



THE EVIDENCE FROM KNOSSOS ON THE MINOAN CALENDAR

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ABSTRACT

From the early results of our archaeoastronomical investigations at the peak sanctuaries on Petsophas and Mt Juktas, we inferred that the Minoans had a lunisolar calendar that began at a particular phase of the moon on or following the autumn equinox. We used classical archaeoastronomical methods: a digital theodolite with observations of the sun to determine the orientation of the coordinate system, measuring the orientations of foundations to celestial bodies, and determining the positions of celestial bodies at the appropriate times in the past using our own programs. In our later investigation of the palace at Knossos, we found further evidence including the impressive use of a reflection in the central palace sanctuary to determine the beginning of the Minoan year and for knowing when to intercalate a lunar (synodic) month in the lunisolar calendar. The reflection occurred at the precise moment of sunrise at the equinoxes and also during the eleven days before the spring equinox and after the autumn equinox. We also discovered that the non-integral length of the solar year would have been revealed by the unique shift of the reflection during a series of four years. Later results at three other Minoan sites underscored the probability that the Minoans had a solar calendar and twelve solar months.

KEYWORDS: Archaeoastronomy, double axe, Minoan astronomy, lunisolar year, Orion, solar year

INTRODUCTION

In our archaeoastronomical investigation of the peak sanctuaries on Petsophas (Henriksson and Blomberg 1996, Blomberg and Henriksson 1996, Blomberg 2006) and Mt Juktas (Blomberg, Henriksson and Papathanassiou 2002), we found good evidence for a lunisolar calendar that began in connection with the autumn equinox. Here we present evidence found at the palace at Knossos showing that a reflection could be used to mark the morning of the equinoxes and also the eleventh morning after the autumn equinox. It seems also possible that the reflection could have been used to regulate a solar calendar based on the tropical year of the sun, i.e., from one autumn equinox to the other. This evidence supports our findings from Petsophas and Mt Juktas and, in addition, may indicate that the Minoans had a solar calendar with 365 days and that every fourth year they added one day to keep the beginning of solar years at the autumn equinox.

The palace is of central importance for the discovery of such evidence. It was by far the largest and grandest building in the island and had deep influence on Minoan culture. It was inhabited for hundreds of years, but despite many alterations due to a number of destructions and reconstructions, in addition to the usual repair and renovation required by long usage, the evidence could be discovered due to the careful excavations and publications now available to us from over a century of study. An entry into the vast literature on the site can be found in the *Festschrift* dedicated to Sinclair Hood, director of the excavations for many years (Evely, Hughes-Brock and Momigliano 1994), and in the volumes of the *Annual of the British School at Athens* from 1900 and afterwards.

The development of lunisolar and solar calendars implies a long history of systematic observations of the motions of the celestial bodies. We can see from the written records of Mesopotamia and Egypt that astronomy had an important role in those cultures by the early Bronze Age (3rd millennium BCE). They had calendars (Cohen 1993; Claggett 1995), and navigation, with its dependence on knowledge of the posi-

tions of the stars, was underway in these cultures by the Early Bronze Age (Wachsmann 1998).

It is unfortunate that such records have not survived from Crete, but we can assume a similar interest there. There are star-like decorative objects on many seals, which, however, are not differentiated as to star, sun, moon or planet (Goodison 1989). There are also sailing boats on seals from the Early Bronze Age, giving evidence that Minoans were navigating in the Mediterranean by that time (Betts 1973; Blomberg and Henriksson 1999). Another source of information about Minoan astronomy is our discovery that the Minoans were making exact orientations of important buildings to major celestial events, such as sunrise and sunset at the equinoxes and solstices, from the beginning of the Middle Bronze Age (ca 2000 BCE). Thus it is likely that they had considerable knowledge of the motions of the celestial bodies much earlier.

The debated dates of the Greek constellations arising from descriptions in Aratos not being of his time has indicated to us that he was, in part, following a very long tradition dating from as long ago as 2000 BCE, and that changes were made as the changed position of important stars due to precession compromised their use in a calendar and for navigation (Henriksson and Blomberg 2002). It has been assumed that there was a Minoan tradition passed down by the Mycenaeans. We may have here an argument for a derivation of some of the Greek constellations from Minoan predecessors. Aratos's descriptions give us some idea of the stars in some of the constellations, but not the earlier names of those constellations. The lack of Minoan written records or art with recognizable astronomical content makes it difficult to find any support in this important question.

