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# Elements of Greek Astronomy and Religion in Minoan Crete

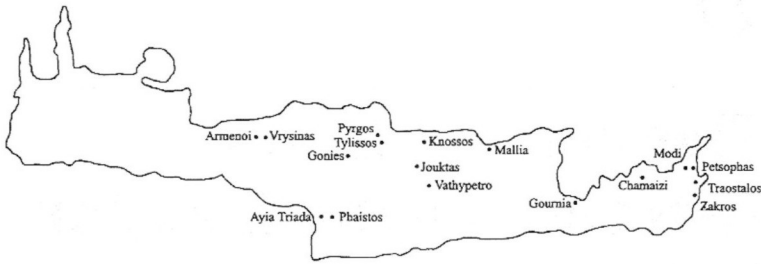
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Archaeoastronomical investigations of important Minoan monuments show orientations at two peak sanctuaries to the heliacal rising and setting, and the acronychal rising and cosmical setting of Arcturus ca. 1830; all dates are B. C. E. unless otherwise stated. The heliacal rising occurred one lunar month before the autumn equinox and this event relative to the phases of the moon would have made it possible to regulate a lunisolar calendar like that of the later Mycenaean and Greeks. In addition the summer solstice and the equinoxes are clearly marked on one of the peaks by alignments to sunrise and sunset behind distant foresights.

The corridor in the Central Sanctuary Area of the palace at Knossos was oriented towards sunrise at the equinoxes and a device was arranged such that the exact day of the equinoxes and also the eleventh day preceding the spring and following the autumn equinox were clearly shown. The result was a simple method for keeping an accurate lunisolar calendar. A similarly placed corridor in the palace at Zakros was oriented towards the moon at its southernmost risings in the Middle Bronze Age (ca. 2000–1600). This and the recovery of many figurines with moon-like head-dress from the nearby peak sanctuaries together with the orientation of the chamber graves in the cemetery at Armenoi within the major standstills indicate a religious role for the moon in Minoan Crete, perhaps a forerunner of the Greek goddess Artemis. Our findings indicate a long tradition of astronomical observations on the part of the Minoans and some transmission of their accumulated knowledge to the later Mycenaean and Greeks. The implications of these findings for the history of Greek astronomy and religion are discussed.

\* \* \*



**Figure 1.** Map of Crete with location of Minoan sites in the Uppsala project. Not to scale.

## Introduction

Minoan astronomical observations and orientations occurred in a context of similar activity in contemporary Europe, Mesopotamia, and Egypt (North 1994). We have copious written evidence from both Mesopotamia and Egypt bearing on the early astronomical activity in these neighbouring regions to Crete (Clagett 1995; Cohen 1993; Neugebauer 1969, 1975; Parker 1978; van der Waerden 1974). We have little precise evidence of astronomy in Greece before the 4th century (Dicks 1970). However Martin P. Nilsson (1920), through a careful analysis of the surviving material, recognised the existence on the Greek mainland perhaps as early as the 8th century of the eight-year intercalary cycle for maintaining a lunisolar calendar. This early use of the cycle was an enigma to Nilsson, as he knew of no adequate evidence for the requisite astronomical knowledge among the Greeks. Neither the civilisation of Mesopotamia nor of Egypt had a lunisolar calendar with regular intercalations and, in general, the astronomical interests of the two areas were directed towards quite different aims than those of the Greeks (Clagett 1995; Parker 1978; Cohen 1993). Our knowledge of early European astronomy is still too vague to say much of comparative use concerning the aims motivating it.

In a paper delivered at the Uppsala symposium on religion and power in the ancient Greek world (Blomberg & Henriksson 1996), we argued for a Minoan origin of the Greek lunisolar calendar. Much of the evidence which we used was not known when Nilsson made his study. It consisted primarily of the indications in the Linear B texts for a Mycenaean lunisolar calendar and of the orientations at the Minoan peak sanctuary on Petsophas, which would have served very well towards maintaining a lunisolar calendar. We have continued with our investigations of Minoan orientations and present here the final results from two peak sanctuaries and results to date from the palaces at Knossos and Zakros (Figure 1). The evidence corroborates our view of systematic astronomical observations on Crete in the Middle Bronze age (ca. 2000 to 1600), the period of one of the two high points of the Minoan civilisation. We follow up the presentation of the evidence with our conclusions as to the significance of the particular Minoan astronomical interest for the history of Greek astronomy and religion. The Gregorian calendar has been used for all datings.

## Petsophas

At Oxford IV we gave the preliminary results from our investigations of the peak sanctuary on Petsophas (Blomberg & Henriksson 1993). The sanctuary lay above the important Minoan harbour town near modern Palaikastro (Figure 2). The site seems to have been selected because the sun could have been observed to set at the equinoxes behind the isolated conical peak of Modi which lies about seven kilometers away to the west and on which there was a similar sanctuary. A shift in position north or south of the structure on Petsophas of only 30 meters results in a change in the observations by one day. Also the moon would have been observed to set behind Modi sometimes at the equinoxes (Figure 3). Another important astronomical fact is that when the the sanctuary was in use the sun rose at the summer solstice just south of the highest peak on Karpathos, Kali Limni, 90 kilometers to the northeast (Figure 4), in the same direction as the main axis of the sanctuary building (Figure 2).

In the final evaluation of our data, we became aware that the walls AA' and AB, considering the mean errors, were oriented in the same direction as the heliacal rising and setting, and also the acronychal rising and cosmical setting of Arcturus in the years around 1830 (Table 1). The horizon can be seen in both directions from the corner at A. The orientations of the walls have been calculated by the orthogonal regression method from 10 measurements for AA' and 6 measurements for AB. The visibility of Arcturus was calculated according to the parameters in Tables 1 and 2.

## Traostalos

In view of the results from Petsophas we decided to measure the orientations at the contemporary peak sanctuary on the highest part of the nearby mountain massif of Traostalos. The site lies nine kilometers due south of Petsophas and is visible from there. Modi is also clearly visible as well as the entire eastern coast of Crete (Figure 1).

The Minoan structure is on the northeastern slope about 35 meters from the highest point and only a few meters from a broad plateau. There are two walls which correspond in orientation to AA' and AB on Petsophas (Figure 5). That is, considering the margins of error, they could have been oriented originally in the same direction as the heliacal rising and setting and the acronychal rising and cosmical setting of Arcturus in the years around 1830. On Traostalos, however, these walls seem to have been part of the structure itself, whereas on Petsophas they lie adjacent to the main building. The wall AB is in poor condition and some of its stones have been moved; others are in situ. We judged that further points measured here would not have contributed to a more accurate determination of the orientation. The wall AA, on the other hand, is partly carved from the bedrock and is well defined. We determined the orientation of the walls at both sites on two different occasions at intervals of about a year each between the measurements and we got very similar results on each occasion (Table 1). This provides some reassurance that our choice of measuring points for determining the original orientations is not unduly subjective.

