



## The roles of observational astronomy in ancient Greece

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### ABSTRACT

This paper offers an investigation into the interface between science, in the form of astronomy, and culture, in the form of religion and the calendar. Early societies made use of a variety of mechanisms to mark time, based on the cycles of the sun, moon and stars, whether separately or in combination. In this paper I provide a survey of the use of one of these cycles, namely that of the stars, in one ancient culture, that of the Greeks. I show how gradually the night sky was mapped out with a number of distinct constellations, the number increasing over time. The Greeks used the first and last visible risings and settings of these stars at dawn and dusk as 'event markers', in order to signal the appropriate time for pivotal activities, especially in the agricultural sphere, such as ploughing, sowing and harvesting. At the same time, Greek societies used the moon as the basis for their civil and religious calendar, and within the lunar months were situated regular festivals of an agricultural nature. Agriculture is tied to the seasons and hence the sun, which the star cycle matches fairly well, but the moon runs on a different cycle which does not keep pace with the sun and stars. The increased refinement of the star calendars with a larger number of constellations might be a result of a desire to help synchronise the divergent seasonal and lunar timetables. Examples are provided to illustrate how particular stars might have been associated with particular divinities and festivals.

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**KEYWORDS:** *Astronomy, constellations, sky maps, calendar, agriculture, event-markers, religious festivals.*

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## 1. INTRODUCTION: COSMIC CYCLES

It has become popular in recent years in the 'Western' world to mark in some public fashion the start of several 'New Years' in the course of a single calendar year. Western/European New Year falls always on 1 January; Chinese New Year occurs at varying times in the early part of the western calendar; and less obviously, the first day of Muharram, the start of the Islamic religious year, runs gradually over time through all the seasons (the ninth month, Ramadan, tends to attract more attention). Underlying each of these lies a different methodology for calculating the start of the year – the cycle of the sun for Western New Year; the cycle of the moon for the Islamic New Year; and the combined cycles of sun and moon for Chinese New Year. Other holidays or festivals in the course of the calendar year also use these cycles. The placements of Jewish Passover and Christian Easter rely on calculations of the combined solar and lunar cycles, with the added complication in the Christian context of conventional rather than astronomical definitions of the terms 'full moon' and 'equinox'. Similarly, the increasingly popular Hindu festival of lights, Diwali, is timed according to a mixed lunar and solar, or lunisolar, calendar. In some parts of the world the combined cycles of the stars and the moon provide a time signal, as in New Zealand for Māori New Year (Hannah, 2005: 5–15; Hannah, 2009: 14, 157–58 n. 7–8).

That these cosmic cycles still govern the marking of time today is testament to how fundamental they are to the human perception of time, regardless of the fact that we have now other, more precise mechanisms to measure and mark time, notably the atomic clock, which is independent of the slight but significant vagaries of the cosmic bodies. In common speech we still talk of sunrise and sunset, terms that imply that the sun really rises or sets. Our ordinary language of time does not acknowledge that it is simply the motion of the earth around its axis that gives us the impression of the sun's rising or setting. Sense perception dominates, whatever our brain tells us is really happening.

## 2. STAR CYCLES

In this paper I wish to focus on just one of these older mechanisms for marking time, the cycle of the stars, because it is this which provides, I believe, a new key to understanding ancient social practices.

One great advantage that the stars offer over other celestial bodies is that they rise and set always at the same points on the horizon. Where the Pleiades rise in June, that is where they will rise every month of the year for several decades. In this respect they dif-

fer markedly from the sun and the moon, whose size and brightness otherwise naturally attract us to them over and above the tiny stars, but their movements are very variable in space and time due to their proximity to the earth. The sun shifts up and down the horizon with the seasons. While the moon does this too, to further confuse us it rises and sets at considerably different times of the month, making tracking it more complicated. With the stars being much further away from the earth, on the other hand, all that changes in the course of the year is the period of visibility for each star. We can see the Pleiades rise just before dawn in June, but at other times of the year they rise at other times of the night or day. At some point people also realized that those stars that rise and set are visible only in certain seasons but invisible in others. Therefore they could be used as seasonal or monthly markers.