ARCHAEOLOGICAL SUMMARY

The old palace was constructed above a settlement that had been inhabited continuously from the second half of the 8th millennium BCE (J.D. Evans 1994). The part of the west wing where the temple repositories and the pillar crypts were found is known as the central pal-

ace sanctuary and may well have been the most important religious area of the building (Fig. 1).

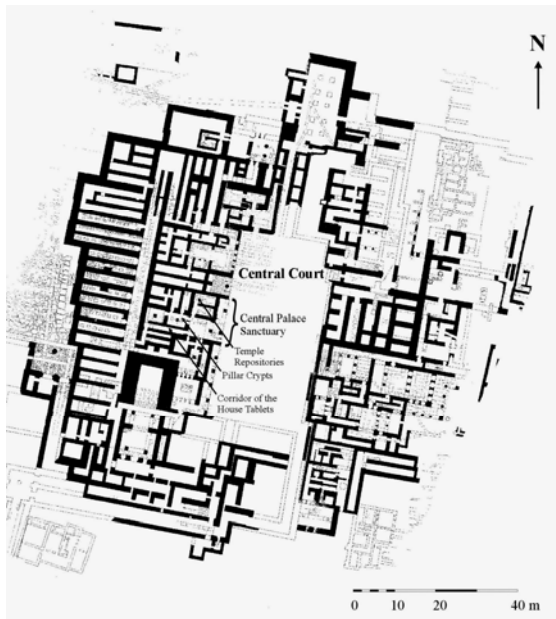


Fig. 1. Plan of the palace at Knossos (Myers, Myers and Cadogan 1992, with permission).

Quite naturally, the sanctuary became a focus for our attention. Its excavation history has been thoroughly analysed by Marina Panagiotaki (1999). Below the west wing there had existed a previous "palace" with the same orientation, built in the Early Minoan III period (2200-2000 BCE).¹ Most traces of this early building seem to have been removed when the Old Palace was built in MMIB (1910-1875 BCE) (Catling 1973-1974; Shaw 1977). The evidence of the vat room deposits indicates a destruction of the shrine in MMIB. All other test pits underneath the floors of the shrine seem to rest immediately on top of Neolithic or EMI-II deposits. The absolute chronology of this part of the Bronze Age in Crete is much disputed, but we accept the dating proposed by Manning, with the MMIB period ending about 1875 BCE (1995:217). The area was changed, for example by the Mycenaeans, who were in control of the island from about 1450 BCE, but the orientation of the original area of the central palace sanctuary seems not to have been changed (Driessen and Macdonald 1997).

¹ We are grateful to Sinclair Hood for showing us a remaining wall from this building.

When first excavated, there was a corridor south of the pillar crypts and a door in the southwest corner leading to the famous storage rooms to the west. The corridor is known as the corridor of the house tablets because of the house-like sign on the Linear B tablets found in it. A conspicuous but much worn alabaster concave stone lies near the door (Fig. 2).

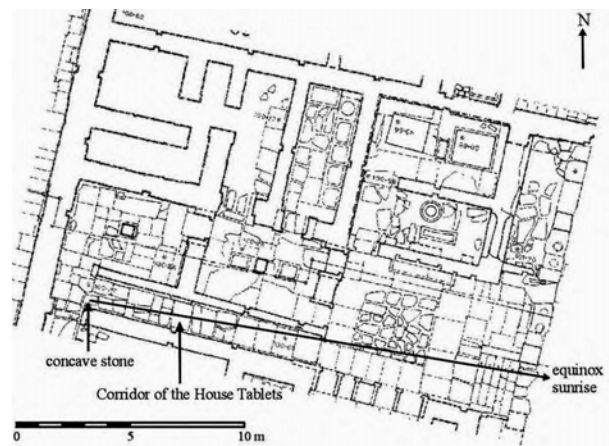


Fig. 2. The central palace sanctuary as excavated (Hood and Taylor 1981, with permission).