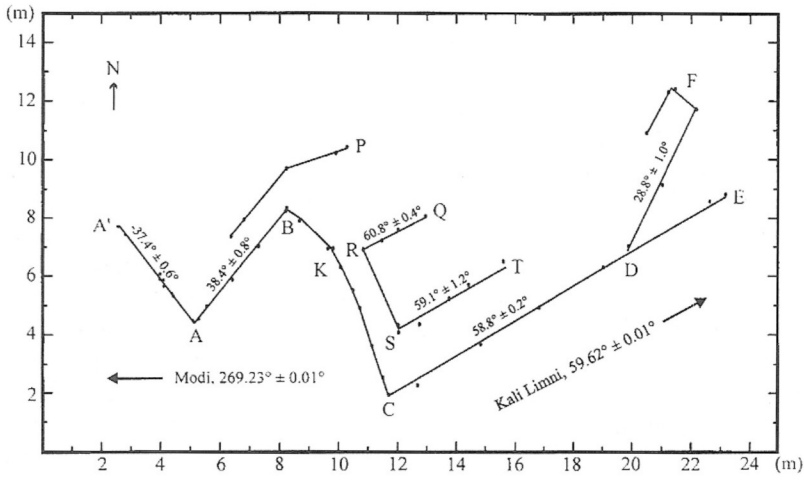


Figure 2. Petsophas. Orientation of the walls.

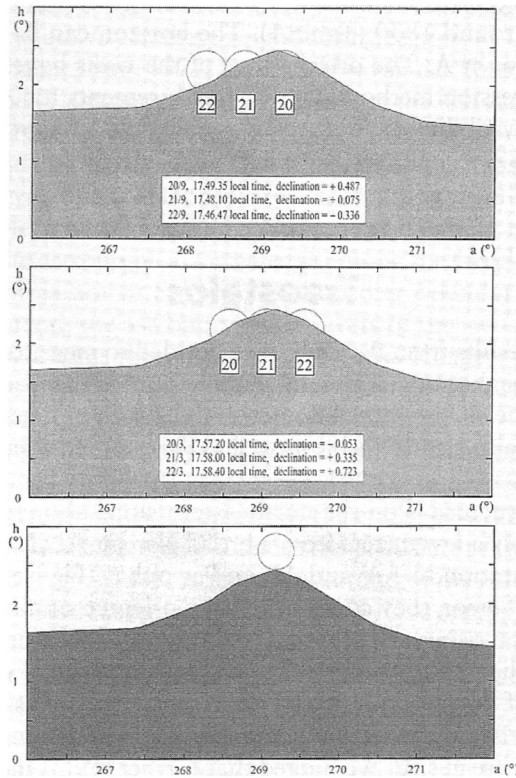
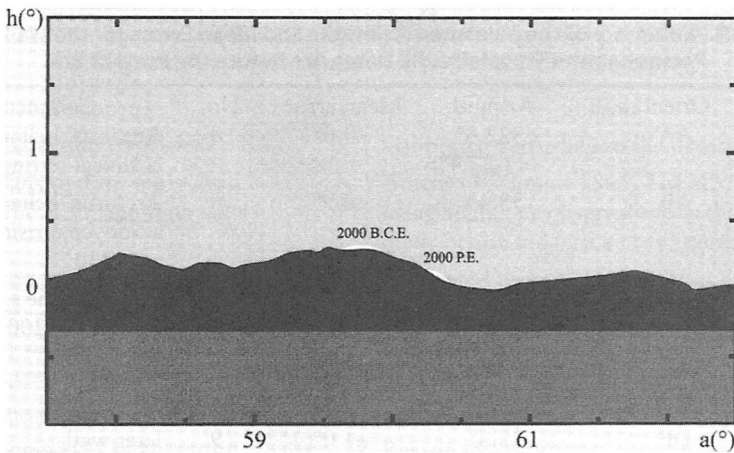


Figure 3. Top and middle: sunsets behind Modi as observed from Petsophas, 1997 September 20, 21 & 22 and March 20, 21 & 22 B. C. E. (refraction for  $t = + 10^7$  Q. The relationships are valid for many centuries. Bottom: full moon setting behind Modi as observed from Petsophas at the autumn equinox, 2121 September 21, 05.13.45 local mean solar time (refraction for  $t = + 10^7$  Q.



**Figure 4.** Theoretically calculated position of sunrise at the summer solstice above Kali Limni, Karpathos' highest peak (1215 m), 2000 June 23 B.C.E., 04.39.35 local mean solar time (sun on the left), as it would have been observed from the peak sanctuary on Petsophas (H. 255 m). The sun on the right shows sunrise 2000 June 21 present era, 05.01.38 Greek standard time. Refraction calculated for + 20° C and atmospheric pressure 760 mm. Hg.

Modi lies close to the direction of AA' and Arcturus will have appeared directly above that peak at its heliacal setting in the years around 1730 (Figure 6). Another useful orientation on Traostalos is that of the wall BY which is the same as the extreme western limit for the circumpolar stars at that latitude (Figure 7).

We evaluated our measurements of the walls on Petsophas and Traostalos using Student's T-test with pooled variance. Table I provides a summary of the results. AA' and AB on Petsophas do not differ significantly in their deviation from the north-south direction. This indicates that they may have intentionally been built symmetrically with respect to north. The same is true for Traostalos, but the result here is not entirely convincing due to the poor condition of the wall AB. We have also analysed the correlation in the directions of the two pairs of walls. There is 90% probability that they were intentionally oriented in the same directions (Figure 7). In view of the margin of errors we cannot exclude the possibility that the eastern wall of the pair was used to observe both the heliacal and acronychal risings and the western wall was used to observe both the heliacal and cosmical settings. We find no more likely explanation for this correlation than observation of the same celestial object. Arcturus is a very likely candidate as its heliacal rising and setting and acronychal rising and cosmical setting occurred in the directions of the walls for the period when the sanctuaries were in use. Since it can be difficult under unfavourable weather conditions to see the star in the early morning and late evening light, the orientation of some device such as walls would have improved the chances of observing its first appearance.

Figure 8 is a theoretical presentation of the change in azimuth for the heliacal rising and setting and acronychal rising and cosmical setting for Arcturus from 2200–1500 at the latitude of Petsophas. The measured orientation of the wall AB at both sites can in principle correspond to either the heliacal or the acronychal rising, and the corresponding optimal construction dates can be read from the horizontal axis. The walls AN can in similar fashion correspond to the heliacal or cosmical setting and their optimal construction dates read in the same way.

