the association between shamanism and astronomy (Krupp 1999), this further justifies the view that Göbekli Tepe's animal symbols probably represent constellations.

5. Further evidence linking the Greek constellations with Neolithic animal symbols

Evidence for much earlier knowledge specifically of some of the Greek zodiacal constellations is found in Near Eastern artistic works. In particular, Greek zodiac-like symbols are seen on many third and fourth millennium BCE Egyptian, Mesopotamian, Ancient Iranian and Indus Valley artefacts, including with many Master-of-Animals symbols. The Master, or Mistress, is usually flanked by two opposing zodiac-like animals. Often, they are grasped in his/her hands.

For example, Figure 8a shows an ornamental weight in the shape of a 'handbag' belonging to the Jiroft Culture (Iran) from the mid-third Millennium BCE. It displays two Greek zodiac-like symbols, felines and scorpions, surrounding a Master-of-Animals motif. This artistic style and these symbols are known as 'intercultural' because of their widespread appearance across the Eastern Mediterranean and Near East throughout the Early Bronze Age (Counts and Arnold 2010). This similarity across neighbouring cultures suggests evolution from a much earlier common source culture.

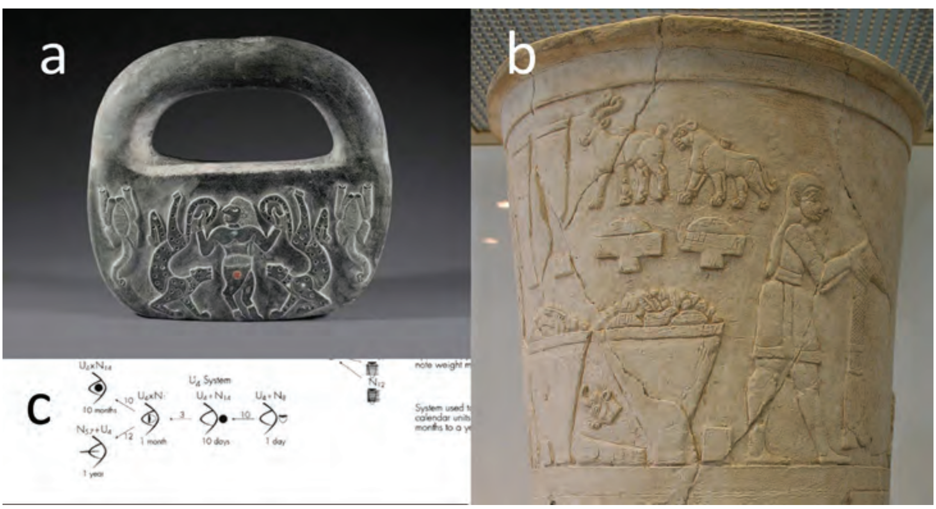

Figure 8. (a) Ancient Iranian Jiroft 'handbag' with Master-of-Animals symbol, circa 2500 BCE (from Wikipedia, CC-BY-4.0). (b) Uruk Vase, Mesopotamia, circa 3500–3000 BCE (from Wikipedia, CC-BY-4.0). (c) Bottom of Figure 2.9 from Woods (2010) showing proto-cuneiform time-keeping symbols that resemble a sunset symbol turned on its side (adapted from Figure 41 of Englund 1998).

In terms of a zodiacal date, Scorpius is the autumn equinox constellation from around 3800–2300 BCE, while Leo is the summer solstice constellation from around 4000–1500 BCE. Thus, this scene is consistent with Gurshtein's prediction for an early system of zodiacal dating, but here only two, not four, animal symbols are seen. Other popular animal symbols among Jiroft artefacts include bulls, ibex, birds of prey and snakes (Basafa, Rezaei, and Rezaei 2014; Salajeghe, Tavighe, and Naeemi 2018). Note that Taurus is the spring equinox constellation from around 3800–1700 BCE, and earlier work has suggested the ibex likely represents a constellation similar to Aquarius (Avner, Horwitz, and Horowitz 2017; Hartner 1965), which is the winter solstice constellation from around 3700–2000 BCE. Therefore, the most popular animals, except snakes, on these specific ancient artefacts can all be interpreted zodiacally. The snakes, as will be shown later, might have a different meaning.

Similarly, Figure 8b shows the Uruk Vase. As its name suggests, it was recovered from the ancient Sumerian city of Uruk and is thought to date to the late-fourth millennium BCE. At the top of the vase, supported by symbols that can be interpreted as setting suns, are two animal symbols; a lion and an ibex. Once again, this vase can be interpreted as providing a date using precession of the equinoxes in line with Gurshtein's prediction. Moreover, these potential sunset symbols on the Uruk Vase suggest a reason for the shape of the previously mentioned stone weight; the semi-circular 'handbag' shape might allude to a sunset. More examples of the potential existence of an ancient zodiacal dating system like that on the Uruk Vase within widely separated Neolithic, Bronze and Iron Age cultures are given elsewhere (Sweatman 2020).

Figure 9 shows further examples of the inter-cultural Master-of-Animals symbols from a wide range of Near Eastern Iron and Bronze Age cultures. In nearly all cases, the animal symbols are consistent with Gurshtein's prediction for a system of zodiacal dating based on precession and either the Greek zodiac or a Palaeolithic zodiac deduced by Sweatman and Coombs (2019). There are only two exceptions here: there are some cases where the Master/Mistress grasps snakes instead of zodiac-like animal symbols; and the elephant on the Pashupati Seal from the Indus Valley has not yet been deduced to be a zodiacal symbol. However, proboscideans are a popular symbol in European Palaeolithic cave art, so it is possible the Indus Valley were using a variant of an ice-age zodiac.

The possibility that a zodiacal dating system based on precession existed before the Bronze Age in Mesopotamia is further supported by the existence of many seal scrolls that are often covered in zodiac-like symbols. These symbols might have played a pivotal role in the development of writing, as they are thought to be precursors to the earliest Mesopotamian hieroglyphs which eventually became cuneiform from the early third millennium BCE onwards (Woods 2010). It makes some sense that symbols that were already important, such as zodiacal symbols used for dating artefacts,

Figure 9. More inter-cultural Master-of-Animals symbols. (a) Classical Greece where the Mistress-of-Animals is recognized as Artemis, ~500–700 BCE. (b) Minoan Crete, ~1700–1400 BCE. (c) Seal stamps, Indus Valley, 2400–1500 BCE. (d) Ur, Sumer, ~2500 BCE. (e) The Gebel-Al-Arak knife, Egypt, ~3500–3200 BCE. (f) Hierakonpolis in Egypt, ~3400 BCE. All images from Wikipedia, CC-BY-4.0.

might be some of the first ones converted to hieroglyphs, rather than simply using symbols of animals without any higher meaning. We see mainly the same animals on these seals; lions, bulls, ibex, but also fish (Woods 2010). Possibly, in this case, the fish represent a constellation similar to Pisces which is the winter solstice constellation before Aquarius, that is, before 3700 BCE. We also see that proto-cuneiform time-keeping symbols for 'day', 'month' and 'year', are similar to the potential sunset symbols mentioned earlier (see Figure 8c). These symbols are also similar to the Egyptian 'Ahket' symbol for the horizon (Wikipedia, Akhet hieroglyph) and a proto-cuneiform pictogram for the Sun (Encyclopaedia Britannica, Sumerian Writing).

Given the presence of the semi-circles, we can thus interpret the stone weight in Figure 8a as meaning 'epoch of the feline and scorpion', while on the Uruk Vase in Figure 8b we can read 'epoch of the feline and ibex'. This view aligns well with that of Hartner (1965), who interpreted fourth millennium BCE images of the 'lion–bull combat' zodiacally in terms of the constellations Taurus and Leo, respectively. To support his interpretation, he provided many examples of artefacts where the lion and bull can obviously be interpreted as constellations. For example, they might be set on a starry background, have star-like inclusions on their bodies or have exaggerated features with astronomical connotations.

Another example of this zodiacal dating system is inscribed at the Gebel Djauti rock shelter in the Egyptian desert around 25 km from Thebes (see Figure 10), thought to date to around 3200 BCE or slightly earlier (Darnell and Darnell 2002). This rock 'graffiti' is claimed by Darnell and Darnell (2002) as evidence for a mythical Scorpion King. According to their interpretation, the symbol at the top-left might be a chair with a canopy, although it is unclear how this relates to the animal symbols present. Sweatman (2019) shows instead how this scene is consistent with a zodiacal date using precession, circa 3600–3500 BCE, with the semi-circular symbol at the top-left interpreted as a sunset and the belted anthropomorphic figure holding a raised club interpreted as Orion. The remaining figures can all be seen on Pillar 43. For example, the hawk and scorpion are similar to the bird of prey and scorpion on Pillar 43, while the bending bird and ibex are similar to the small figures at the top of Pillar 43 next to the sunset symbols (alternatively, the ibex might represent pseudo-Aquarius, as for the Uruk vase earlier). Finally, the tall bending bird with downward wriggling snake in this graffiti scene is also seen on Pillar 43, where it is thought to represent a constellation similar to Ophiuchus. Note that Ophiuchus is the autumn equinox constellation between 4100 and 3600 BCE, which is consistent with the interpreted date of this inscription. Overall, there is a very high similarity in the symbols in this rock graffiti and the symbols on Pillar 43

Figure 10. Copy of the inscription at the Gebel Djauti rock shelter site discovered by Darnell and Darnell (2002).

which means it is highly likely that the respective artists knew the same astronomical code. The possibility that astronomical knowledge was important in ancient Egypt is suggested by the very close alignment of the Giza pyramids to the cardinal directions (Magli 2004). Furthermore, Brady (2015) argues that the astronomically related religion described in the Pyramid texts likely originated at a much earlier time. Therefore, it is reasonable to interpret some pre-dynastic Egyptian symbols, like those at Gebel Djauti rock shelter, astronomically.