## 3. MAPPING THE SKY

In the ancient world, the mechanisms for marking time via the cosmic cycles are usually found to be tied to religious beliefs. For the ancient world we must mentally work our way into a religious context, however hard that is now at the theoretical level – what do we mean by 'religion'? – let alone at the practical level. Fortunately, one modern aspect of this investigation is in our favour. Our night sky is still populated by constellations, many of whose names reflect their origins in Classical antiquity. The Pleiades, Pegasus and Perseus are just a few of the ancient Greek configurations, which populate the modern celestial map. These names represent originally mythological figures, who were 'catasterized', or transformed into stars, by the Greeks (Aratus, *Phaenomena*; Pseudo-Eratosthenes, *Katasterismoi*; Kidd, 1997). Of course, people from time immemorial appear to have created pictures by joining the dots that are the stars in the night sky, although the further back we go in time, the harder it is to be certain that the images we have from the Paleolithic or Neolithic periods do indeed constitute 'star charts' of some sort, because the words which might tell us this do not survive (Magli, 2009; Kyriakidis, 2005). Even if the words did survive, would we understand them, and how literally should they be taken? In the western tradition, it is not until we get to Egyptian and Babylonian written records that we can be sure that people were not only observing the night sky in a systematic fashion, but were mapping it as well (Hunger and Pingree, 1989; Neugebauer and Parker 1960–1969; Lull and Belmonte, 2009). The constellations which these peoples created, some of which were passed on to the Greeks and then to the Ro-

mans and so to us, represent complex processes of comprehension, conceptualisation and categorisation, which have allowed observers then as now to locate bodies in the celestial sphere (Hannah, 2002). In this regard, NASA is no different from the nameless scribes of Babylon: all have recourse to the mapping facility offered by the constellations, however arbitrary and culturally-situated they are.

Before the Greek astronomers from Hipparchos to Ptolemy, between the second century BC and the second century AD, developed a coordinate system for placing stars on the celestial globe, these constellations provided the usual means of situating anything in the night sky (Dilke, 1987: 181-82). In the third century BC Aratos wrote a poem which described the stars in a pre-coordinate fashion. It is clear from him that the imaginary mythological or zoological figures, which formed the constellations, also provided rough-and-ready means of navigating one's way across the sky:

Let the left shoulder of Andromeda be a sign for the northern Fish, for it is very near to it. Both of her feet indicate her bridegroom, Perseus, as they move always on his shoulders. He is taller than others in the north. His right hand is stretched out towards the seat of his mother-in-law's throne, and as if pursuing on foot he lengthens his stride, running in the world of his father Zeus. Near his left knee altogether are the Pleiades. Not much space at all holds them all, and they are faint to observe (Aratos, *Phaenomena* 246-256; trans. author).

But mapping is one thing, and a complex thing at that. Knowing why people map is another. Why did the Babylonians and Greeks – since this is the tradition we still work in – populate the sky with these particular figures?

The earliest records suggest the night-sky was mapped initially for practical purposes, such as navigation (even in the Egyptian afterlife) or the timing of agricultural activities (e.g. Hesiod, *Works and Days*). This process is made complicated because of the apparent movement of some of the celestial bodies. The band of sky which the sun itself appears to move across in the course of a year encompasses stars which were parcelled out from around 3000 BC by the Mesopotamian peoples into what was eventually called the zodiac by the Greeks, because of the animate forms into which they configured the stars (a bull, a lion, a scorpion, etc.). This zodiacal band of stars was regarded as special because it was seen to be populated not only by the light-giving sun and moon but also by those stars which were not fixed in place relative to others, but which moved or wandered – the planets, as the Greeks called them, from their word for 'wanderers'. These special stars, or planets, were deified by these societies, and regard-

ed as having power over human events and eventually, under the Babylonians, Egyptians and Greeks, over individual human lives (Neugebauer and Van Hoesen, 1959; Barton, 1994; Jones, 1999; Holden 2006; Rochberg, 1998, 2004, 2010).