**Table 1. Summary of the Measured Azimuths and Mean Errors for the Walls on Petsophas and Traostalos. All Dates Are Before the Present Era.**

Site	Orientation	Azimuth	Mean error	No.	Comment
Petsophas	AA'	322.6° (-37.4°)	±0.6°	10	Arcturus' heliacal and cosmical setting ca. 1830
	AB	38.4°	±0.9°	6	Arcturus' heliacal and acronychal rising ca. 1830
	CE	58.8°	±0.2°	8	sunrise at the summer solstice ca. 2000
	ST	59.1°	±1.2°	4	"
	RQ	60.8°	±0.4°	8	"
	DF	28.8°	±1.0°	9	later wall
	to Modi	269.23° (-90.77°)	±0.01°		Sunset at the spring and autumn equinoxes ca. 2000
Traostalos	to Traostalos	179.31°	±0.01°		true south 180.00°
	AA'	320.6° (-39.4°)	±0.8°	8	Arcturus' heliacal and cosmical setting ca. 1830
	AB	38.9°	±1.8°	4	Arcturus' heliacal and achronychal rising ca. 1830
	BY	325.0° (-35.0°)	±0.8°	8	western limit for the circumpolar stars at Traostalos' altitude (35.15°)
	to Modi	320.28° (-39.72°)	±0.01°		Arcturus' heliacal setting ca. 1730
to Petsophas	359.31° (-0.69°)	±0.01°		true north 0.00°	

As there is 90% probability that the pairs of walls at the two sites were intended to have the same orientations, we determined the weighted mean of their deviation from north, which is  $38.3^\circ \pm 0.4^\circ$ . From this mean value we get the optimal construction date,  $1827 \pm 77$  years. This gives us an independently determined date for the sanctuaries which agrees very well with the archaeologically determined date of 1900–1800 (MacGillivray and Driessen 1990; Manning 1995).

The risings and settings of Arcturus at the two peak sanctuaries occurred in the Middle Minoan Period at four times of the year that would have been useful for calendaric purposes in Crete. An important astronomical fact which must be kept in mind here is that the positions of the stars change slowly due to precession. This means that particular risings and settings of Arcturus today occur nearly two months later than they did in the early Middle Bronze Age. In the case of Arcturus it is also important to take into account the proper motion.

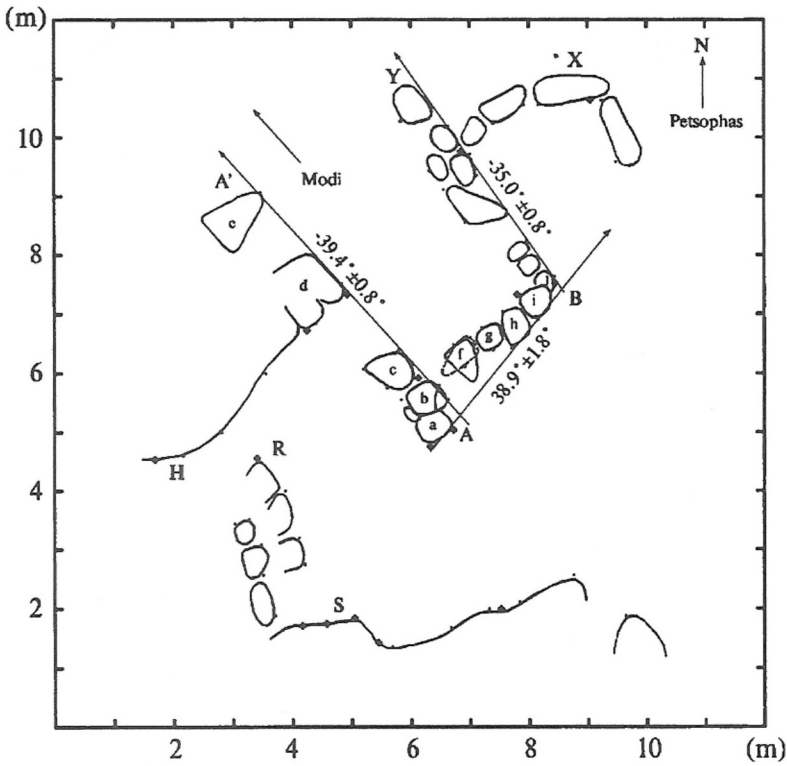
At the time when the walls were built on the two mountains, the heliacal rising of Arcturus occurred on the 24th of August. This is one lunar month before the autumn equinox. We have independent evidence from the Hellenistic Period that the

**Table 2. Parameters Used in Calculating the Visibility of Arcturus at Its Heliacal Rising and Setting, Acronychal Rising and Cosmical Setting.**

Parameters	Sources
Visual extinction coefficient = 0.13 This means that the extinction coefficient in Vmagnitude = 0.17	Calibrated according to the observations at Athens of Schmidt 1865. The advantage of using Schmidt's observations is that they were made before modern air pollution.
Extinction Air Mass	Computed using the tables from Bemporad 1904
Visibility of faint stars, taking into account contrast at faint levels of light.	Siedentopf 1941
Brightness of the sky at twilight	Ljunghall 1949
Refraction for air temperature = + 10° C and air pressure = 760 mm Hg	Reasonable estimates
Arcus visionis, heliacal rising and setting = 9.3° Altitude for Arcturus = 2.9°	Our own calculations based on the above sources
Arcus visionis, acronychal rising and cosmical setting = 8.2° Altitude for Arcturus = 2.0°	Our own calculations based on the above sources

year in Crete began at the first crescent moon following the autumn equinox (Guarducci 1945). If this seems like a long time for the continued use of a calendar, we can compare it with the longer periods of the Egyptian use of their calendar and of our use of the Julian calendar. The only change in the latter has been the slight adjustment in the length of the year made by Pope Gregory XIII in 1582 of the present era. Crete was an exception to most other areas of Greece where the year began at the first sight of the crescent moon after either the spring equinox or the summer solstice (Samuel 1972). Thus the heliacal rising of Arcturus may have served to herald the equinox and also the beginning of the new year. The orientation of the palace at Knossos seems also to have had the autumn equinox as its object (see below). Arcturus could have had an important role in the regulation of a Minoan lunisolar calendar, as the star's heliacal rising relative to the phases of the moon would have indicated when it was time to intercalate a month, intercalations being necessary to compensate for the incommensurate motions of the moon and the sun, and thereby to keep the months in the correct seasons. A simple rule could have been used, for example: 'whenever the new moon appears in the evening sky on one of the II days following the morning rising of Arcturus, it signals the beginning of an intercalary month'. Similar rules were used in Egypt and the Near East (Clagett 1995; Cohen 1993).

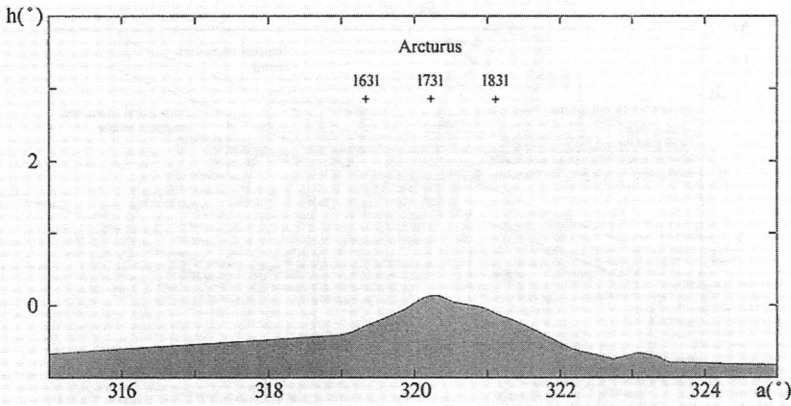
The acronychal rising would have occurred on the day in the Middle Bronze Age corresponding to our 2nd of February, which was midway between the winter solstice and the spring equinox. This may indicate that there was also a division of the solar year into eight equal parts. Such a year would have been practical for farmers, whereas the lunisolar calendar would have been necessary for seasonal religious observances.