However, it is worth noting that the Master-of-Animals symbol is potentially much older than the fourth millennium BCE. Figure 11 shows three Neolithic examples. In Figure 11a we see three stone plaquettes recovered from Tepe Guyan and thought to date to the fifth millennium BCE. The left-most of these

Figure 11. Neolithic Master-of-Animals symbols. (a) Stone plaquettes from Tepe Guyan (fifth millennium BCE) possibly showing Ophiuchus as the Master-of-Animals. (b) A Mistress-of-Animals from Çatalhöyük, 7100–6000 BCE. (c) A Master-of-Animals from Sayburç near Göbekli Tepe. Images a and b from Wikipedia, CC-BY-4.0, image c adapted from Özdoğan 2022.

likely shows another Master-of-Animals holding a pair of snakes. The middle Master is very similar, but now the serpent crosses its torso and reminds us of the Greek constellation Ophiuchus. Note that a single star appears in the background and the head sports a long, curved beak similar to the corresponding symbol on Pillar 43 at Göbekli Tepe. Recall that Ophiuchus is the autumn equinox constellation between 4100 and 3600 BCE. The rightmost figure is also similar but has added V-symbols in the background. Going back even further to Çatalhöyük and the seventh millennium BCE, we see a Mistress-of-Animals holding two leopards by the neck (see Figure 11b). Previously, Sweatman and Coombs (2019) deduced that the four kinds of plastered wall reliefs that appear in Çatalhöyük's lower levels are also consistent with Gurshtein's prediction. In this case, the leopard is associated with a constellation similar to Cancer, which is the spring equinox constellation at the time. It makes sense, therefore, to link the large lady in Figure 11b with fertility, possibly as a solar goddess. Recently, an even older Master-of-Animals has been discovered at Sayburç (Özdoğan 2022), a Taş Tepeler site only around 25 km from Göbekli Tepe (see Figure 11c). In this case, the scene is consistent with the Greek zodiac and Gurshtein's prediction as Leo is the spring equinox constellation in the ninth millennium BCE.

Considering that animal symbols associated with the Master-of-Animals in the later Bronze Age are frequently consistent with Greek zodiacal constellations and precession, and that the Master-of-Animals symbol seems to be used continuously from the time of Göbekli Tepe through to classical Greece, this adds further weight to the interpretation of Göbekli Tepe's symbolism astronomically, and to the interpretation of its animal symbols as constellations.

Moreover, considering that Sweatman and Coombs (2019) based their Palaeolithic zodiac on the surviving Greek set together with deductions made from Göbekli Tepe, it appears the origin of some of the Greek constellations might be traced far back into Upper Palaeolithic Europe. This view aligns with arguments given previously about the very early existence of some of the most obvious constellations and associated myths, such as Orion and Ursa Major, in the Palaeolithic.

Therefore, it appears that Göbekli Tepe could be a kind of bridge in time and place that connects European Upper Palaeolithic astronomical symbolism with Bronze Age astronomical symbolism from the Near East. Indeed, Peters and Schmidt (2004) already suggested that Göbekli Tepe represented a link between the zoomorphic symbolism of the Palaeolithic and the Neolithic. The importance of this site regarding the development of Neolithic culture in the Fertile Crescent after the Younger Dryas mini ice-age is already recognized. But the significance of its symbolism potentially amplifies its status even further.

6. The Younger Dryas impact and the Taurid meteor stream

A catastrophe at the dawn of civilization has long been suspected by many, including Newton's successor, William Whiston, who suggested in 1696 that a comet was the cause of the Biblical flood (Whiston 1696). In fact, the debate surrounding catastrophism versus gradualism can be traced at least as far back as Plato and Aristotle (Palmer 2003). In recent decades, however, the idea has received a firm foundation in the form of the Younger Dryas impact hypothesis (YDIH) (Firestone et al. 2007). This idea proposes that Earth's interaction with a fragmented comet around 10,835 ± 50 BCE is responsible for triggering the onset of the Younger Dryas mini ice-age, the extinction of many species of megafauna on several continents and the end of the Clovis culture in North America.

Although some earlier reports and review articles opposed the hypothesis, geochemical evidence for a cosmic impact event is now so strong it led Sweatman (2021) in a comprehensive review of the impact evidence to suggest that the YDIH should now be considered a 'theory':

> . . . the overwhelming consensus of the evidence from scores of YDB sites across nearly half the world's surface is that a major cosmic impact occurred around 10,785 ± 50 BP. (2 sd)

Although Sweatman regards the cosmic impact event as 'essentially confirmed', he also states regarding the other claims, i.e. the Younger Dryas cooling, megafaunal extinctions and cultural changes, that:

> . . . the scale of the event, including extensive wildfires, and its very close timing with the onset of dramatic Younger Dryas cooling suggest they are plausible and should be researched further. (2021)

Regarding research that claims to refute the YDIH, Sweatman notes that:

> 'Even work purported to contradict the impact hypothesis, when examined closely, actually supports it'.

Powell (2022) later asked in his review whether the evidence supports Sweatman's claim that the YDIH should be elevated to the status of 'theory':

> In this author's opinion, there is a strong case that it does. Moreover, it should not be forgotten that no other single theory can explain the Younger Dryas and its associated effects.

A more recent review, on the other hand, claims a 'comprehensive refutation' of the YDIH (Holliday et al. 2023). However, a careful reading of this lengthy paper reveals the title is inappropriate as it contains no actual refutation arguments. Instead, their work is full of distortions and egregious errors. It also fails to employ a key scientific principle, Occam's razor. Instead, it treats all the evidence independently rather than as a cohesive whole. In fact, the microspherule evidence alone strongly suggests a widespread cosmic impact event near the Younger Dryas onset.

Note that the effects of this impact event are found to be on a global scale, including an airburst event around 150 km south of Göbekli Tepe that destroyed one of the world's first villages, Abu Hureyra (Moore et al. 2020), as well as extensive biomass burning (Wolbach et al. 2018a; Wolbach et al. 2018b). Evidence for the latter in the region around Göbekli Tepe can be observed as thick layers of micro-charcoal in Lakes Akgol and Van, only a few hundred kilometres from Göbekli Tepe in Turkey, with compatible radiocarbon dates (Turner et al. 2010).

The culprit for this impact event is generally thought to be Taurid meteor stream which is associated with comet Encke (Napier 2010; Moore et al. 2023; Wittke et al. 2013). This meteor stream is the largest to affect Earth, although currently it is not the most intense due to its age and dispersion. Due to longitudinal precession of the Taurids, more intense episodes of meteoric activity are expected to occur roughly every 3000 years, although due to the expected long-term decay of comets and meteor streams orbiting within the inner solar system these episodes are expected to become weaker on the timescale of millennia. This phenomenon is known as 'coherent catastrophism' (Asher et al. 1994). Furthermore, while the autumn Taurids currently emanate over the course of two months from the direction of Pisces–Aries–Taurus, due to apsidal (nodal) precession of the meteor stream they are expected to emanate from the direction of Capricornus–Aquarius–Pisces when Göbekli Tepe was occupied if their dispersion has remained unchanged (Sweatman and Tsikritsis 2017b). However, we can expect their path was less dispersed 12,000 years ago than it is today.

7. An astronomical interpretation of Göbekli Tepe's pillars

The preceding discussion provides ample motivation for decoding many of Göbekli Tepe's symbols astronomically. Because the main focus of this work is to provide evidence for a lunisolar calendar system at Göbekli Tepe and other Taş Tepeler sites, and since this interpretation supports the work of Sweatman and Tsikritsis (2017b), it is essential that their interpretation is reviewed next.

Recall that in Section 2 the disc on Pillar 43 was suggested to represent the sun and the animal symbols were suggested to represent constellations (see Figure 4). The preceding discussion provides some justification for this. If this is true, then the head and wings of this bird symbol must represent an asterism very close to the path of the sun. Using Stellarium (2022) with the Western constellation set, we find that the only asterism defined along the ecliptic with this geometry is the 'bow' of Sagittarius, also known as the 'teapot', viewed at sunset. The apparent fit of this constellation to the head and wings of the vulture, including the relative positions of the disc and the sun, appears to be very good (see Figure 4).

This choice orients the main panel and suggests that if the animal symbols represent constellations, they might be ancestral to some of the ancient Greek ones. In fact, Sweatman and Tsikritsis (2017b) show using Stellarium and the Western constellation set how the lower panel on Pillar 43 can be interpreted as a scene in the sky around the Scorpius constellation as the sun sets, with the disc representing the position of the sun relative to Sagittarius on the summer solstice. Pillar 43 can therefore be interpreted as displaying a date 10,950 BCE to within a few hundred years, using precession of the equinoxes.

Now consider the upper panel with three sunset-like symbols, each next to a small animal symbol (see Figure 4). Recall from Section 5 how a sunset-like symbol is a known intercultural symbol which can be linked to both time-keeping and a system of zodiacal dating, especially when it appears with zodiac-like animal symbols. Recall also how the Master-of-Animals and associated animal symbols appear to have survived from the time of Göbekli Tepe through to classical Greece.