One debased trace of this practice in the modern world is our continuing familiarity with our astrological 'star signs' – supposedly those zodiacal constellations across which the sun passes in the course of the year. We talk of 'when the sun is in' Pisces or Aries or whichever of the twelve 'signs' of the zodiac. While the sun is now never 'in' these constellations at the moments when we say they are, nonetheless we have an idea of these stars being able to tell us the time of year because of where the sun is supposedly situated in relation to them (Beck, 2007: 23-25). Deducing when the sun occupied the space devoted to one constellation or another was something that was best done just before sunrise or just after sunset, because then the immediately neighbouring constellation could still be discerned. In our western tradition, this notion goes back directly to the Babylonians at least as far back as the second millennium BC (Rochberg, 1998, 2010). Their records list the appearance and disappearance of certain stars and the planets through the course of the year. They can be situated within a context that we call astrological, but which was generally not distinguished from observational astronomy until the late Roman and early Medieval period. For the astronomer Ptolemy, observational astronomy and horoscopal astrology were 'a single predictive enterprise, of greater or lesser certitude, searching for regularities and significance in the motions and positions of the celestial bodies' (Beck, 2007: 2).

The belief in the ability of stars, planets and constellations to influence human life we call astrology today in disparaging tones, but we must never lose sight of the fact that however superstitious such activity appears to us now, it was this metaphysical activity which gave the impetus to astronomy as we know it, not only in antiquity but long afterwards as well. Ptolemy, Newton and Kepler, great astronomers though they were, were also practising astrologers (Campion, 2008, 2009; Holden, 2006).

Having set aside the wandering stars, which included the sun and moon, and other occasionally periodic oddities like comets and meteors, the ancients were left with a vast number of dots in the sky, which remained in the same position relative to one another. Of course, these so-called 'fixed' stars have their own proper motion, but that is not important at this level of observation. To any casual observer they look utterly unconnected, as indeed most are in reality, being made by our eyes to look as though they are lights on a two-dimensional can-

copy of the sky. Yet some do seem to stand out for one reason or another in certain configurations, perhaps because of the surrounding blackness of the sky once our eyes move outside that thickly populated band which we call, with the Greeks and Romans, the Milky Way. At other times we can assume that the 'en-figuring' of the night sky occurred in the way it did because certain stars could be readily grouped into configurations, which were easily recognisable within certain cultures. The longevity of some configurations shows how some shapes have stood the test of time and culture: the Scorpion is a good example in the Middle Eastern–Mediterranean worlds, since it was devised by the Babylonians and passed on to the Greeks and Romans, all of whom knew what a real scorpion looks like. Egyptian constellations, on the other hand, seem not to have filtered across and remain today difficult to identify (Lull and Belmonte 2006). The stars that we call Pegasus were seen by the Babylonians, not unreasonably, as simply a Field, whereas the Greeks imagined them as the body of a Horse, which eventually came to be identified with the mythological Pegasus (Boll and W. Gundel VI (1924-37) col. 928-31; Kidd, 1997: 258-59). It is not that the Babylonians were simply more prosaic than their Greek neighbours, for they could certainly picture elaborate figures in the sky, and they could coordinate these thematically, if they wished. The constellations which we call Aries, Auriga, Taurus and Orion, for example, the Babylonians called the Hired Man, the [shepherd's] Crook, the Bull, and the True Shepherd of Anu, all reflecting agricultural influence and all rising at dawn in spring time, when work in the fields would start up again (Hunger and Pingree, 1989: 137-38). But the Babylonians seem not to have had an inclination to use mythological stories which connected one constellation with another. This the Greeks did with gusto, creating thus a celestial carpet of interconnected catasterism myths linking the constellations with one another. An example of this is the catasterism myth which links Artemis' maidens, the Pleiades, the hunter Orion and his dog Sirius (Condos, 1997: 172).

But again, this simply states the obvious, that the Greeks told stories through the stars. Why did they do so? To answer that, we may start by asking: who are these 'stars' of the celestial stage?

The particular constellations relating to the myth of Perseus seem to have been placed in the sky ('catasterised') as a narrative group in what looks like a conscious project at the end of the fifth century BC. We find this reflected – not necessarily initiated – in the plays of Sophokles and Euripides (according to pseudo-Eratosthenes, *Cat.* 15, 16, 17, 36, and Hyginus, *Astr.* 2.9–11), who between them place as con-

stellations in the sky the princess Andromeda, her mother and father Cassiopeia and Cepheus, and the sea monster Cetus. Perseus must have been sent up there too then or earlier, but the record does not survive to tell us so (Hannah, 2002).