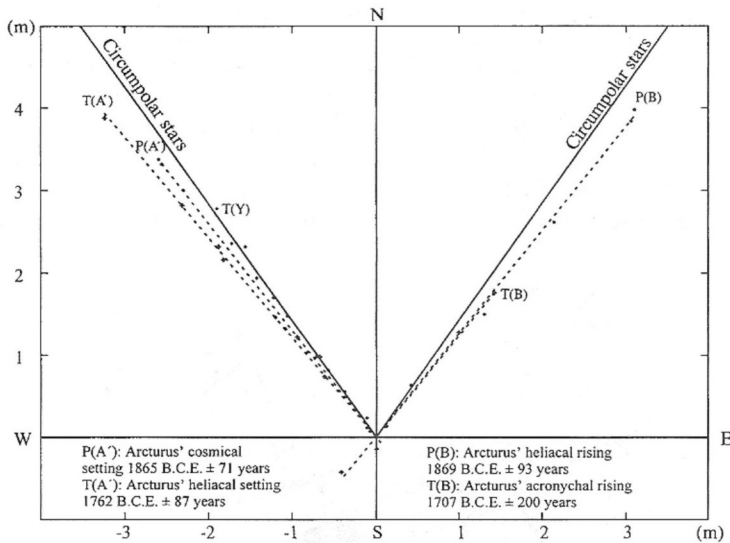
**Figure 5.** Traostalos. Orientation of the walls.

The cosmical setting on the 11th of May and the heliacal setting on the 13th of October would have been practical for indicating the limits of the sailing season in Crete. The peak sanctuaries were close to the two important Minoan ports in eastern Crete, those at Palaikastro and Zakros. The beginning of May and October have been the traditional dates for the sailing season in the Aegean until recent times. We find this information in a number of ancient and modern sources (Lambrou-Phillipson 1991; Casson 1986). The Pleiades were used to tell the limits in the Archaic period (ca. 700–500). By that time, due to precession, the settings of Arcturus were no longer appropriate; we find them, nevertheless, associated with storms at sea down into the first century (e. g. Aratos, 3 d cen.; Geminus, 1st cen.) This may have been a superstitious survival from the Bronze Age when the settings and risings were signals for the beginning and end of stormy weather and, consequently, the limits of the sailing season. There are a number of survivals in later sources of references to stellar positions which do not conform to the time of their writing, but which would have been correct in an earlier period (Blomberg 1992). Similar effects of conservative forces can be detected in the Egyptian astronomical texts (Neugebauer 1969; van der Waerden 1974).





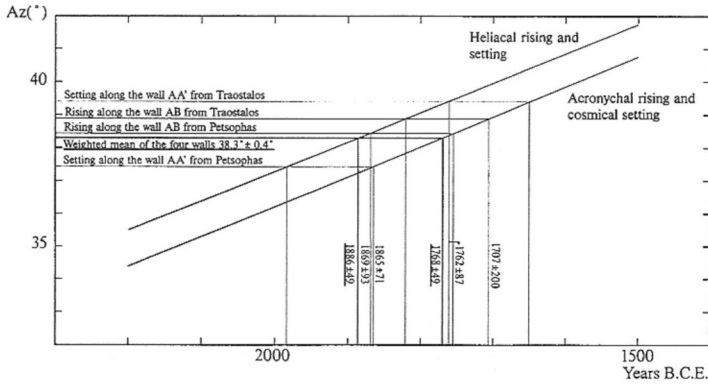
**Figure 6.** Heliacal setting of Arcturus above Modi as it would have been observed from Traostalos in the years 1631, 1731, and 1831 B.C.E.



**Figure 7.** Orientation of the walls AA' and AB on Petsophas and AA', AB, and BY on Traostalos. The wall BY on Traostalos is oriented towards the extreme western limit for the circumpolar stars at that latitude.

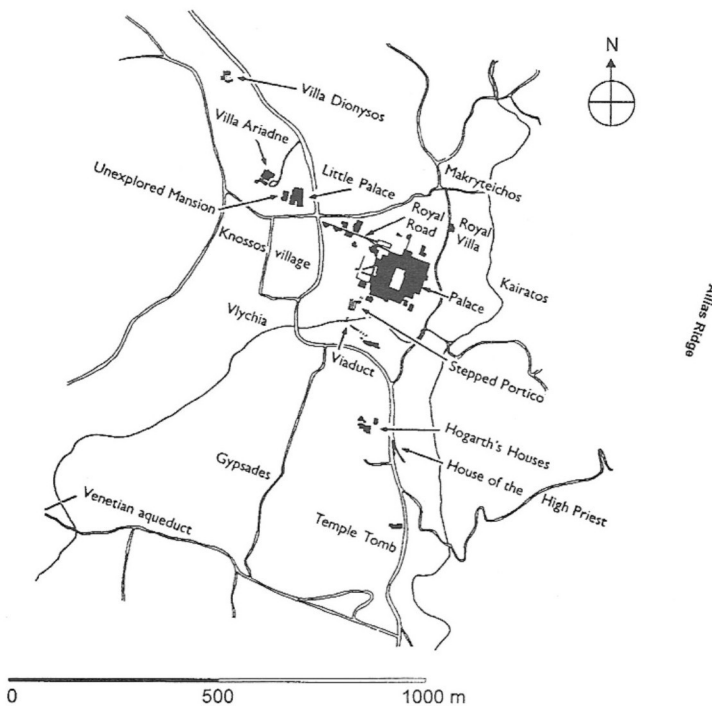
## Knossos

It was early observed that the main axes of the Minoan palaces are neither north-south nor eastwest and that this could be due to orientations towards the heavenly bodies (Marinatos 1934; Shaw 1977). However no detailed study of the orientations and their objects has been presented. We have found that in the palace at Knossos (Figures 9 & 10), the so-called Corridor of the House Tablets—named after the Linear B tablets with ideogram of a house which were found there—is oriented to sunrise behind the Ailias ridge on the morning of the equinoxes. The