In this case, in precisely the same way as for the stone weight shown in Figure 8a, the semi-circular symbols at the top of Pillar 43 can be interpreted as giving the winter solstice and equinoctial constellations on the same date, represented by the three small animal carvings. Pillar 43 is therefore also consistent with Gurshtein's (2005) theory, although it appears at Göbekli Tepe far earlier than he predicted. Actually, Pillar 43 displays slightly more advanced astronomical knowledge than suggested by Gurshtein, since he did not predict use of the precise position of the sun relative to any of the four constellations as a method to refine the date. He only predicted the use of four constellations to write an astronomical age. Providing the relative position of the sun allows a date to be expressed far more accurately than he expected.

Sweatman and Tsikritsis (2017b) argue the zodiacal date written on Pillar 43 likely corresponds to the summer solstice, rather than the winter solstice or either of the equinoxes, because that choice provides by far the closest date to the construction of Göbekli Tepe. The other choices give dates either very far into the past or very far into the future.

This interpretation, which associates animal symbols on Pillar 43 with Greek constellations (including the bending bird at the top left of Pillar 43 with Pisces) as they set on the western horizon, is supported by a compelling statistical analysis (Sweatman and Coombs 2019; Sweatman and Tsikritsis 2017b). Since we already expect an astronomical interpretation for the many reasons given earlier, the strength of the observed correlation strongly suggests this hypothesis is correct. To dispute this claim, one would need to show the statistical analysis is flawed. One way this might be achieved is to challenge the ranking table derived by Sweatman and Tsikritsis (2017b) that compares Göbekli Tepe's animal symbols with Stellarium's constellation patterns, since this is based on a subjective evaluation.

The interpreted date of 10,950 BC, to within a few hundred years, is consistent with the Younger Dryas impact (Kennett et al. 2015), which provides an explanation for the headless man symbol, likely representing death, at the bottom of the pillar. While this date precedes the oldest radiocarbon date obtained from Göbekli Tepe so far (which corresponds to the construction of the wall of Enclosure D) by more than 1000 years, this is not unexpected. As explained earlier, Göbekli Tepe's origin could be much older than the earliest construction date for this enclosure wall and we should expect much earlier phases of construction preceding Enclosure D. And, in any case, it is not unreasonable to find dates referencing important long-past events in cultic or religious buildings. Pillar 43 can therefore be viewed as a memorial to the Younger Dryas impact event. This view is consistent with Peters and Schmidt's (2004) 'cult of the deceased' and with Schmidt (2010), who suggested a Palaeolithic origin for Göbekli Tepe.

Now let us turn our attention to Pillar 33, which is embedded in the south-western portion of the wall of enclosure D (see Figure 1). We have already interpreted Pillar 33 as a very nice picture of a meteor stream (see Figure 5) with meteors (snakes) emanating from the direction of the tall bird and fox constellations. But which meteor stream specifically does Pillar 33 depict? Recall, from the top-left of Pillar 43 that the tall bending bird is associated with Pisces. The fox, on the other hand, closely resembles the northern part of Aquarius as it sets on the western horizon (see Figure 12).

As already mentioned, the Taurids are thought to have radiated from the direction of Aquarius and then Pisces over a span of a few weeks at the time Göbekli Tepe was occupied. Therefore, we can view Pillar 33 as a good picture of the Taurid meteor stream, the same meteor stream implicated in the Younger Dryas impact event. Sweatman and Tsikritsis (2017b) show how a few other pillars at Göbekli Tepe can also be interpreted within this theme of the Younger Dryas impact event.

Notroff et al. (2017) opposed an astronomical interpretation for Göbekli Tepe's symbolism for several reasons, summarized as follows:

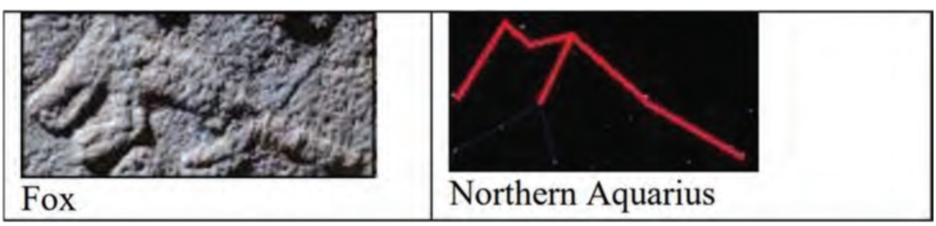

Figure 12. Comparison of a fox symbol on Pillar 2 at Göbekli Tepe with the northern part of Aquarius.

(1) They argued that some pillars are not in their original positions and the special enclosures were likely roofed, which would limit their use as observatories.
(2) They suggested that the gap in the date thought to be represented on Pillar 43 and the earliest radiocarbon date obtained so far for Göbekli Tepe (which is from mortar in the wall of Enclosure D) is 'extremely far-fetched'.
(3) If the animal carvings at Göbekli Tepe do symbolize constellations, they doubted they could be related to the Ancient Greek ones.
(4) They suggested the selection of pillars is arbitrary and others are ignored.
(5) They indicated an alternative interpretation for some of the symbols, including the animals, the 'handbag' symbols on Pillar 43 and the head-less man. They prefer an interpretation for Göbekli Tepe's symbolism based on a presumed skull cult (Gresky, Haelm, and Clare 2017).

Sweatman and Tsikritsis (2017a) responded by claiming that Notroff et al. used spurious and unsubstantiated arguments, and therefore their statistical analysis should take priority. Regarding the points earlier:

(1) This point is irrelevant. This astronomical interpretation does not depend on the position of the pillars or whether the large, rounded enclosures were roofed.
(2) Since the artwork on Pillar 43 is partially covered by the enclosure wall in which it is embedded, and it is admitted that many pillars have likely been moved or recycled, it is possible that Pillar 43 is much older than the radiocarbon date for this enclosure wall. And, as already discussed, a Palaeolithic origin for Göbekli Tepe was suggested by Schmidt (2010) and has not been ruled out by Kinzel and Clare (2020). Therefore, the time gap of concern to Notroff et al. is unknown. In any case, a significant time gap between the impact event and the construction of Enclosure D is entirely expected if the impact motivated a new religion which eventualy led to Göbekli Tepe's construction. Moreover, religious or cultic buildings that are much younger than the dates of events they reference are common.
(3) This point concerns the cultural decay or evolution rate for constellations and symbols. Notroff et al.'s view that constellations and their symbols decay far too quickly for constellations related to the Greek ones (which we use in the Western constellation set) to be observed at Göbekli Tepe is unsubstantiated and contradicted by the evidence discussed above. For example, as discussed earlier, it is known that European Palaeolithic cave art was highly conserved for nearly 30,000 years, and there is strong evidence these animal symbols might symbolize constellations. Moreover, other research suggests some constellations, such as the

Pleiades, Orion and Ursa Major, might be extremely old with an origin far into the Palaeolithic. Thus, a range of evidence suggests the decay rate for some constellations can be extremely slow. In addition, it appears that the meaning of some symbols, such as the Master-of-Animals and the sunset-like semi-circle, survived from the time Göbekli Tepe was occupied through the Neolithic period to the Bronze Age (see Figures 8 to 11). Schmidt (2011) suggested similar connections for some of the animal symbols. Thus, if some symbolic connections are deemed possible over this timespan, similarities in constellations are plausible. In any case, Sweatman and Tsikritsis (2017b) do not claim the constellations and symbols they identify at Göbekli Tepe are identical to the Greek ones in Ptolemy's Almagest. For example, they associate the bird of prey with the teapot asterism of Sagittarius and the fox to the northern part of Aquarius. Thus, it is clear their hypothesis incorporates the evolution of constellations and their symbols with time.

(4) This is wrong. The astronomical interpretation is developed logically and supported by Sweatman and Tsikritsis' statistical argument. Moreover, a complete interpretation for all the symbols in not needed. That is, we do not need to know everything in order to know something.
(5) Interpretation of Göbekli Tepe's symbolism in terms of a cult of the deceased or skull cult is plausible and can complement this astronomical interpretation. They are not necessarily incompatible interpretations. However, we can have far more confidence in the astronomical interpretation described here since it is very 'efficient', i.e. it can explain a lot of the details in the symbolism with relatively few inputs. This is the most important signal of a good theory. See the conclusions at the end of this article for a discussion of this point.

Therefore, with the symbolism of Enclosure D at Göbekli Tepe likely referencing the Younger Dryas impact event, circa 10,800 BCE, we should consider to what extent this event motivated the construction of Göbekli Tepe and the role that the Younger Dryas impact played in stimulating the Palaeolithic–Neolithic transition in this region.

8. Lunisolar calendar systems at Taş Tepeler sites

The previous sections provide the background information needed before evidence for lunisolar calendar systems at Taş Tepeler sites is discussed. However, first it is useful to briefly review more recent lunisolar calendar systems. After that, evidence for knowledge of lunisolar calendar systems at Göbekli Tepe and Karahan Tepe is discussed.

8.1. *Ancient lunisolar calendar systems*

Many ancient cultures used calendars to regulate their important civic occasions, such as ceremonies and feasts (Stern 2012). Due to seasonality of resources, solar calendars were popular. Indeed, the Gregorian calendar we use today is solar as it maintains the equinoxes and solstices at specific fixed days in the calendar. The 12 months of the Gregorian calendar, however, likely have their origin in a much earlier lunar or lunisolar calendar since there are 12 synodic lunar months in a tropical solar year.