The constellation Perseus therefore belongs to a new class of figures in the sky whose source lies in narrative mythology. Extensive areas of the sky were now populated by inter-connected characters from Greek mythology. In this way the heavens were mapped out in a manner which we continue to utilize today, and this very process of mapping, this method of articulating a way through the whole panorama of the stars, is part of the reason why these catasterisms were invented. But that begs the question why should people need to navigate their way through the sky. One obvious answer lies in the need for peoples in the Mediterranean to find their way from one landfall to another in their seafaring journeys. This is illustrated early on in Greek literature in a famous, if contentious, passage in Homer's *Odyssey*, in which Odysseus is given sailing instructions by the goddess, Athena (Hannah, 1997):

*Glad with the wind, noble Odysseus spread sails. Sitting down, he skilfully held it straight with the steering-paddle, and sleep did not fall on his eyelids as he looked to the Pleiades and late-setting Boötes, and the Bear, whom they also name Wagon, which turns round about there and watches Orion closely, and alone is without a share in the baths of Ocean. For Kalypso, noble among goddesses, commanded him to pass over the sea, keeping the Bear on his left hand. Seventeen days he sailed, passing over the sea, and on the eighteenth day there appeared the shadowy mountains of the land of the Phaiakians, where it was nearest to him, and it looked like a shield on the sky-like sea (Homer, *Odyssey* 5. 269-81 (trans. author)).*

Certainly in this realm the use of large constellations rather than tiny pinpoints of single stars makes a great deal of sense, as research on star navigation methods in other cultures has demonstrated (Lusby, Hannah and Knight, 2010a, 2010b; Lewis, 1994). But lists of constellations are more likely to have been kept in seafarers' heads than in city centres, and yet it is in city centres – arguably Classical Athens itself and certainly Hellenistic Miletos – where we happen to have found them archaeologically (Hannah, 2001) These findspots demand another explanation for the peopling of the sky.

#### 4. ASTRONOMY AND AGRICULTURE: EVENT MARKING

A traditional role of observational astronomy in ancient Greece was to provide indications of pivotal moments of change in the seasonal year.

That Minoan Cretans may have used a sophisticated astronomy and even instrumentation, such as the magnetic compass, in orienting their palaces and other buildings towards the rising-points of the solstices and apparently even of the equinoxes as well as the moon and certain stars on the horizon – is currently being argued and demonstrated. On this basis a native Minoan lunisolar calendar has been proposed, and its preservation into the historical period presumed (Henriksson and Blomberg 1996, 1997-8, Blomberg and Henriksson, 2000, 2003; Downey 2011, 2015 forthcoming). However, the degree to which there was continuity of thought and practice from the Bronze Age to the historical period, across the great divide of the so-called Greek Dark Age, remains problematic.

For Homer and Hesiod, at the dawn of Greek literature, the rising and setting of just a handful of stars and constellations served as agricultural ‘event markers’, much like calendar dates, signalling or reflecting the appropriate time for various activities. In particular, Hesiod’s wisdom-poem, *Works and Days*, provides a rough-and-ready calendar for activities down on the farm, each often timed by the appearance or disappearance of a star (West 1978). So, for example, the time of winter ploughing is signalled by the dawn setting of the Pleiades, the Hyades and Orion (*Works and Days* 614-17). Hesiod exhorts his farmer to start the harvest at the dawn rising of the Pleiades, at the end of their 40-day period of invisibility (*Works and Days* 383-7, 571-3). Elsewhere he mentions the culmination of Orion and Sirius at the time of Arcturus’ dawn rising to indicate the period of the grape harvest in September (*Works and Days* 609-11). In all, he provides just nine observations of the risings or settings of five stars or star groups – Sirius is mentioned once, while the Pleiades, the Hyades, Orion, and Arcturus are all noted twice – and he adds the culmination of Orion and Sirius to the rise of Arcturus. These observations are so arranged that the farmer was given a remarkably economical safety-net of successive warnings of the appropriate date for a certain activity on the land (Reiche, 1989).

Homer also has occasion to use the stars as event markers, though his intention is not at all didactic like Hesiod’s is. Star lore is simply part of the backcloth the poet has at his disposal to add depth to scenes he imagines. At *Iliad* 18. 483-89, for instance, Homer describes the decoration placed by Hephaistos on a new shield for Akhilleus (Hannah, 2005: 18-27; Ferrari, 2008: 88-89):

*He made on it earth and sky and sea, and untiring sun and moon coming full, and all the signs with which heaven is wreathed, Pleiades and Hyades and the strength of Orion and Bear, whom they also name Wagon, which*

*turns round about there and watches Orion closely, and alone is without a share in the baths of Ocean* (Homer, *Iliad* 18. 483-89 (trans. author)).