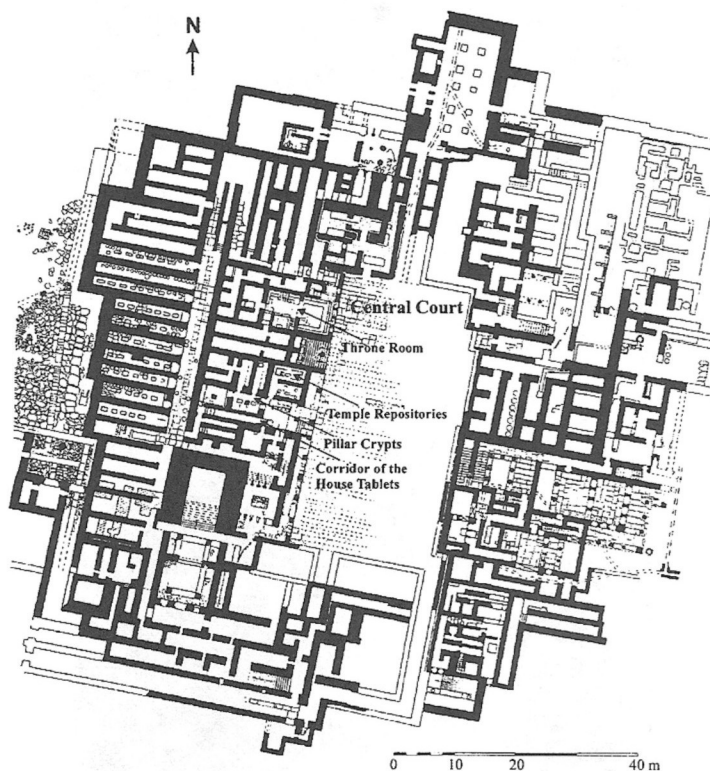


**Figure 8.** The measured azimuths of the walls on the Minoan peak sanctuaries at Petsophas and Traostalos can be found on the vertical axis. The corresponding optimal years for observations of the heliacal rising and setting and the acronychal rising and cosmical setting of Arcturus can be found on the horizontal axis from the computed lines. For every wall there are two possible optimal years, but only the identifications which give the smallest deviations are accepted and the corresponding years have been presented with their mean errors.

distance to the ridge is about 775 meters. The palace lies on a hill which had been the site of a village from about 8000. The village grew continually and about 2000 the entire summit was levelled for the construction of the first palace. There is nothing in the terrain itself which constrains the present orientation of the building.



**Figure 9.** Knossos Area. Courtesy authors of The Aerial Atlas of Ancient Crete.



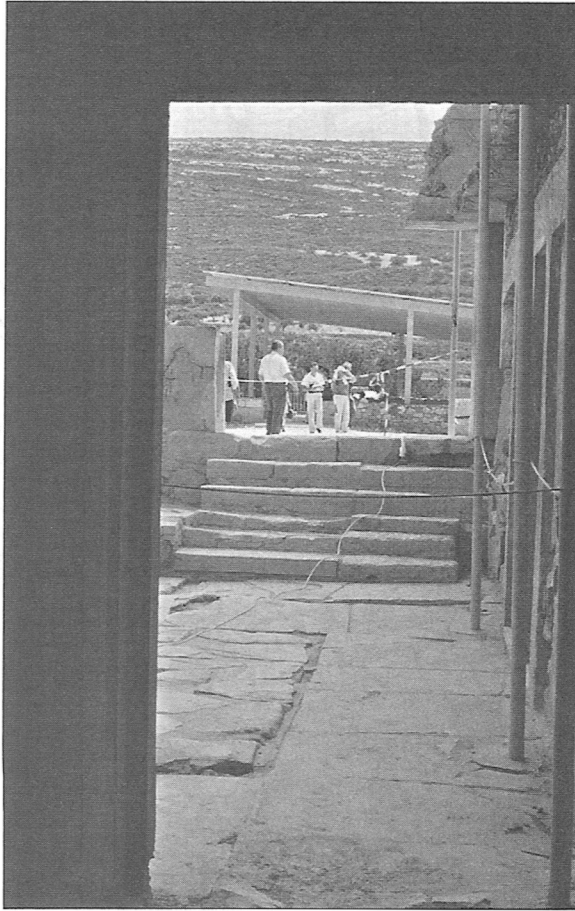
**Figure 10.** The palace at Knossos. Courtesy authors of *The Aerial Atlas of Ancient Crete*.

The longer axis of the Central Court is 10.4' east of north, for the western facade (Figure 10). In the west wing lay the most important cult rooms—the throne room, the pillar crypts, and the temple repositories—with doors opening towards the east. The floor level here was retained throughout the 700-year life of the palace and has resulted in a difference of about a meter up to the Central Court of the last phase of the palace (Figure 11).

In the Central Sanctuary Area of the palace lies the Corridor of the House Tablets from which we see the top of the Ailias ridge (Figure 11). The orientation of the Corridor to the rising sun, as it appeared above the Ailias ridge on the morning of the equinoxes from a point near the middle of an unusual concave stone just to the north of the door in the southern wall of the Corridor (Figures 12 & 13), is valid if four conditions obtained:

1. the floor level of the Corridor was about the same as it is today,
2. the wing opposite had no more than two stories,
3. there was a structure such as a doorjamb or pillar at point A (Figure 13),
4. the height of the Corridor's eastern door was not much less than 2.0 meters (about the equivalent of six Minoan feet, according to the different estimations which have been made). There is no archaeological evidence against these conditions.

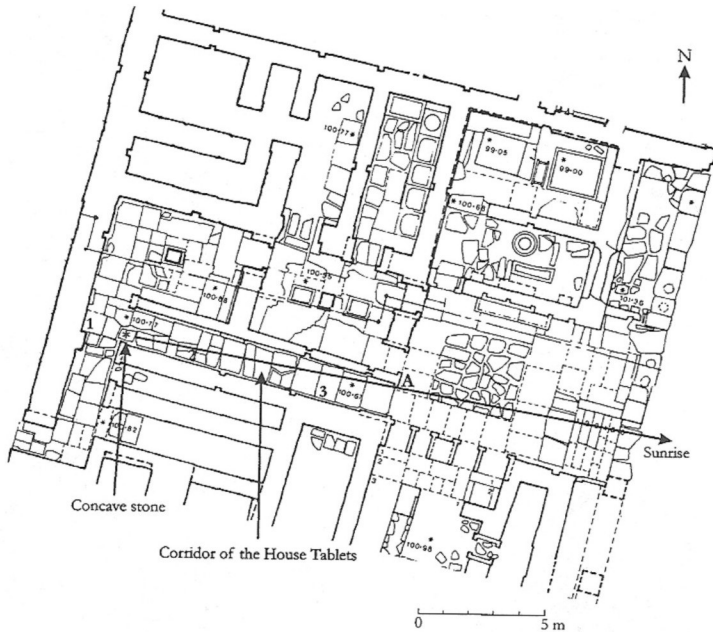
On the morning of the autumn equinox, the rays of the sun would have illuminated the southern half of the concave stone. The stone is in situ and the question is whether or not it is the remnant of an installation of some kind which existed in



**Figure 11.** Eastern doorway of the Corridor of the House Tablets with the Ailias ridge in the background.

the Minoan period to heighten the effect of the sun's rays. The sun never reaches further into the Corridor. If liquid is placed in the stone, a small distinct reflection is cast in the southwest corner of the Corridor at the moment of sunrise on the equinoxes (Figure 14). At sunrise close to the equinoxes the upper limit of the shadow on the southern wall will touch the top of the middle double axe in the southern wall, however this may be fortuitous (Figures 14 & 15).