All of the other paving stones are flat, but the edges of this stone rise a few centimetres above the floor level to form a bowl (Fig. 3).



Fig. 3. The concave stone in the corridor of the house tablets. Photo Göran Henriksson 1996.

Preliminary measurements in 1992 using a magnetic compass and estimating the altitude of the Ailias Ridge opposite indicated to us that there might have been an orientation to sunrise at the equinoxes from the bowl. This suggested the use of the bowl filled with liquid to reflect the rays of the sun, as it was known to ancient astronomers that looking directly at the sun was dangerous to eyesight (Plato 1914: 343 (99D)).

The reconstruction of the sanctuary as it was originally is the result of a careful archaeological study made in the 1980's (Driessen 1990).

The corridor of the house tablets did not exist from the beginning; the area was then an integral part of the sanctuary (Fig. 4).

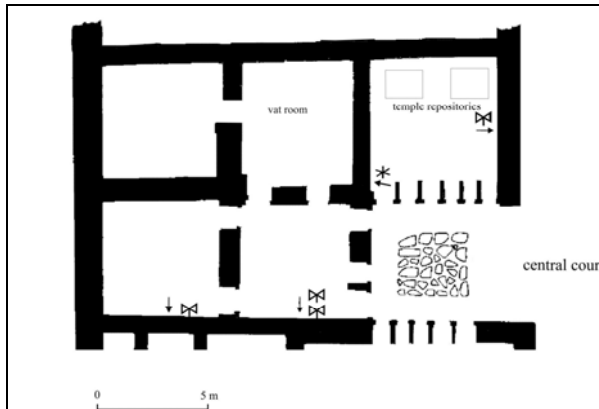


Fig. 4. Reconstruction of the original central palace sanctuary (Driessen 1990, with permission).

There was no door in the southwestern corner, as a double axe inscribed in the wall near the floor was partially destroyed when the door was cut through (Fig. 8). Thus the bowl had been placed in one of the darkest corners of the room. The floor level of the sanctuary was retained down through the centuries, whereas the level of the central court rose about 0.8 m.

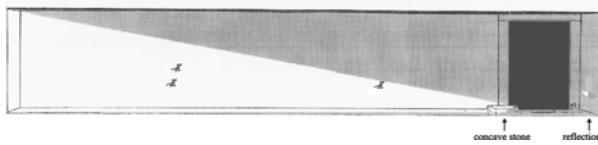


Fig. 8. Drawing of the relationships in the corridor of the house tablets at the equinoxes. By Allan Klynnne.

METHOD

We measured the relevant details of the walls, floor, and doorway of the sanctuary and of the Ailias Ridge opposite with a digital theodolite. The distance to points on the horizon of the ridge were measured by the parallax method from two distant points in the central court and these coordinates were transformed to a common coordinate system with origin in the middle of the bowl. We also made a thorough study of the excavation reports in order to make a correct reconstruction of missing parts of the palace, such as the façade of the eastern wing opposite the sanctuary.

The Ailias Ridge, which lies about 775 m to the east and is ca 142 m above the central court,

stretches north-south with an even horizon for some hundred meters opposite the southern door of the sanctuary (Fig. 5).