On the new shield Homer lavishes a great deal of decorative detail about human life, in the city and the countryside, which arguably has much to do with the larger themes of the poem. This description of human life begins with the lines quoted above, and these lines foreshadow the seasonal work of the countryside detailed soon afterward in the shield’s description. The astronomical content of the decoration of the shield is very season-specific. We have seen already that for Hesiod the time of winter ploughing is signalled by the dawn setting of the Pleiades, the Hyades and Orion, three of the star-groups listed by Homer; only the Bear is missing from Hesiod. But the Bear is doing something significant astronomically at this time. This large constellation is situated so far north in the Greek sky that it neither rose nor set over the horizon, but always stayed above it in the course of its circuit round the sky. In this circuit, it reached its upper transit, or culmination, across the north-south line of the meridian at the time of the setting of the Pleiades, Hyades and Orion. This took place around November in our terms, and signalled the time for ploughing and sowing. As is apparent in the last line of the above excerpt, the Greeks were aware of this difference in the Bear’s movement from a very early date.

But these same stars can do double duty. Let us recall that for Hesiod the dawn rising of the Pleiades marked the time of summer harvesting. In fact, harvesting and threshing would span a long period, about May-to-July in our terms, and during this time not only the Pleiades but, of course, the Hyades and Orion would also rise successively just before dawn. Simultaneously, the Bear – neither rising nor setting – reached its lower transit across the meridian, just skimming the northern horizon. The relationship of the Bear to the other three star-groups is a close one in the geometry of the sky, and it would seem also in the related activities on the land, where ploughing and sowing are first signalled, and later harvesting. We may also see the significance of the Bear’s second name, the Wagon, a useful vehicle at harvest time.

## 5. AGRICULTURE, RELIGION AND THE CALENDAR

The agricultural cycle was also intimately bound up with the religious cycle in ancient Greece. Festivals of ploughing, sowing and harvesting articulate both the agricultural and the religious year.

A skyphos (bowl), found in the vicinity of an Archaic temple at Halai in East Lokris in mainland Greece, and dated on the basis of its Corinthian-style

decoration to ca. 625 BC, gives a hint of the link between the stars and the seasons within a religious context. The bowl carries a painted frieze of animals, now only partially preserved: still remaining are a bull, a snake, a hare, a dog, a scorpion, a dolphin, and a lion/panther. The animals have no obvious narrative or mythological connection, but have been convincingly interpreted as representations of some of the constellations: the bull for Taurus, the snake probably for Hydra, the hare for Lepus, the dog for Canis Major, the scorpion for Scorpius, the dolphin for Delphinus, and the lion/panther for Leo. These have further been interpreted as groups signaling the four seasons: autumn, winter, spring and summer, via the rising and setting of the relevant constellations at sunset. It has been speculated that this seasonal decoration may reflect the function of the skyphos as a votive object for the nearby temple, with the four seasonal groups matching the timings of religious events. Unfortunately we have no specific information about the religious calendar at Halai, so for now this must remain only speculation (Barnes, 2014).

The particular association of the Pleiades, the Hyades, Orion and the Bear / Wagon with agricultural activities that we have also seen, may go deeper still in ancient Greek society. The great agricultural and religious festivals of Demeter and Persephone in Athens occurred, not surprisingly, at times significant to agricultural activity. These festivals took place within fixed months of the Athenian festival calendar (Mikalson, 1975). However, this calendar was not a solar one like ours is, but a lunisolar one, tied to both lunar and solar phenomena, like the Jewish religious calendar or the Asian calendars today. This means that in any given year in antiquity, we cannot usually tie a given Athenian date to a given modern equivalent. (I say 'usually' because on very rare occasions it is possible to pin down a date if it is related to a phenomenon like a lunar or solar eclipse, which we can date independently of the ancient calendar.)