The sun illuminates the concave stone for the last time eleven days following the autumn equinox (Figure 13). Since this is the difference between the solar year and twelve synodic months, the phase of the moon eleven days following the autumn equinox will be same as at the next autumn equinox, when the sun will reappear at the upper north-eastern corner of the door, as seen from the stone. Using a similar rule of thumb as described above for Petsophas, the Knossians would have known when to intercalate a month: 'when the new moon appears in the evening on any of the II days following the autumn equinox, it signals the beginning of the intercalary month'. These appearances of the sun will be similar but reversed at the spring equinox and not useful for predicting the phase of the moon at the following spring equinox.

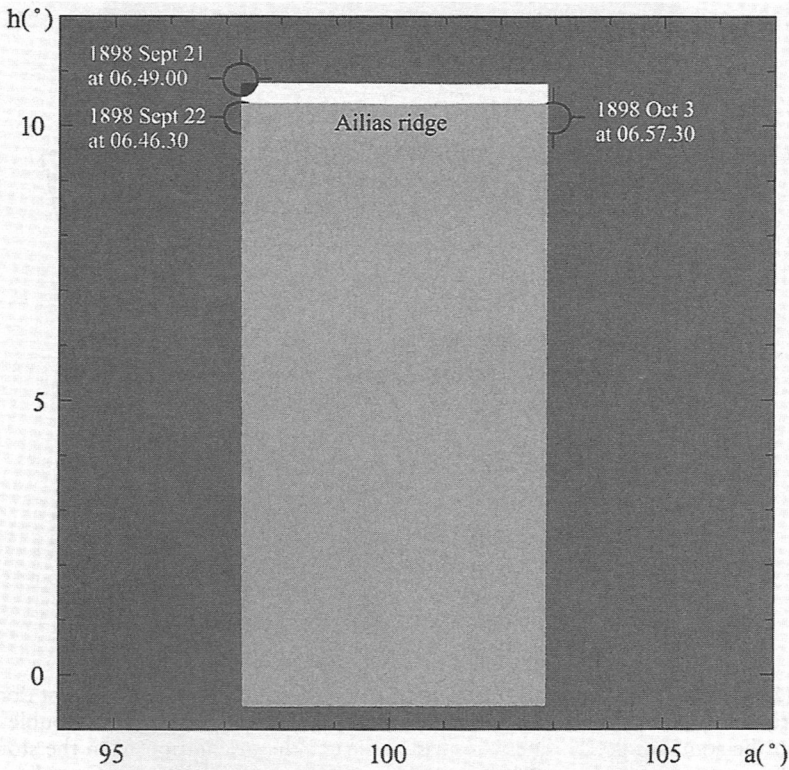


**Figure 12.** Central Sanctuary Area of the palace at Knossos. A: frame to the east doorway of the Corridor of the House Tablets; \*: concave stone; 1-3: positions of the double axes engraved in the south wall. The line to sunrise indicates the orientation from the stone to the sun on the morning of the equinoxes. Orientation of the south wall of the Corridor =  $102.6^\circ$ . Courtesy S. Hood and W. Taylor, reproduced with permission of the British School at Athens.

We think it likely, therefore, that the autumn equinox was the object for the orientation of the Corridor and we conclude that the general orientation of the palace was the result of the need for a reliable method for determining the day of the autumn equinox, showing when it was time to intercalate a month, and predicting the phase of the moon for calendaric and religious purposes. This implies that the Minoans were using a lunisolar calendar, as did their successors the Mycenaeans and the Greeks, and that their year began in the Bronze Age at the first crescent moon following the autumn equinox, as it did in Crete also in the Hellenistic period (Guarducci 1945).

## Zakros

At Zakros the western side of the palace's central court is oriented  $37.6^\circ$  east of north (Figures 16 & 17). It was earlier observed that the direction at right angles to the major axis of the court was close to the direction of moonrise at the southern major standstill (Shaw 1977). We have independently reached the same conclusion, but specifically with respect to the northernmost corridor of the west wing and the cliff opposite (Figures 17 & 18). The corridor adjoins the religious areas of the palace, as was the case with the Corridor of the House Tablets at Knossos. The distance to the cliff is about 710 meters. The first palace at Zakros, like the one at

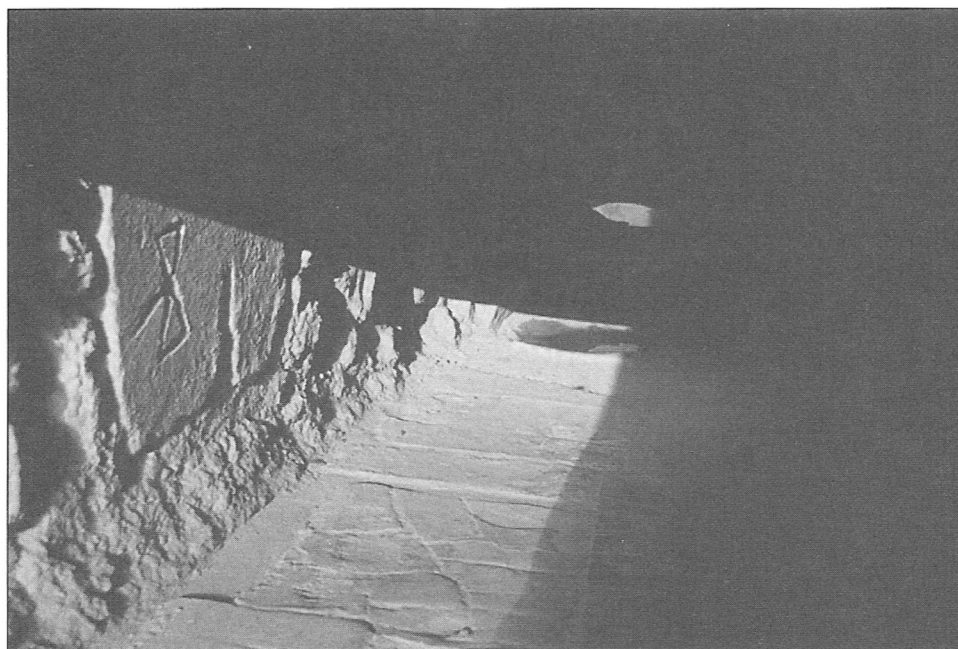


**Figure 13.** At the upper left the sun as it appeared from the concave stone in the Corridor of the House Tablets at the autumn equinox 1898; all dates B.C.E. At the upper right the sun eleven days after the autumn equinox. Based on measurements made with the digital laser theodolite SOKKIA SET 4C, which gives an error of only a few millimetres. The orientation error is less than 1/100 of a degree. Such exact measurements reduce the likelihood that we introduce errors into the results.

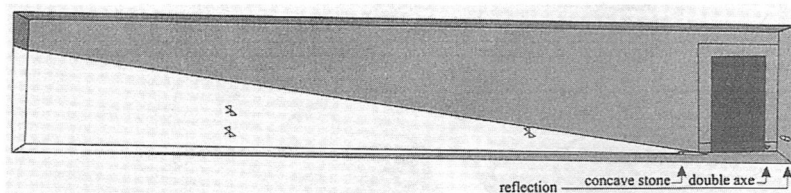
Knossos, was built early in the Middle Bronze Age. Also here, as at Knossos, the location does not inhibit the orientation of the palace.