In fact, a tropical solar year currently consists of 365.242 days while a synodic lunar month contains only 29.5306 days. Therefore, there are 365.242 / 29.5306 = 12.368 lunar months per solar year, which equates to 12 lunar months plus 10.9 additional days per solar year. This incommensurability has resulted in many different lunisolar calendar systems developed by cultures across the world that attempt to respect both the lunar and solar cycles. For example, many ancient cultures adopted accurate lunisolar calendars by inserting, or intercalating, additional synodic lunar months at irregular intervals within specific years (Stern 2012). For example, the Metonic calendar system of Ancient Greece, also used by ancient Babylonians and Hebrews, inserted seven intercalary lunar months every 19 solar years. This results in $12 \times 12 + 13 \times 7 = 235$ months each with 29.5306 days, which provides 6939.69 days in total. The actual number of days in 19 solar years is 6939.60, which means the Metonic cycle drifts by less than 1 day in 219 solar years. Essentially, the solar year and the lunar month are commensurate over a 19-year solar cycle with an accuracy of around 2 hours.

Another pertinent calendar is one used by the Ancient Egyptians. Their civic calendar is thought to have consisted of 12 months of 30 days each plus 5 epagomenal days, making a civic year of exactly 365 days (Stern 2012). Darvill (2022) suggests that the megalithic circle of Stonehenge encodes a similar kind of calendar through its numerous pillars, albeit with an additional quarter-day. These calendars are solar, but not lunisolar, since the lunar cycle is quickly lost because it is not commensurate with a single solar year. However, as the Egyptian civic year is around 0.25 days short of a seasonal solar year, their civic calendar lost 1 day every 4 solar years, approximately. This resulted in the seasons drifting by a complete cycle every 1508 years, known as the Sothic cycle. However, if we use 12 lunar months with an average of 29.5 days each instead, then we require 11 epagomenal days ($12 \times 0.5 + 5$), rather than just 5, to complete the year, at least approximately.

Another early example of a lunisolar calendar is thought to exist at Yazilikaya next to the archaeological site of Hattusa in central Turkey (Zangger and Gautschy 2019; Zangger et al. 2021). The lunisolar calendar there is interpreted to feature a 19-year Metonic cycle and is represented in terms of a long list of local deities. Included among them are both male and female solar deities.

8.2. A likely lunisolar calendar system at Göbekli Tepe

We are now able to discuss the main point of this article, which is the likely existence of lunisolar calendar systems at Göbekli Tepe and Karahan Tepe. This system appears to be expressed clearly in terms of V-symbols, which are evident on Pillar 43 at Göbekli Tepe and elsewhere. To examine this issue, it is necessary to consider known cases of V-symbols found within the Taş Tepeler culture. The premise here is that these sites are contemporaneous and connected by a common culture that used similar symbols with similar meanings.

First, let us summarize reported cases of V-symbols on artworks found at Taş Tepeler sites. Most notably, many V-symbols are found on Pillars 43 and 33 at Göbekli Tepe. V-symbols are also found on a small, stone plaquette recovered from Göbekli Tepe (Dietrich et al. 2019). Beyond Göbekli Tepe, other clear V-symbols currently known are found at the necks of three anthropomorphic carvings; the Urfa Man statue, a similar male statue at Karahan Tepe and a similar male figure at Sayburç.

Let us first return to Pillar 43 and consider the V-symbols on the main panel, just above the bird-of-prey. Figure 13 *shows that in the top row there are 14 double V-symbols with alternating vertical orientation, plus a single V-symbol at the end of the row*. Just as for the bone tally stick found at Abri Mege at Tarjat (see Figure 6), *a likely interpretation is that this row of V-symbols can be counted as a lunar cycle of either 29 or 30 days, as follows* (Gordon 2021). *Counting right to left using the upright V-symbols, including the single V-symbol at the beginning of the row, gives 15. Counting back using the same symbols gives another 15, for a total of 30. However, counting back using the 14 upturned V-symbols instead (that look like Lambda, Λ) gives a total of 29. Using this counting device, a lunar month can be either 29 or 30 days long, as expected.*

Directly below the upper row of double V-symbols is a row of 11 square symbols. Given that the V-symbol likely represents a single day, these square symbols likely have a different temporal meaning. If we take each square to represent a whole lunar month, then we have 12 lunar months in total.

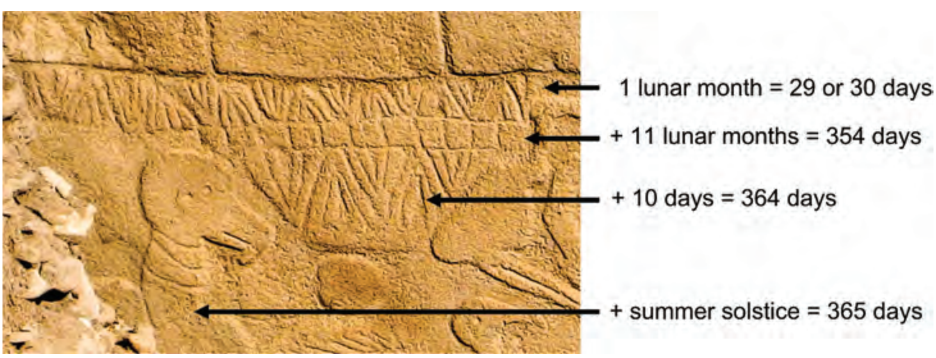

Figure 13. Detail of the centre of Pillar 43 at Göbekli Tepe.

Essentially, we expect each square means ‘repeat the above count’. If we take a strictly alternating series of 29 and 30 days for each lunar month, then we have a total of 354 days.

Directly below the row of squares is a row of five more double V-symbols. This equates to 10 days. If we take these to be epagomenal days then we have a total of 364 days, which is approximately one day short of a solar year. However, there remains one more V-symbol carved on the main panel of Pillar 43. It is the V-symbol at the base of the bird of prey’s neck. This particular V-symbol might be thought to be depicting the bird’s plumage only, similar to the lines on its wings. But it is possible that it also represents a single day, to complete a count of 365 days per year. Thus, this V-symbol appears to indicate that the bird of prey signifies a special day of the year rather than an actual bird.

Recall, in the previous section how the bird of prey is interpreted to symbolize the summer solstice constellation at the time of the event depicted, thought to be the Younger Dryas impact event. Also, recall the moon, sun and H-symbols positioned at the ‘neck’ of Pillar 18, as though representing a necklace (see Figure 3). Thus, it appears that symbols positioned at the neck have a special significance.

This argument is given further weight by considering the Urfa Man statue, a similar male statue at Karahan Tepe and the wall carving at Sayburç. Urfa Man is a stone-carved statue recovered from excavations at Şanliurfa, specifically Balikligöl Höyük, shown in Figure 14. The statue likely represents a human male (he is grasping his penis), or male deity. He is around 2 m tall and has a double V-symbol at the neck similar to the bird of prey on Pillar 43 at Göbekli Tepe (Murdoch 2021). Following the earlier discussion, we can expect that the double V-symbol refers to time in some sense. Possibly, placement of this symbol at his neck indicates control or creation of time. Therefore, the Urfa Man might represent a time-controlling or time-creating deity, or perhaps a creator deity more generally, possibly a male solar deity. Very recently, a similar statue of a male grasping his penis with a clear V-symbol at his neck has been recovered from Karahan Tepe.

Recall also the Master-of-Animals at Sayburç, where a wall carving shows a male figure also grasping his penis with another double V-symbol at his neck (see Figure 11c). In this case, if the flanking animals are taken to represent zodiacal constellations, then this figure can also be interpreted as a time-controlling deity, or more generally as a prime creator deity, perhaps a male solar deity, as for the Urfa Man statue. In this case, the animals might represent the much longer precessional timescale. Therefore, for the Sayburç carving, the figure perhaps controls both the short timescale of days, that is, the human domain indicated by the double V-symbol necklace, as well as the longer precessional timescale of the gods indicated by the opposing animals. It is therefore possible that many later Master-of-Animals symbols, such as the

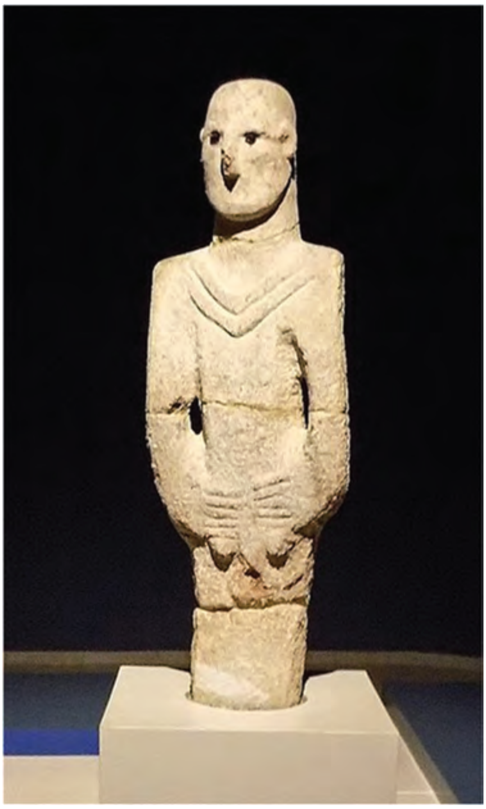

Figure 14. The Urfa Man statue, now in Şanliurfa Museum. Image from Wikipedia, CC-BY-4.0.

Bronze Age intercultural examples, also indicate a time-controlling or creator deity, or perhaps a solar deity.

Given the appearance of V-symbol necklaces on both the Urfa Man statue, a statue at Karahan Tepe and the Sayburç wall carving, it follows that the V-symbol at the neck of the bird of prey on Pillar 43 at Göbekli Tepe is probably not spurious or solely intended to indicate plumage as that would be inconsistent and confusing. More likely, the vulture/eagle's necklace also carries important information which reinforces the notion that it represents the summer solstice constellation.