To get a sense of the vagaries of a lunisolar calendar, let us imagine our New Year's Day falling on Jewish Passover or Easter Sunday every year. We are familiar with these shifting around a period of weeks in the early part of our year. This is because both are fixed to the first full moon after the northern spring equinox, although there are disturbances in the similarity brought on by artificial, rather than astronomical, definitions of some of the terms in the algorithm, notably 'full moon' and 'equinox' in the Christian tradition. Now let us think of either of these festivals as New Year's Day. From one year to the next, New Year would fall on a different date in the year, but

within a determinable period of about six weeks following the March equinox.

To illustrate the point, the following Table 1 gives the dates of Passover for the period between 1994 and 2013:

**Table 1. Passover dates for 1994-2013**

Year	Passover	Year	Passover
1994	27 March	2004	6 April
1995	15 April	2005	24 April
1996	4 April	2006	13 April
1997	22 April	2007	3 April
1998	11 April	2008	20 April
1999	1 April	2009	9 April
2000	20 April	2010	30 March
2001	8 April	2011	19 April
2002	28 March	2012	7 April
2003	17 April	2013	26 March

Some years have 12 months, others need to have 13, so as to keep New Year's Day falling soon after the March equinox. If we did not add this extra month every two or three years, the brake would be lifted off our calendar and it would run instead like the Islamic religious calendar, which has only 12 lunar months every year and therefore only 354/355 days, with the result that Islamic New Year's Day and every other holiday of the year run through all of the seasons over a period of 30 years. This is why Ramadan, for instance, occurs at different times and seasons of the year.

At some point in ancient Greece it was discovered that a reasonable degree of synchronicity between calendar and seasons could be maintained if one added an extra lunar month at irregular intervals of two or three years, but on a regular basis over a set number of years. The eight-year cycle, or *octaeteris*, is just such a method. Censorinus (*On the Birthday* 18.5) reports that its invention was sometimes attributed to Kleostratos, whom we may place with some probability towards the end of the sixth century BC. It is not impossible that the cycle existed in various forms before this time and that what Kleostratos did was simply to invent a particular form of it. So the cycle could have been used from the first celebrations in Delphi from 582 BC.

The Pythian Games were celebrated at Delphi every four years – indeed, it makes its appearance in this format on the recently discovered 'Olympiadial' of the Antikythera Mechanism, along with other sets of games held also on four-year cycles (the Olympic Games and the Naa at Dodona) or two-year cycles (the Isthmian and Nemean Games) (Freeth et al. (2008)). However, writing in the 3rd century AD, Censorinus (*On the Birthday* 18.6) noted that many

Greek cults celebrated their festivals at an interval of eight years, and he expressly mentioned the Pythian Games as an example of just such a festival. On this basis, then, it is reasonable to assume the use of an *octaeteris* as a means of calculating when the Games at Delphi should take place (Hannah, 2012).

Literary and epigraphic sources indicate that the Pythian Games were celebrated on the seventh day of the month Boukatios, which was the second month after the summer solstice in the lunar calendar of Delphi. It can be shown that in order to celebrate the Pythian Games in the same lunar month, Boukatios, every four years, there must be an alternating interval of 49 and 50 months between successive celebrations. This alternation managed to preserve attachment to the same lunar month. Table 2 shows an *octaeteris* incorporating the Pythian Games in month ii (standing for Boukatios).

We can see that celebrating the Pythian Games always in month ii leads to unequal intervals of alternately 49 and 50 lunar months between celebrations. The festival would be held first in month ii of year 1 of the cycle. Maintaining attachment to month ii, the next celebration would be in year 5, by which time an intercalary month has been added. Then the next Games would occur in year 9, by which time two further intercalary months have been added.

Also at Delphi there were occasions when oracles were given, and times of year when they were not. The observations of certain stars may have helped to signal the appropriate time for the delivery of oracles. The time when the oracular god Apollo was absent from the site and was imagined to be visiting the northern Hyperboreans corresponded to winter (Ahl, 1980). During those months, between December and March, it has been calculated that the constellations Lyra and Cygnus, which were associated with Apollo, were visible only for a short time at night, and never reached the zenith. This period possibly also coincided with the time when hallucination-inducing vapours from the underlying rock formations were reduced, thus limiting the time when the priestess could be under their influence to deliver oracles. The god then 'returned' to the temple at Delphi, arguably around the time of the spring equinox, when Lyra and Cygnus first reached the zenith at sunrise. Furthermore, regular observations of these stars could be used to assist in signaling when the extra, intercalary month should be added to the calendar (Liritzis and Castro 2013; compare Salt and Boutsikas 2005).