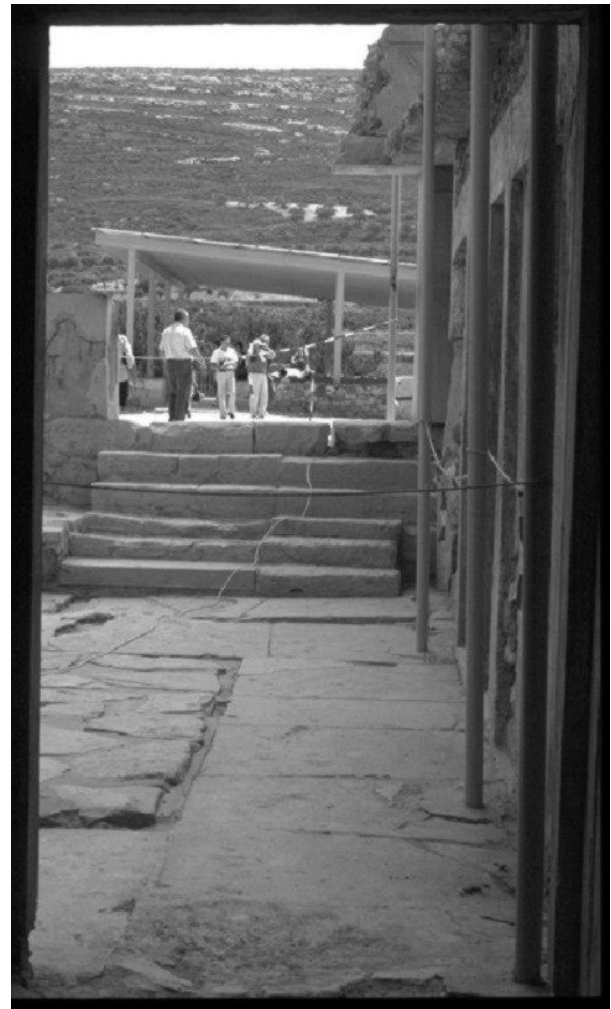


Fig. 5. The Ailias Ridge in the east opposite the corridor of the house tablets. Photo Göran Henriksson 1993.

The lower part of the doorway is original and, although the original height is not known, it is unlikely that it was so low that it blocked the path of the rays of the sun at sunrise. We have reconstructed it in our drawings on the basis of the Minoan foot peculiar to Knossos (Preziosi 1983: 483-93), using a width-height ratio of 1:2, which gives a door height of 7 Minoan feet (= 2.1 m.).

The east wing opposite had no more than one level above the central court (A. Evans 1921: 325-42; Graham 1987: 180-89). Even had there been a covered terrace on the roof of that wing, it would not have been in the way of the rays of the sun at sunrise (Fig. 6).

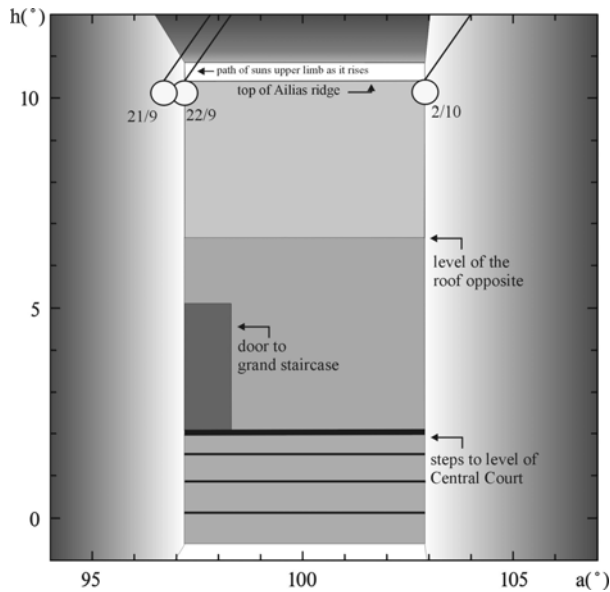


Fig. 6. The calculated height of the east wing opposite the corridor of the house tablets. Also the position of the upper limb of the sun on the equinoxes and 11 days after the autumn equinox as it was on 1944 BCE.

THE ORIENTATIONS

Using a digital theodolite we measured the orientation of the corridor from the southern wall, which is $101.5^\circ \pm 0.2^\circ$. The deviation from due east was no doubt occasioned by the height of the Ailias Ridge, behind which the sun rises. We measured the alignment from the middle of the concave bowl to the intersection of the Ailias Ridge with the northern side of the doorframe of the door leading into the corridor from the east. It is this alignment that is crucial for the reflection. The azimuth, measured from the centre of the bowl to the northeast part of the doorway where sunrise occurs on the equinoxes, is 97.2° . The altitude of the horizon, measured from the same place, is 10.4° . Using the computer programs developed by Henriks-son (2009), we found that on the morning of the equinoxes the upper limb of the sun will appear at this intersection just as it did in the Middle Bronze Age (Fig. 6). The sun is always on the equator at the equinoxes and therefore the position of the sun at sunrise at the equinoxes has not changed from the period in question until today. There is also no essential change in its position above the Ailias Ridge on the eleventh days after the equinox until today, but the appearances of the sun at sunrise as given on Fig. 6 is calculated as it was in 1944 BCE. This year

was chosen because on September 22 that year the declination of the sun was only -0.092° at the very moment when the first rays of the sun was reflected in the bowl and lit up the inner wall of the corridor of the house tablets.