Therefore, it appears that Pillar 43 encodes the summer solstice constellation and a date via precession of the equinoxes through two different but complementary data structures. First, through the system of animal symbols representing constellations along with the disc symbol representing the summer solstice sun on the main panel and the half-disc symbols representing the winter solstice and equinoxes on the upper panel. Second, through enumeration of a calendar structure on the main panel. Indeed, the structure of the 29 V-symbols is compelling evidence for counting a lunar cycle. Once this counting device is understood, the rest of the calendar structure follows very naturally. This suggests that the designers of Pillar 43 were determined that its meaning should not be misunderstood. Clearly, this was a very important artefact for them, which means it is likely to be important for understanding the motivation for Göbekli Tepe's construction and the cultural changes that followed in the region.

To summarize, it seems the number '11' has as special significance at Göbekli Tepe: 11 is the number of lunar months in a year in addition to the first, as well as the number of epagomenal days, of which one, the summer solstice, is special. We can write this data structure as follows:

1 lunar month = 29 or 30 days
+ 11 more lunar months = 354 days
+ 11 epagomenal days (of which one, the summer solstice, is special) = 365 days
≅ 1 solar year

Although it seems relatively clear that this data structure was known at Göbekli Tepe, it is not yet clear how it was used. *One possibility is that this knowledge was used simply to predict important future astronomical phenomena, such as the solstices and equinoxes* (Gordon 2021). However, given that the lunar cycle appears to be represented (by counting either 29 or 30 days), and that the total number of days (approximately) in a solar year was also known, it is possible that it was used to construct a lunisolar calendar, which would make it the oldest yet known.

Further evidence for the existence of calendar systems at Göbekli Tepe can be found by examining the plan of Enclosures C and D. Figure 15 shows an

Figure 15. Cupules on pillar tops from Enclosure D at Göbekli Tepe. Image courtesy of Claire Murdoch.

elevated view of Enclosure D at Göbekli Tepe. It is formed by 11 T-shaped pillars embedded within the sub-circular enclosure wall, with an additional pair of tall T-shaped pillars near its centre (see Figure 1a). Probably, it is no coincidence that the number of T-shaped pillars embedded within the enclosure wall equals the apparently special number 11. Moreover, by adding one or both of the central pillars to the count we obtain 12 or 13 pillars respectively, which equals the number of lunar months in each year when using a lunisolar calendar. *Possibly, then, Enclosure D was designed as a giant calendar* (Gordon 2021). The inner circle of Enclosure C also has 11 T-shaped pillars, with a pair of tall pillars at its centre (see Figure 1a), and therefore might have had the same function. Use of these megalithic enclosures in this way would be similar to the use of Stonehenge as a solar calendar (Darvill 2022). However, the other rounded enclosures so far uncovered at Göbekli Tepe do not feature 11 T-shaped pillars. This indicates either that the other enclosures had a different function or that it is simply a coincidence that Enclosures D and C both feature 11 T-shaped pillars in their inner walls.

The tops of these pillars display many sets of dimples, or cupules. Such cupules are common at many megalithic sites across the world, including dolmens and stone circles, and are suggested to indicate counting of astronomical phenomena (Magli 2015). Figure 16 shows the top of Pillar 32. Although it is highly eroded, there appear to be 29 cupules, and possibly more. Perhaps, then, these cupules were used to count the days of the lunar cycle. However, the tops of other pillars are too highly eroded to count their cupules, and it remains unclear which phenomena they were used to count, if any.

Of course, if the enclosures were roofed, use of the cupules in this way might be problematic. However, it is possible these cupules were not used at the same time as the enclosures were roofed or that roofs were designed to not obstruct

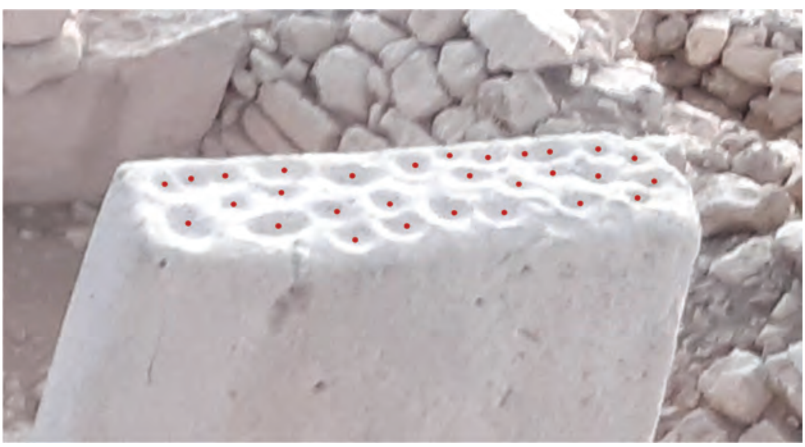

Figure 16. Detail of the top of Pillar 32, Enclosure D. Image courtesy of Claire Murdoch. The 29 added red dots indicate individual cupules.

the cupules. It should also be noted that it is not yet proven these large enclosures were ever roofed and that many of the pillars are thought to have been moved from their original positions. Therefore, the possibility that Enclosures C and D were roofed at one time does not prevent use of the cupules for counting astronomical phenomena at some other time.

Let us now return to Pillar 33 from Enclosure D. This is the only other pillar at Göbekli Tepe known to exhibit V-symbols. Earlier, it was explained how Pillar 33 can be viewed as a picture of the Taurid meteor stream if the animal symbols on its broad faces correspond to the constellations Pisces (tall birds) and Aquarius (fox), with the snakes representing meteors. Indeed, it was suggested that it shows how the Taurid meteor stream radiant moves from Aquarius to Pisces over the course of a few weeks. However, Pillar 33 also has V-symbols on its inner, narrow face (see Figure 17). On the right, 13 V-symbols ascend vertically, while on the left there are 14. *As for Pillar 43, these are expected to represent the counting of days* (Gordon 2021). In this case, these symbols might count the duration of the meteor shower from the direction of each constellation as the

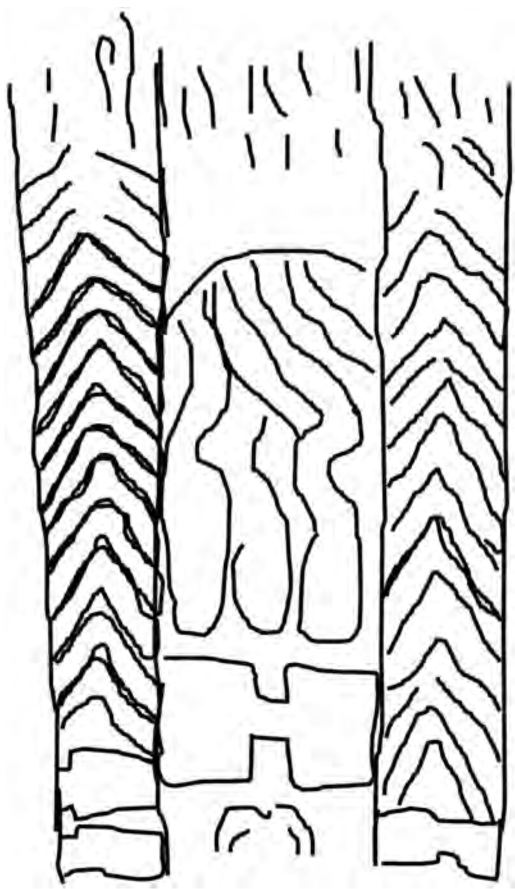

Figure 17. Sketch of part of the inner face of Pillar 33, Enclosure D, showing the V-symbols.

radiant point moves over the course of nearly one lunar month; 13 days from the direction of Aquarius (the fox) and 14 days from the direction of Pisces (the tall bird). Thus, interpretation of the V-symbols as representing individual days is consistent across Göbekli Tepe and supports the earlier interpretation of Pillar 33.

Also consider a small stone plaquette recovered from Göbekli Tepe (Dietrich et al. 2019). It displays a vertical series of six V-symbols between two long serpentine arrow symbols (see Figure 18). Given the interpretation of Pillar 33, it appears this stone plaquette records another meteor stream, perhaps one lasting 6 days. This suggests Göbekli Tepe was used as an observatory.

Given the apparent focus on the Younger Dryas impact via Pillar 43 and on meteor streams via Pillar 33 and this plaquette, it is possible that Gobekli Tepe's enclosures were used for ceremonies linked to these events, as well as other astronomically related events such as the solstices and equinoxes. Perhpas enclosure pillars and cupules on pillar tops were used to count and keep track of periods of time related to these ceremonies. This would be consistent with the general view that they were used for shamanistic practices and the ethnographic research of Hayden and Villeneuve (2011) into the astronomical interests of relatively modern 'complex' hunter-gatherer groups.

Finally in this section, we can interpret a bone plaquette from Dja'de el-Mughara (Kodas et al. 2022), which is about 60 km south-west of Göbekli Tepe, circa 9000 BCE, as a lunar calendar (see Figure 18). The plaquette is divided into four sections by crossed incisions. The four sections have 3, 8, 10 and 8 dimples respectively, plus an extra hole. The dimples could be used to count the days of a lunar calendar as follows. Three is the number of days each lunar month that

Figure 18. Left: Stone plaquette recovered from Göbekli Tepe potentially showing a meteor stream. Right: Bone plaquette from Dja'de el-Mughara potentially showing a lunar cycle (from Kodas et al. 2022).

the moon is effectively invisible (the new moon). This leaves 26 or 27 days of visibility. If we take 26 days, this can be constructed from a waxing phase of 8 days, a symmetric phase of 10 days wherein the moon is full and a waning phase of 8 days. The hole might have been used to count the extra day for a 30-day lunar month.