From the corridor the cliff can have been used as a foresight for observation of moonrise at the southern major standstill. This observation would have been especially impressive in the case of the full moon at the summer solstice when the moon would have followed the contour of the hill as it climbed into the evening sky (Figure 19). The traces of an older foundation course along the southern wall of the corridor may be evidence that this was the exterior wall of the building at some earlier period. At a later rebuilding, the view to the cliff may have remained visible through the door to the open court opposite (Figure 20).

We have found that the orientation of the corridor (126.5' east of north) is very close to the azimuth for the northern edge of the cliff, which is very near the azimuth to the southernmost point for the upper limb of the full moon at the summer solstice at the beginning of the Middle Bronze Age (126.27). The moon no longer rises so far south due to the change in the inclination of the earth's axis.



**Figure 14.** The rays of the sun reach the concave stone in the Corridor of the House Tablets at the moment of sunrise on the autumn equinox. The shadow touches the top edge of the double axe inscribed in the southern wall of the Corridor.

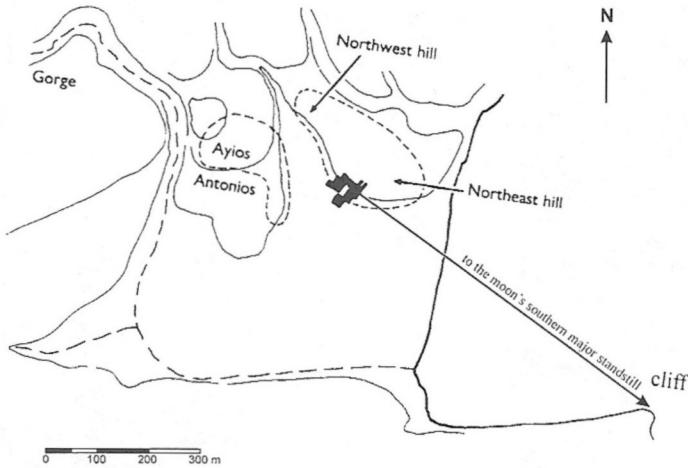


**Figure 15.** Drawing of the effects of the sun at sunrise in the Corridor of the House Tablets at the equinoxes. By Allan Klynne.

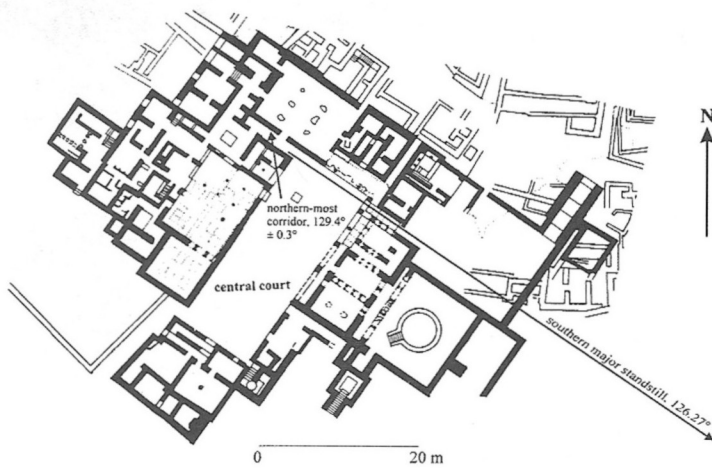
We propose that the orientation of the palace and its position on the plain was the result of the wish to know when the moon had reached its southern-most point, most probably for religious rather than calendaric reasons.

## Conclusions

Minoan astronomical observations were nearly contemporary with those of other Bronze Age cultures in the lands around the Mediterranean-Europe, the Near East, and Egypt. It is likely that there was exchange of astronomical ideas and information among these cultures just as there is documented exchange of raw materials and manufactured products. Nevertheless all four areas maintained their own cultural



**Figure 16.** The area of the palace at Zakros. Courtesy authors of *The Aerial Atlas of Ancient Crete*. The original has been modified to include the cliff.



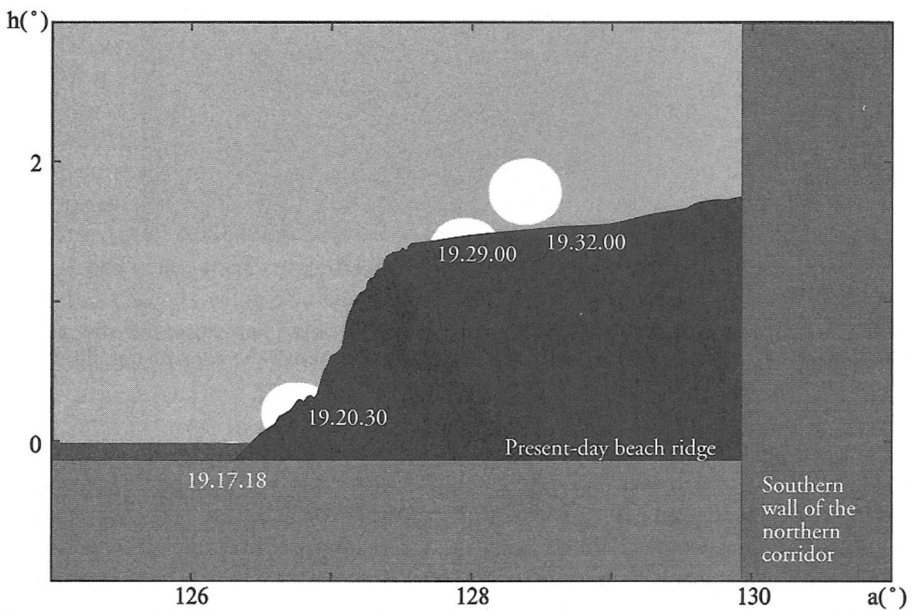
**Figure 17.** The palace at Zakros. Courtesy authors of *The Aerial Atlas of Ancient Crete*.

identities and these are reflected in all aspects of their respective societies—their art, architecture, religion, leadership and, not least, their astronomy. There is no good support at present to justify the view that any one of these cultures was the innovator or leader in astronomy. Astronomical orientation in the British Isles may be older than those elsewhere (North 1994), but this is likely to be a logical consequence of local incentives playing on natural human curiosity and intelligence and, therefore, not at all unlikely to occur independently in other areas and periods. The evidence we have indicates centuries-long development of astronomy for specific purposes in different cultural areas. We support a model of astronomical development in early societies being based primarily on culture-specific factors in the societies. This does not rule out the possibility of influence coming in as a result of exchange with other peoples.