Because of the wandering character to the Athenian calendar, even with its periodic insertion of an intercalary month, it is practically impossible to be precise about when in terms of our calendar an event in the past took place. But we can be sure of the sea-

son, and as a result we can see that the festivals held in honour of the agricultural goddesses, Demeter and Persephone, occurred not only at significant moments in the agricultural cycle, as we would expect, but also at times that were culturally significant in astronomical terms. The Stenia and Thesmophoria festivals were held in the first half of the month of Pyanepsion, the fourth month of the Athenian year, corresponding roughly to our October-to-November. This situates the festivals around the time of the dawn setting of the Pleiades, Hyades and Orion. The festival of Skira, a summertime event, was held in its eponymous month, Skirophorion, the last month of the Athenian year and the month that we know contained the summer solstice. New Year's Day, and with it the first month of the new year, would begin in the evening of the day of the first sighting of the new moon after the solstice. So we are in June-to-July with Skirophorion, a period that would have witnessed the dawn rising of the Pleiades, Hyades and Orion. The great Eleusinian Mysteries were celebrated in the middle of the month of Boedromion, the third month of the year. They will have taken place at the one time of the year when these same constellations were visible throughout the whole night from dusk to dawn – and we know that an all-night ceremony was part of the proceedings, so the coincidence, if it is only that, is striking. And finally the Haloa festival, in Poseideon in mid-year, belonged to a time when the Pleiades were culminating at dusk.

Added to these possible connections between religious and astronomical/calendrical phenomena is the potential for the landscape to have played a role also. The western horizon from the Akropolis is an important one in terms of sacred space: it looks out towards the site of Eleusis, home of the Mysteries held in honour of Demeter and Persephone. The Sacred Way, which connected Athens to Eleusis, runs in the direction of sunset on the summer solstice when viewed from the Akropolis. A coincidence perhaps, since the road runs through a hill pass that happens also to lie on this alignment, but a suggestive one nevertheless that astronomy, religion and landscape could be intimately connected.

That similar possibilities exist elsewhere in the Greek world may be illustrated by an example from Cyprus. Evidence from the major surviving calendar on Cyprus, from Akanthos (the so-called 'Bulwer Tablet', dating to the 5th century BC: Neumann, 1963; Masson 1983), provides a probable indication of relevant cultic activity in the period of spring and early summer, with month-names indicating reference to Aphrodite (*a-po-ro-ti-si-jo*, 'of Aphrodisios') and Dionysos (*ti-wo-nu-si-o*, 'of Diwonusios'). [While the Cypriot rendering of Dionysos (*ti-wo-nu-si-o*) is

**Table 2: The Pythian Games organized according to an *octaeteris*. Columns Y1–Y8 are years in the cycle, each comprising months i–xii, alternately of 30 and 29 days, plus an intercalary month of 30 days to be set somewhere in years 3, 5 and 8. Sum of months stands for between successive celebrations.**

Month	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9
i	30	30	30	30	30	30	30	30	30
ii	<b>29</b>	29	29	29	<b>29</b>	29	29	29	<b>29</b>
iii	30	30	30	30	30	30	30	30	30
iv	29	29	29	29	29	29	29	29	29
v	30	30	30	30	30	30	30	30	30
vi	29	29	29	29	29	29	29	29	29
vii	30	30	30	30	30	30	30	30	30
viii	29	29	29	29	29	29	29	29	29
ix	30	30	30	30	30	30	30	30	30
x	29	29	29	29	29	29	29	29	29
xi	30	30	30	30	30	30	30	30	30
xii	29	29	29	29	29	29	29	29	29
Intercalary			30		30			30	
Sum of months:					49				50