8.3. A possible lunisolar calendar system at Karahan Tepe

Let us turn now to consider Karahan Tepe, another site belonging to the Taş Tepeler culture situated around 50 km east of Göbekli Tepe (Karul 2021). Of particular significance is an 11-pillar structure carved directly out of the bedrock (see Figure 19). This 7 m × 5 m structure is roughly trapezoidal with rounded corners, with its long axis oriented approximately 20° west of north. A winding channel on the northern edge of the structure was possibly used to guide water into it. It is therefore called a 'pool' here. The 11 pillars of this pool are not T-shaped. Instead, 10 of them appear almost phallic. The 11th pillar, however, is much slimmer and appears curved with a recessed inner border, and therefore might once have formed a complete oval-shaped annulus. Several of the pillars elsewhere at Karahan Tepe appear to be highly fractured, so it is possible this 11th pillar is not complete. In fact, this 11th pillar is the only one not carved directly out of the bedrock; rather, it is inserted into a little socket at its base, which emphasizes its special status.

Figure 19. An 11-pillar pool structure at Karahan Tepe hewn out of the bedrock. The 11th pillar is different to the other 10 and appears to be incomplete. Note the carving of a face looking over the pool.

The 11 pillars in the pool structure are of similar height and might once have supported a lid or roof, which would have also rested on the edge or lip of the pool. On the western edge of the pool, just under the lip, we see a detailed carving of an almost circular face projecting inwards. Like the three-dimensional sculpture of a predator on a pillar at Göbekli Tepe, this face is carved directly out of the bedrock. The whole structure is very impressive and would undoubtedly have required an immense amount of work and high technical skill to create.

Entry to this covered 11-pillar pool structure appears to have been through a narrow opening in its southern edge which connects to a large sub-circular enclosure more than 20 m in diameter. This latter enclosure contains T-shaped pillars as well as seats or benches carved directly out of the bedrock. Possibly, this large enclosure was also roofed and appears to have been a communal meeting place or perhaps a large family home. Another possible pool structure, this time without any pillars, is carved into the bedrock just to the north-west and partly adjoins the 11-pillar pool structure.

Once again, we see the significance of the number 11. Recall at Göbekli Tepe 11 T-shaped pillars form Enclosure D and the inner ring of Enclosure C. Recall also the 11 square box symbols and 11 additional V-symbols on the main panel of Pillar 43 at Göbekli Tepe which, together with the row of 29 V-symbols, likely encode a calendar. Also recall how one of the 11 additional V-symbols on the main panel of Pillar 43 at Göbekli Tepe is apparently special and likely denotes the summer solstice.

Since this structure at Karahan Tepe also has 11 pillars, and one of them is quite different, perhaps it also encodes a lunisolar calendar system identical to the one discovered at Göbekli Tepe. But how? Obviously, the 11 pillars can immediately be interpreted as representing the 11 epagomenal days required to complete a solar year. Also, given its slimmer, rounded shape, we can interpret the 11th pillar as representing the summer solstice, which appears to have been counted as a special epagomenal day at Göbekli Tepe. But to count 12 lunar months we need an additional pillar or structure. Possibly, then, this is the role played by the circular face. If the circular face is taken to represent an entire lunar month, then the 11 pillars can be interpreted as representing 11 more lunar months using precisely the same data structure as on Pillar 43. Essentially, a more efficient encoding of the data structure on Pillar 43 is suggested where the 11 pillars have a dual role. To clarify:

Circular face = 1 lunar month = 29 or 30 days
+11 pillars = 11 more lunar months = 354 days
+11 pillars = 11 epagomenal days (of which one, the summer solstice, is special)
= 365 days ≅ 1 solar year

This interpretation requires the carved circular face to represent an entire lunar month. Indeed, its circular profile reminds us of the full moon, and the carved face is reminiscent of our familiar 'man in the moon' meme. This should not be surprising as the people living at Karahan Tepe saw similar patterns in the moon's craters to those we see today. Indeed, the Babylonians also saw a 'man in the moon', although theirs was imagined standing and not just as a face (Beaulieu 1999). Nevertheless, the dual use of the 11 pillars to count both lunar months and epagomenal days is perhaps less clear than the data structure written on Pillar 43 at Göbekli Tepe.

9. Discussion

The previous sections present evidence for lunisolar and lunar calendar systems at Taş Tepeler sites that support an astronomical interpretation of their symbolism. Included in that astronomical interpretation is a record of both the date and the mechanism of the Younger Dryas impact. Essentially, we can view Pillar 43 at Göbekli Tepe as a memorial to that that event.

Given Göbekli Tepe's prominence at the beginning of the Palaeolithic–Neolithic transition which later influenced a much wider region, it is sensible to consider potential symbolic links between the Göbekli Tepe culture at Taş Tepeler sites and later cultures in the Fertile Crescent and in neighbouring regions. We should look for links especially with those nearby cultures with grand megalithic temples or astronomy-related religions, such as ancient Egyptian and Mesopotamian cultures. We should also consider the possibility that the Younger Dryas impact had an important influence on the Palaeolithic–Neolithic transition. These issues are discussed next.

9.1. Symbolic connections with later cultures

The basis of this astronomical interpretation is that the animal symbols on the broad sides of Göbekli Tepe's pillars can be interpreted as constellations, similar to those known by ancient Greek and Mesopotamian cultures. The possibility that this similarity can occur simply by coincidence is thought by Sweatman and Tsikritsis (2017b) to be very small. If this correspondence is correct, then we can expect much more of Göbekli Tepe's symbolism was preserved. For example, it is possible that the lunisolar calendar system apparent at Yazilikaya (Zangger and Gautschy 2019; Zangger et al. 2021) inherited some knowledge from the one apparent on Pillar 43. It is also thought that a lunisolar calendar system was in use in Egypt before the civic calendar with 5 epagomenal days became accepted (Ruggles 2015). It was also argued earlier that the intercultural Master-of-Animals and Potnia Theron symbols found across the ancient Near East might be descended from similar symbols found at Sayburç and Çatalhöyük. Moreover, another intercultural symbol, the semi-circle, which is often found in association with animal symbols and interpreted here as representing a sunset, also appears at Göbekli Tepe at the top of Pillar 43 adjacent to animal symbols with precisely the same interpretation. Recall also the Gebel Djauti rock graffiti scene (see Figure 10), which shows it is highly likely that the astronomical code known at Göbekli Tepe survived at least until the mid-fourth millennium BCE in Egypt.

Schmidt also made several references to similarities between the symbolism of Göbekli Tepe and Egypt. For example, he compared the snake symbols at Göbekli Tepe with Wadjet and, specifically, the Uraeus symbol (Schmidt 2011). Moreover, at Karahan Tepe several statues have been found that show animals, especially foxes (see Figure 20), riding on the backs of humanoid figures, which is similar to the common representation of Egyptian deities with animal heads. Such human–animal hybrids are often associated with shamanism (see Dietrich [2023] for example). But it should also be remembered that megalithic stone circles and shamanistic practices are both often associated with astronomy (Krupp 1999; Magli 2015). Given also that the Egyptian deities Sah-Osiris and Nut are linked with the constellation Orion and the starry sky, respectively (Pinch 2004), we can propose that many other Egyptian deities ultimately might have an astronomical origin. If we accept that the animal symbols at Göbekli Tepe also represent constellations, then we can cautiously associate many of the animal symbols at Göbekli Tepe with some of the oldest Egyptian deities.

Figure 20. Two stone statues found at Karahan Tepe, now displayed at Şanliurfa museum, showing a fox riding on the back of a humanoid. Other similar statues have also been recovered from Karahan Tepe.

For example, if we consider the main section of Pillar 43, we can tentatively make the following associations: scorpion → Serket, wolf/dog → Anubis, duck/goose → Geb, the bending bird with curved beak → Thoth, eagle or vulture → Horus and/or Nekhbet. Furthermore, the numerous fox symbols at Göbekli Tepe → Set, the popular bovine symbol → Apis, Hathor and/or Bat, a feline symbol on Pillar 51 → Seshat and/or Sekhmet, and a ram symbol on Pillar 1 can be associated with Khnum and/or Amun.

These associations suggest a system of constellations related to that known in classical Greece was known to pre-dynastic Egyptians and was associated with their earliest deities. It has already been discussed (see Section 5), in line with the views of Hartner (1965) and Gurshtein (2005), how a similar constellation system might have been in use at around the same time, circa 3500 BCE, in Mesopotamia. However, in later dynastic eras, we know the Egyptians invented their Decan constellation system (Lull and Belmonte 2006). It is possible, therefore, that the Decans superseded a more ancient constellation tradition because they were found to be more useful, for telling the time at night for example (Conman 2003).

Regarding the many snake symbols seen at Göbekli Tepe, ophiolatry is widespread among many ancient cultures. Within ancient Egypt, in addition to Wadjet there is Apep, a serpentine god of chaos. Apep was also the greatest enemy of Ra, the Sun god, and thus associated with darkness. This would accord well with the association of snakes with meteors at Göbekli Tepe. The Sun and Moon symbols at Göbekli Tepe on Pillar 18 can obviously be associated with Ra and Khonsu, respectively.