In four consecutive years we filmed sunrise on the morning of the autumn equinox and also the reflection cast on the western wall of the corridor when the first rays of the sun struck the water-filled bowl. We noted that the shadow cast onto the southern wall of the corridor at sunrise just touches the uppermost tip of a double axe incised there (Figs. 7 and 8). Eleven days following the autumn equinox, the sun rises in line with the southern side of the doorframe and strikes the bowl for the last time until eleven days before the spring equinox (Fig. 6). On the days before the autumn equinox the rays of the sun do not reach the bowl at the moment of sunrise.



Fig. 7. On the morning of the equinoxes the rays of the sun strike the middle of the water-filled bowl, and a reflection occurs on the western wall of the sanctuary. At the same time the shadow on the southern wall just touches the tip of the double axe inscribed there.

Photo Mary Blomberg 1996.

The reflection becomes lenticular in shape as the sun rises higher and it reaches its largest size after about four to five minutes (Fig. 7). Its present irregular shape is due to the damaged condition of both the stone and the wall caused by the passage of time. On closer examination of the wall, we found to our surprise a lenticular depression of similar size exactly at the site of the reflection (Fig. 9). The lenticular shape was probably originally marked in some way on the stucco, which was the usual covering of Minoan walls. The corridor of the house tablets

seems to have been an alteration made by the Mycenaeans as a passageway into the storage rooms from the central court, and the worn condition of the concave stone was probably a consequence of this.

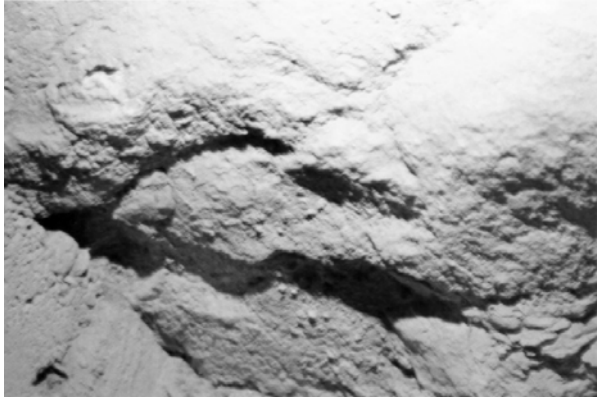


Fig. 9. Above: the lenticular-shaped depression at the site of the reflection, photo Göran Henriksson 1998. Below: the depression with reflection and the damaged double axe to the lower left, photo Mary Blomberg 1998.



At the peak sanctuary on Mt. Juktas, which lies about 15 kilometres southwest of Knossos, we had discovered orientations to equinoctial sunrise and to sunrise eleven days after the autumn equinox, both marked by natural foresights (Blomberg, Henriksson and Papathanassiou 2002). At the peak sanctuary on Petsophas, which is just above the Minoan town Palaikastro on the east coast of Crete, sunset at the equinoxes was marked by a natural foresight, the conical peak of Modi, and there are walls oriented to the heliacal rising and setting, in the Middle Bronze Age, of the bright star Arcturus. Its rising occurred one synodic month before the autumn equinox (Henriksson and Blomberg 1996). The parameters for calculating the visibility of bright stars close to the horizon at dawn and twilight

are from Bemporad (1904), Siedentopf (1941), Ljunghall (1949), and Schmidt (1865). It is important to use Schmidt's visibility calibrations for Athens from ca. 1850, as his observations were made before modern air pollution.