similar to the syllabic rendering in Linear B (*di-wo-nu-so*), the month-name does not recur in the scanty evidence of Mycenaean calendars in Linear B (Hannah, 2005: 16-17)]. Given Aphrodite's and Dionysos's relationship with fertility, this is not surprising but worth having confirmed, especially as no mainland Greek calendars preserve so direct an association with these two gods in their month-names. Given the overriding importance of the goddess to Cyprus in myth and cult, it would not be surprising that the Cypriot calendars should honour her (Karageorghis, 1977). The link between Aphrodite and Dionysos with springtime, to which the Bulwer Tablet testifies, may help us to discover archaeoastronomical significance in the temples on Cyprus. For instance, the Great Mother on Cyprus evolved to be associated with or to become the Greek goddess Aphrodite (Karageorghis, 1977; Karageorghis, 1998). Both goddesses were linked with ideas of generation and regeneration in nature. At Tamassos, the Temple of Great Mother (Masson, 1964; Buchholz, 1973) is unusually aligned both towards north and yet slightly off true north by just 10° east. The temple faces the low hill of Pano Vouno in the distance, so there is an obvious topographical focus, but what significance this may have had is not yet clear. The temple also faces the circumpolar stars – the Great and Little Bears and most notably the constellation of Draco (the Snake). In spring at dawn and dusk Draco stands vertically above the hill of Pano Vouno. The snake in Greek and other ancient cultures was a symbol of the underworld and afterlife, but also of rebirth (Toynbee, 1973), so there may be a conscious linkage between its appearance and configuration at

this time of year and the cult of the Great Mother at Tamassos. This needs further investigation, especially with regard to Cypriot and Near Eastern conceptions of the circumpolar constellations.

In comparison with Hesiod's nine observations of star phases around 700 BC, 42 observations of 15 stars or star-groups survive from the late fifth century BC Euktemon's data set, which we find excerpted in later, Hellenistic and Roman *paraepemata*; whether he originally recorded more, we have no way of knowing now (Hannah, 2002; Lehoux 2007). So large an increase in star observations may have resulted from a desire to secure the placement of seasonal, and hence solar, events related to the agricultural year within the awkwardly mobile lunar calendar that Greek city-states maintained. In particular, agriculturally-focussed religious festivals could have benefitted from a more stable calendar to maintain synchrony between nature and ritual. It is unlikely that this increase was the result of an attempt to 'weatherproof' the observations (i.e. by having more observations for the same time period the chances of missing the desired moment in the year because of poor weather conditions may be greatly reduced). Should this have been the reason for the great increase in the recording of fifth century observations we would expect that the majority of added star phases would have been during the winter months when bad weather conditions are more likely to occur, which is not the case.

More work needs to be done on this aspect of the Athenian calendar. It touches on aspects of Athenian society well beyond the religious sphere – although we should never underplay this aspect of ancient



society, since religion and cult practices permeated every fibre of society in a way that we witness nowadays in, say, Islam and orthodox Judaism.

## 6. CONCLUSIONS

In this paper I have demonstrated how science, in the form of astronomy, and culture, in the form of religion and the calendar, were interlinked in ancient Greece. The Greeks used a variety of mechanisms to mark time, based on the cycles of the sun, moon and stars, whether separately or in combination. In order to use the stars, the Greeks over time gradually mapped out the night sky, populating it with a number of distinct constellations, the number increasing over time from just a handful around 700 BC to 42 by the end of the 5th century BC. The actual identification of the constellations seems to have been a function of the Greeks' desire to narrate myths and stories through the stars, a feature which appears distinctive to them among contemporary and neighbouring cultures. On the other hand, like their Egyptian and Babylonian neighbours, the Greeks also brought observational astronomy to bear on their sky mapping, by using the first and last visible risings and settings of their stars at dawn and

dusk as 'event markers', so as to signal the appropriate time for pivotal activities, especially in the agricultural sphere, such as ploughing, sowing and harvesting. Examples have been given in this paper of how particular stars might have been associated with particular divinities and festivals. Agriculture is tied to the seasons and hence the sun, which the star cycle matches fairly well. At the same time, however, Greek societies regularly used the moon as the basis for their civil and religious calendar, and within the lunar months were situated festivals of an agricultural nature. The moon does not follow the solar seasonal cycle, so mechanisms had to be found in order to synchronise the lunar and solar cycles. While the addition of lunar months at certain intervals over a period of years was one such mechanism, observing the stars could also help in this time-keeping enterprise. The increased refinement of the star calendars with a larger number of constellations by the end of the 5th century BC might be a result of a desire to help synchronise the divergent solar/seasonal and lunar timetables. Thus astronomy and religion were intimately bound together, the former in the service of the latter.

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