In ancient Egypt, Atum is the prime creator deity of the Heliopolitan Ennead, an early ancient Egypt pantheon. In some ancient Egyptian texts, he is said to have created the world through the act of masturbation (New World Encyclopedia 2022). Atum is also said to represent the sun specifically as it sets. Perhaps, then, Atum and similar early prime creator, time-controlling or solar deities in this region, evolved from the more ancient Urfa Man deity (which also resembles figures found at Karahan Tepe and Sayburç). Recall how the animal symbols at Göbekli Tepe are associated with Greek constellations as they set on the western horizon.

These potential symbolic connections between the culture at Taş Tepeler sites and ancient Egypt are supported by genetic analysis. Notably, Schuenemann et al. (2017) analysed the DNA of three New Kingdom mummies and found their ancestry is most closely associated with Natufian populations (about 50%), with some admixture with Neolithic Anatolian groups (about 30%) and Iranian groups (about 20%, presumably from the Zagros mountains). Therefore, it is possible that the symbolic connections mentioned earlier might be generated by more than just cultural diffusion, that is, migration could be a contributing factor.

Along with symbolism, it is also possible that some ancient myths might retain information from the time of Göbekli Tepe. For example, zodiac-like creatures are popular in Mesopotamian mythology, including bulls, lions, scorpions and serpents. Notably, the Bull of Heaven is highly destructive and has been associated with the constellation Taurus (Black and Green 1992). The earliest version of this tale, like the constellation names mentioned earlier, also dates to the Sumerian era. It is also notable that Tiamat, sometimes described as a giant serpent in Babylonian myths, creates 11 monsters on her death and 11 Slain Heroes are central to another Babylonian myth. It is not clear why the number 11 is prominent in these myths, but it is possible it is used as a mnemonic for a lunisolar calendar. Ultimately, in the Babylonian creation myth, the *Enūma Eliš*, Tiamat is slain by the Babylonian deity, Marduk, and falls to Earth causing further devastation. Thus, Mesopotamian and Egyptian serpent and bovine symbolism is consistent with the astronomical interpretation presented here involving the Taurid meteor stream. Clube and Napier (1982) already suggested that ancient serpent and bovine symbolism in many cases is linked to comets, meteors and cosmic impacts.

Indeed, James and van der Sluijs (2016) argue it is likely that many widely dispersed catastrophic myths associated with fire and destruction from the sky, such as the Greek Phaethon myth, are inspired by historic cosmic impacts. In the specific case of the Greek Phaethon myth, as told by Plato in his Timaeus (Jowett 1998), the destruction is said to be cyclic:

> There is a story, which even you [Greeks] have preserved, that once upon a time P[h]aethon, the son of Helios, having yoked the steeds in his father's chariot, because he was not able to drive them in the path of his father, burnt up all that was upon the earth, and was himself destroyed by a thunderbolt. Now this has the form of a myth, but really signifies a declination of the bodies moving in the heavens around the earth, and a great conflagration of things upon the earth, which recurs after long intervals.

This is an accurate description of coherent catastrophism. Recall how the Younger Dryas impact event is thought to be caused by the decay of a giant progenitor comet within the inner solar system, i.e. by coherent catastrophism. Of course, interpretation of myths is often uncertain, much like the interpretation of symbols. But, if a cosmic impact interpretation is correct for these myths, then the Younger Dryas impact 10,835 ± 50 BCE is clearly a suitable candidate. James and van der Sluijs (2016) suggest more recent cosmic impacts might also play role. However, due to the wide dispersion of such myths, they favour a more ancient source.

9.2. The origin of civilization

Göbekli Tepe is clearly an important site within the Taş Tepeler culture of upper Mesopotamia. It is located in space and time just before the onset of the Neolithic revolution in the Fertile Crescent, yet remains of domesticated species of plants or animals appear to be absent. Cauvin had already theorized that this cultural transition was triggered by a change in cognition, rather than agriculture (Cauvin 2000). His evidence included the timing and flourishing of new artworks with apparent religious symbolism compared to the timing, distribution and need for agriculture within the Fertile Crescent. Excavations were only just beginning at Göbekli Tepe when his work was published, so he could not have known that his ideas would be supported by symbolism at Göbekli Tepe and other Taş Tepeler sites. Recent debate on this issue has discussed the importance of 'monumentality'; that is, that this important cultural transition was influenced by the desire to build imposing monuments, like the large enclosures at Göbekli Tepe and Karahan Tepe (Kinzel and Clare 2020). Once they are built, it is argued that they could act as a focus for communal activities, possibly cultic or religious in character, that would attract a growing population.

Probably, we should consider cultural changes in both monumentality and artistic symbolism together as part of the same package. If we consider Cauvin's hypothesis based on artistic symbolism first, it is obviously flawed, or at least incomplete (Cauvin et al. 2001). He proposed the preponderance of bull and female symbols at this time played a significant role in the development of religion in the Fertile Crescent. Yet bull symbols are also prevalent in European Palaeolithic art and many female 'Venus' figurines are also known from that period (Nowell and Chang 2014). Also, in any case, European Palaeolithic cave art is at least the equal of the Early Neolithic artistic package of West Asia in terms of grandeur and finesse. Clearly, the change in cognition he suggests as the trigger for the Neolithic revolution had already occurred elsewhere. Nor could he explain why religion apparently developed and spread rapidly at this time within the Fertile Crescent. Realizing this, he searched for a suitable environmental trigger, but could not find one that was adequate (Cauvin 2000). For example, he suggested a potential role for an earthquake cluster at the beginning of the Holocene in upper Mesopotamia, but evidence was lacking. Again, he could not have known about the Younger Dryas impact (Firestone et al. 2007).

Çelik and Aayz (2022) agree that a specific 'fracture in cognitive factors' is not apparent to them either. Instead, they view Göbekli Tepe's symbolism more as a continuum from the earlier Palaeolithic period, recognizing that it likely carries important mythological and cosmological content:

> . . . they have exerted great effort both mentally and physically through mythological speculations that would even rival the Sumerians in order to make sense of their origins, of life and death. (Çelik and Aayz 2022)

In other words, while a change in cognition is not immediately evident, a change specifically in the effort expended in mythical enquiry, or religion, is. They therefore only partially agree with Cauvin's hypothesis.

If we now consider monumentality, this is also an inadequate explanation for the Palaeolithic–Neolithic cultural transition since it merely moves the goalposts one further step. That is, one still needs to explain why the world's first megalithic monuments were constructed at this specific time. The neighbouring Early Natufian culture from the Levantine region, the most developed culture in the region prior to the Younger Dryas period, instead constructed relatively small sub-circular dwellings with large stone block foundations supporting a wooden frame (Bar-Yosef 1998). There is little hint of Göbekli Tepe's megalithic monumentality or accomplished symbolism in this precursor culture prior to the Younger Dryas onset. That is, if we did not know of any Taş Tepeler sites, their grand monumentality and symbolism would not be predicted based on earlier Natufian sites or later Neolithic sites in this region. This was the state of knowledge prior to Göbekli Tepe's discovery. If, to overcome this difficulty, one then suggests this change in monumentality was triggered by a change in the effort expended on mythical enquiry, i.e. religion, then we have at least partially returned to Cauvin's theory. Again, we can ask what triggered this change in religion.

The proposal that the new religion apparent at Göbekli Tepe solely concerns a cult of the deceased, or ancestor worship, or a skull cult seems also to be insufficient, since if this explanation was correct then we could expect to have observed this important cultural transition together with the construction of grand temple-like enclosures at a much earlier time in pre-history, because we can expect such cults to be relatively common.

This work suggests the Younger Dryas impact completes Cauvin's program. It is probably the rare environmental trigger that Cauvin sought that led to the development of a new religion within the Younger Dryas period in the Fertile Crescent. Religion might already have existed elsewhere, for example in Palaeolithic Europe, but the Younger Dryas impact might have triggered a novel, catastrophic form in the Fertile Crescent (Sweatman 2019). Fear is a powerful organizing principle in human society and the Younger Dryas impact would undoubtedly have inspired great fear and awe. Thus, this event can provide the motivation for the grand construction projects of Göbekli Tepe and related sites. It is also a sufficiently unusual and rare type of event that it becomes easier to explain why this cultural transition did not occur at a much earlier time in pre-history. These ideas are in accord with Hayden's view on shamanistic secret societies and their role in shaping the development of communities, often through self-aggrandizement (Hayden 2019).

Göbekli Tepe's discovery and the decoding of its artworks strongly supports this hypothesis. It appears that Göbekli Tepe's pillars, especially Pillar 43, are memorials to this great event which was retained in cultural memory for millennia via many myths.

10. Conclusions

The presented discussion highlights likely continuity of some Palaeolithic artistic symbolism through into the ancient Near East and even into modern times. The vector for this continuity appears to be the (largely) unchanging stellar sky and the regular motion of the moon and sun, i.e. astronomy, and a desire to understand the cosmos so that seasonal resources can be optimized and important communal activities scheduled. Archaeoastronomy, as a discipline, seeks to understand this phenomenon.

Earlier work provided an astronomical interpretation for animal symbols on the broad sides of pillars at Göbekli Tepe that involved knowledge of precession. Sweatman and Tsikritsis, (2017b) provide a statistical argument that this interpretation is very likely correct based on comparison with constellations in Stellarium. A consistent theme for this interpretation is the Younger Dryas impact, a global-scale cosmic catastrophe at 10,835 ± 50 BCE. The novel calendrical interpretation described in this work both supports and extends those earlier arguments. It also contributes more generally to archaeoastronomical research on the origins of naked-eye astronomy and the ancient Greek and Mesopotamian constellations.