THE LUNISOLAR CALENDAR

The orientations on Mt. Juktas and Petsophas meant to us that the Minoans had a lunisolar calendar with the new year beginning at the first appearance of a specific phase of the moon, most probably the new crescent moon, following the autumn equinox, as we have explained in earlier publications (Henriksson and Blomberg 1996; Blomberg, Henriksson and Papathanassiou 2002). The orientations at Knossos reinforced this hypothesis. Equinox morning is marked there by both a shadow and a reflection, and the eleventh day following the autumn equinox, the last day on which the reflection occurs, is caused by the width of the door (Fig. 6). This arrangement would have provided the Minoans with a simple method for adjusting their lunisolar calendar to the solar year by intercalating a lunar month at the proper intervals. For example, when the new crescent moon appears in the eleven-day interval, it is time to add a lunar month of 29 or 30 days to the year (Blomberg, Henriksson and Papathanassiou 2002).

Also, the phase of the moon on the eleventh day is the same as on the day of the next autumn equinox, a fact which could have been important, for example in the planning of the new year celebration on the following year. The additional lunar month was generally inserted three times in eight years and seven times in nineteen years resulting in a nearly even number of lunar months and tropical solar years.

Since our preliminary publication of the arrangement at Knossos, we have found that our constellation Orion could have played an important part in connection with the Minoan new year at the autumn equinox. In the Middle Bronze Age it dominated the southeastern sky at Knossos in the evening on the autumn equinox and would have done so for a very long time.

If a line is drawn connecting the easternmost star in Orion's belt (ζ Orionis) and Sirius, then the figure formed and the inclination of the han-

dle is very like that of the double axe touched by the shadow on the southern wall of the corridor (Figs. 7 and 10). The double axe seems to have been the most important Minoan symbol. There are large numbers of them carved into the walls and pillars of the central palace sanctuary and they occur in other parts of the palace, in other Minoan buildings, and on objects of all kinds. The similarity of the constellation with the Minoan double axe is very suggestive.

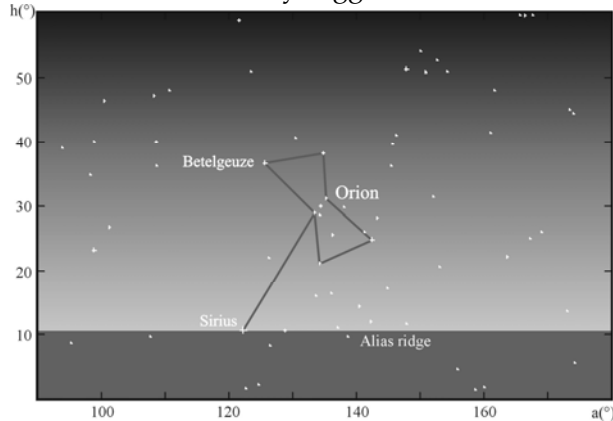


Fig. 10. Our proposed Minoan constellation of the double axe. In the centuries around 2000 BCE, Sirius was first visible above the Ailias Ridge around midnight on the autumn equinox, and the constellation would have dominated the southeastern sky. The calculation has been made for 21 September 2000 BCE, when Sirius appeared at 23:38 local mean solar time at Knossos.

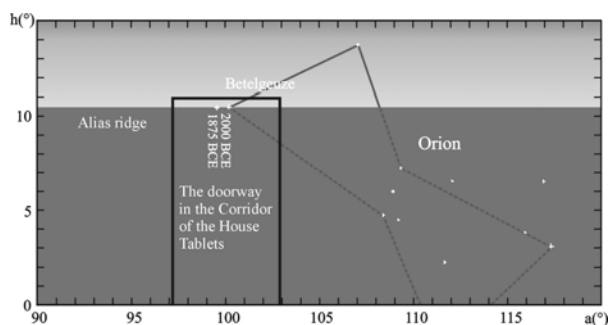


Fig. 11. In the centuries around 2000 BCE, the bright star Betelgeuse appeared in the middle of the doorway of the corridor of the house tablets in the evening at the autumn equinox. The calculation has been made for 21 September 2000 BCE, when Betelgeuse appeared at 21:19 local mean solar time at Knossos. In 1875 BCE the declination of Betelgeuse was -2.14° (no north), well within the opening into the corridor.