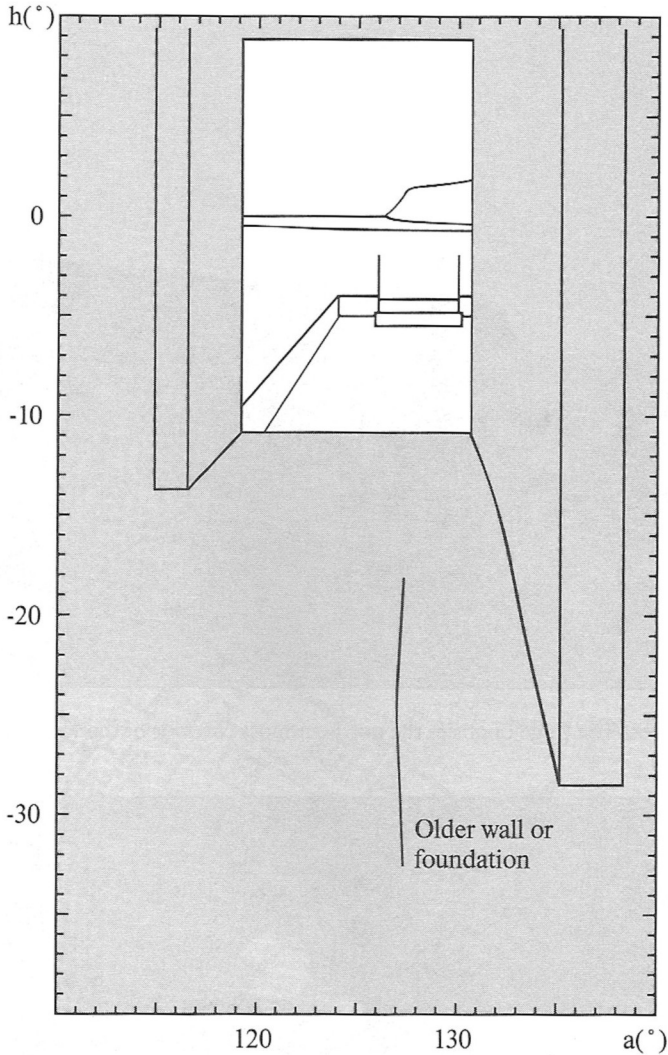




**Figure 18.** Zakros. The ridge opposite the northern-most corridor of the west wing.



**Figure 19.** The extreme southern rising of the full moon at the summer solstice 2034 June 23 B.C.E. from the northern-most corridor of the west wing of the palace at Zakros. The time is mean solar time.



**Figure 20.** The view from a position 20 cm from the south-western corner of the northernmost corridor of the palace at Zakros. Eye level is 160 cm above the present-day floor.

We conclude that, at least in part, later Greek astronomy was based on the accumulated astronomical knowledge of the Minoans which had been conveyed to them via the Mycenaeans. This is made the more feasible by the fact that other traditions and achievements from Bronze Age Crete survived in later Greece. There is nothing inherently implausible in such a course of events, as it is clear that ancient astronomical traditions survived for many centuries in the Near East and in Egypt.

The long tradition of Greek didactic poetry (e.g. Hesiod, ca. 7th cen.; Aratos, 3rd cen.) has been argued to be the later stages of an even longer oral tradition which facilitated the preservation of practical knowledge. We think it likely that the conservative character of tradition, likely to have been especially strong where the sacred heavenly bodies were concerned, would have been a strong contributing

factor in the preservation of Minoan astronomical knowledge. We submit that our findings have significance for the history of both Greek astronomy and religion.

As evidence in the case of astronomy we argue that the Minoans and the later Greeks were using observations of celestial bodies for two specific and similar purposes:

1. The risings and settings of the bright star Arcturus were being used to indicate dates of practical importance, e. g. to mark the limits of the sailing season and the time to intercalate a month in a lunisolar calendar for the Minoans and the time of the year for pruning the grapevines and for recording historical events for the Greeks. The risings and settings of Arcturus continued to be important for farmers, historians, and probably the general population, from Hesiod (ca. 7th cen.) down into Roman times. Thucydides (5th cen.), for example, placed historical events in the year by relating them to the positions of Arcturus. This implies that his readers would have understood the references. There are many instances in Greek literature of a similar use of other stars.

2. The major positions of the sun and the moon were used to maintain a lunisolar calendar. There is evidence that such a calendar was also being used by the Mycenaean, suggesting that they were the intermediaries through whom the astronomical knowledge of the Minoans was conveyed to the Greeks (Blomberg & Henriksson 1996). It is well-known that the Greeks of the historical period used a lunisolar calendar and that their religious observances occurred on specific days of specific months. We know also that it was of great importance that these celebrations occur in the proper seasons (Geminos, 0 cen.). Regular use of both the eight-year cycle and the nineteen-year cycle for the sun and moon were used at earlier dates in Greece than elsewhere in the Mediterranean area, although the Babylonians were using the nineteen-year cycle shortly after the traditional date of its introduction at Athens (Geminos, 0 cen.). There is no evidence of a lunisolar calendar of the same type as that of the Greeks in any other contemporary area.

These similar practical uses of the heavenly bodies in the same geographical area by cultures which succeeded one another, and each of which clearly admired and borrowed from its predecessor, implies a continuous astronomical tradition. In other words the history of Greek astronomy can be extended to include a chapter on local origins in the Bronze Age Aegean, notably in Minoan Crete.

In the case of religion, we add the results from Zakros to our earlier evidence for a Minoan goddess in some way associated with the moon (Blomberg & Henriksson 1996). The orientation to the southern major standstill strengthens the arguments for Mycenaean and Minoan religious interest in the moon on Crete. Such interest in the moon has also been indicated by the results obtained in the study of the more than 220 Late Bronze Age graves at Armenoi in central Crete, as the orientations of all but possibly one lie within the major standstills (Papathanassiou, Hoskin, & Papadopoulou 1992, 1993; Hoskin & Papathanassiou 1996).

Both the origins of Greek religion and Greek belief in the divinity of the sun, moon and stars are relevant for the question of continuity from the earlier periods to historical times, a question of great current interest. Many articles have been written on the Bronze Age origins of Greek religion and books on the subject regularly have a chapter on this aspect (e. g. Nilsson 1950; Burkert 1985). Most scholars recognise that the celestial bodies were in some sense divine for the Greeks, but the origin and character of this divinity are not well understood.

The gaps in our knowledge of early Greek religion are largely due to the fact that the sources for its study from the Mycenaean and Minoan periods are mainly symbols of debatable meaning on small objects of various kinds and therefore not easily interpreted. The symbols in Minoan art which seem more or less clearly to refer to the heavenly bodies have been collected by Goodison (1989), who interprets them largely as referring to the sun. Many of them could refer, instead, to a star or to the moon. We know very little of the Minoan conventions for representation in some branches of art. Therefore any additions to our knowledge of religion in the Bronze Age Aegean are very valuable. The evidence for a Minoan goddess associated with the moon, for example, when compared with the later associations of the Greek Artemis with the moon and the fact that Artemis may be one of the divinities mentioned in the Linear B tablets (Ventris & Chadwick 1973), strengthen the arguments for continuity in Greek religion from the Bronze Age.

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