Specifically, lunisolar calendar systems are likely described at Göbekli Tepe and Karahan Tepe. Indeed, similar to Stonehenge and some other ancient megalithic circles, Enclosures C and D at Göbekli Tepe could represent giant calendars where the number 11 has a special significance; it likely indicates the number of epagomenal days needed to complete a solar year (approximately), given 11 + 1 lunar months. The summer solstice appears to have been regarded as a special epagomenal day. In addition, V-symbols within the Taş Tepeler culture appear to denote the counting of days. Necklace symbols also appear to have great significance. On the Urfa Man statue, Karahan Tepe statue and Sayburç wall carving they appear to indicate time-controlling or creator deities. It would be interesting to see whether these V-symbols occur also in Palaeolithic cave art.

Clearly, this astronomical interpretation for Göbekli Tepe's symbolism relies on comparison with other symbols that are either known or suspected to also be astronomical in nature, including constellations in Stellarium, the Nebra sky-disc, specific artefacts from late Neolithic and Early Bronze Age Mesopotamia and Egypt, and Palaeolithic cave art and figurines. The time difference between Göbekli Tepe and creation of these other symbols might lead one to question the validity of this approach, but evidence presented here suggests astronomical symbolism can have a very long lifetime, perhaps longer even than 50,000 years for some astronomically related myths. Moreover, even if some of this symbolism is convergent rather than culturally transmitted, the correlations still constitute evidence, albeit of a weaker kind, of this astronomical interpretation. In fact, comparison of Göbekli Tepe's symbolism with symbolism at other sites, such as Çatalhöyük, or with Palaeolithic art or with Bronze Age cultures, or with Shamanistic symbolism, is commonplace. Ultimately, if we are to decode Göbekli Tepe's symbolism at all, then comparison with symbols from other locations is the only way forward.

Indeed, comparison between different sets of data is fundamental in science and many other disciplines including archaeology. Whether one compares between two numerical data sets generated by theory and by observation, for example, or pottery sherds and stone tools between one archaeological site and another, or phonemes between two neighbouring languages, or mythical elements between widely separated cultures or genetic codes between widely separated ancient burials, the method of comparison is essentially the same and necessary for scientific progress. This work is no different in this respect.

Nevertheless, the confidence we attached to any hypothesis that attempts to explain Göbekli Tepe's symbolism, or any other scientific theory for that matter, should be proportional to its 'explaining power'. That is, the more observations a hypothesis or theory can explain, relative to its inputs, then the better the theory. This is simply a statement about parsimony, or Occam's razor, which itself concerns probability and therefore logic. The astronomical interpretation for Göbekli Tepe's symbolism, including evidence for time-keeping and calendrical systems presented here, is suggested to be a good theory because it is very 'efficient', i.e. it can explain a great many observations with only a few inputs. That is, if we consider the Western constellation set in Stellarium, precession, the Younger Dryas impact and lunar and solar cycles as inputs, then we can consistently explain all of the following observations:

(1) The precise selection and placement of nearly all animal symbols on the broad face of Pillar 43 at Göbekli Tepe in terms of a memorial to the Younger Dryas impact encoded using zodiacal dating. Sweatman and Tsikritsis (2017b) consider the correlation of animal symbols with known constellations highly unlikely to occur simply by chance. Gurshtein (2005) predicted this kind of zodiacal dating system should occur by 6000 BCE. Göbekli Tepe indicates that an even more sophisticated type existed already in the Palaeolithic era.
(2) All of the V-symbols and small boxes on the main panel of Pillar 43 in terms of a lunisolar calendar, which perfectly complements and supports the interpreted zodiacal date (#1).
(3) The precise selection of animal symbols on the broad sides of Pillar 33 and Pillar 2 and the V-symbols on the narrow face of Pillar 33 in terms of a picture of how the Taurid meteor stream changes over the course of a few weeks.

(4) The consistent astronomical interpretation of many symbols on Pillar 18, including some with obvious astronomical associations such as sun and moon symbols.
(5) The number of T-shaped pillars in Enclosures D and the inner ring of Enclosure C at Göbekli Tepe and the number of pillars in the pool structure at Karahan Tepe in terms of lunisolar calendar systems.
(6) The preponderance of the number 11 at Taş Tepeler sites and in later myths in terms of a lunisolar calendar.
(7) The meaning of all V-symbols at Taş Tepeler sites in terms of day-counting and time-keeping more generally.
(8) The meaning of part of the wall carving at Sayburç and the identity of Urfa Man and a statue at Karahan Tepe in terms of time-controlling, creator or solar deities.
(9) The identity of the four major kinds of zoomorphic wall relief at Çatalhöyük in terms of shrines dedicated to deities related to the solsticial and equinoctial constellations (see Sweatman and Coombs 2019). The Çatalhöyük Potnia Theron is thus associated with feline symbols because this links fertility (the Potnia Theron) with the spring equinox constellation at the time (Cancer, represented by felines).
(10) The same symbol for one of the four major kinds of wall relief (the bear [Türkcan 2007]) occurs at Çatalhöyük with a circle on its belly, but at Göbekli Tepe appears at the top-right of Pillar 43 next to a semi-circular symbol (see Figure 21). This is naturally explained if this symbol represents a constellation similar to Virgo, since Virgo is the summer solstice constellation at Çatalhöyük (hence the full circle) while it is the spring equinox constellation at the time of the Younger Dryas impact (hence the semi-circle).
(11) The meaning of many late Neolithic and Bronze Age intercultural Master-of-Animals, semi-circular sunset-like symbols and related animal

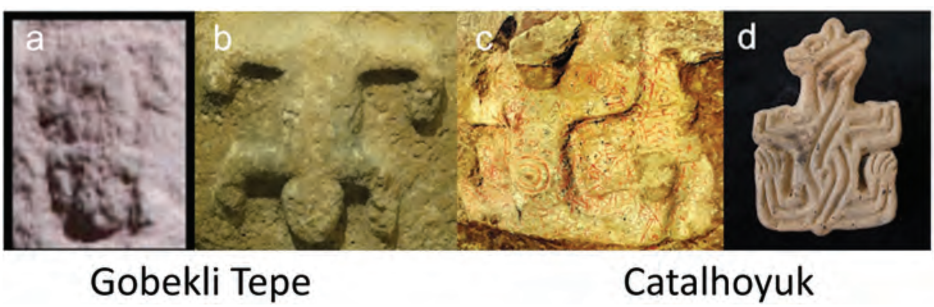

Figure 21. Bear symbols from Göbekli Tepe and Çatalhöyük: (a) down-crawling quadruped at the top-right of Pillar 43 at Göbekli Tepe; (b) sculpture from Göbekli Tepe; (c) one of four types of wall relief from Çatalhöyük (from Mellaart 1967); (d) bear seal stamp from Çatalhöyük (image from www.Çatalhöyük.com).

symbols in terms of zodiacal dating using precession. This includes Hartner's (1965) observations on lion–bull combat symbols, and zodiac-like animal symbols at the top of the Uruk Vase and the Gebel Djauti rock carving.

(12) Semi-circular symbols in early Sumerian pictograms used for both units of time and the sun and similar semi-circular symbols seen on a wide range of artefacts from the Neolithic to the Bronze Age consistent with a system of zodiacal dating in terms of a picture of the sunset on the solstices and/or equinoxes.

(13) The apparently strong correlation between Göbekli Tepe's animal symbols and the most ancient Egyptian deities in terms of an ancient constellation set related to the Greek one.

(14) The origin of theriomorphic forms of many ancient Egyptian and Mesopotamian deities in terms of their relation to constellations described with animal symbols similar to those at Göbekli Tepe.

(15) The preponderance of widely dispersed catastrophic myths involving destruction by fire from the sky or by a solar deity in terms of the Younger Dryas impact and similar cosmic impacts, along with the common choice of mythical bovine or serpent deities to deliver that destruction in terms of the Taurid meteor stream.

(16) The extremely strong correlation between radiocarbon dates and specific animal symbols in European Palaeolithic cave art, along with the orientation of entrances to these painted caves, in terms of observation of solstices/equinoxes and precession. These correlations are considered extremely unlikely to occur simply by chance by Sweatman and Coombs (2019) and by Jegues-Wolkiewiez (2007), respectively.

(17) The appearance of monumental megalithic sites like Göbekli Tepe along with larger-scale communal activities that potentially contributed to triggering the origin of civilization in the Fertile Crescent shortly after the Younger Dryas impact in terms of a new religion inspired by the impact.

Of course, if the astronomical interpretation presented here is correct, it implies that astronomical knowledge and notation around the Palaeolithic–Neolithic transition was far in advance of what is generally recognized. Not only was precession very likely known in the Upper Palaeolithic, it appears it was also used to date important events such as cosmic impacts. Indeed, the Lascaux Shaft Scene shares many similarities with Pillar 43 at Göbekli Tepe, which suggests it could also be a record of another cosmic impact event in southern France, zodiacally dated to around 15,300 BCE (Sweatman and Coombs 2019). This proposed impact might explain an apparent two-millennium hiatus in the occupation of Aquitaine, south-western France, during the late-middle Magdalenian period, radiocarbon dated to around the same date (see Figure 7 of Barshay-Szmidt et al. 2016). It seems, therefore, that a primitive form of astronomical proto-writing was employed, and perhaps designed, to warn future generations of the cosmic dangers they faced. However, this level of cognition should not be surprising. The existence of accomplished Upper Palaeolithic artworks and even musical instruments (Morley 2018) already points to a fully modern mind.

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Disclosure statement

M.S. is author of a popular book related to this topic.

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