The bright star Betelgeuse in Orion rose in the evening of the autumn equinox in the middle of the doorway of the corridor in the Middle Bronze Age, also over a very long period of time (Fig. 11).

The positions of the stars in the constellation have not changed to such an extent that the form of the constellation would not have been recognized as the double axe from the Early Bronze Age until today. In addition to the orientations on Mt Juktas, on Petsophas and at Knossos we have also the focus on bright stars and constellations to indicate that the autumn equinox was the more important for the Minoans, Orion here at Knossos, Arcturus at Petsophas (Henriksson and Blomberg 1996) and Canopus at Phaistos (Blomberg and Henriksson 2007).

THE SOLAR CALENDAR

The reflection differs in size from year to year due to the varying distance of the sun from the true equinox. In Fig. 12 we have the reflection as it was at 10 seconds after sunrise each year for four consecutive years. The reflection is larger the closer the sun is to the true equinox.



Fig. 12. The reflection cast 10 seconds after sunrise each year for the four consecutive years 1996-1999. The reflection is larger the closer the sun is to the true equinox. Photos Göran Henriksson.

The largest reflection in Fig. 12, the one in 1998, was made when the sun was two hours from the true equinox. The Minoans surely noticed this variation, and when counting the days from one autumn equinox to the next, they would also have noted that once every four years there was no reflection on the western wall at sunrise after 365 days. Instead, the reflection would have appeared in that year on

the 366th day since, as is common knowledge for us, the solar year does not consist of a whole number of days, but of approximately 365¼ days. This information from the reflections would have provided the information that a day should be added every fourth year to the solar year just as a lunar month should be added to the lunar year.

We have discovered additional evidence of the solar calendar in the orientations to the sun at sunrise at about 30-day intervals from the equinoxes at the palace of Malia and the villa of Vathypetro (Blomberg and Henriksson 2005), the two Minoan shrines at Gournia (Henriksson and Blomberg 2009), and the peak sanctuary at Modi (Henriksson and Blomberg in press). Their function in indicating the beginning of one of the twelve months of the solar year is simple and useful and may have been connected with a local festival. These orientations to the solar months, together with orientations to the equinoxes, and the winter and summer solstices give the first day of the month for ten of the twelve months in the solar year (Table 1).

Table 1. Minoan orientations to the first day of a month based on the cycle of the sun

SITE	Months
Petsophas, Phaistos, Knossos, Juktas, Vathypetro	first (autumn equinox)
Malia, Vathypetro	second
Modi	third
Chamaizi, Vathypetro	fourth (winter solstice)
Modi	fifth
Malia, Vathypetro	sixth
Petsophas, Phaistos, Knossos, Juktas, Vathypetro	seventh (spring equinox)
Gournia	eighth
Gonies, Petsophas, Pyrgos	tenth (summer solstice)
Gournia	twelfth

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This is an impressive result from 13 of the 15 so far evaluated Minoan buildings in our project (altogether there are 18). At Vathypetro, the orientations of the villa to the equinoxes, the second and seventh months and the winter solstice pointed out the first day of the first, second, fourth, sixth and seventh solar months of the year. At Petsophas the beginnings of the first, seventh and tenth months were pointed out.

CONCLUSIONS

The system of reflections at Knossos was an ingenious device that enabled the Minoans to regulate a calendar that reconciled the complex cycles of the moon and the sun. It gave a precise signal of the beginning of the year on the morning of the autumn equinox; the reflection on the eleventh day after that equinox provided the instrument to indicate the year in which a lunar month should be added to the lunar calendar; and the lack of a reflection on every fourth equinox morning (on the 365th day of every fourth year) indicated that a day should be added to the solar calendar.

Our pilot project to understand Minoan astronomy has shown that they had a broad knowledge of the motions of the celestial bodies that must have resulted from centuries of systematic observations. They had a sophisticated calendar that kept the motions of the sun and moon in synchrony, the only one that we know of in the Bronze Age Mediterranean area. We can also assume that they had deep knowledge of the motions of the stars necessary for navigation (Blomberg and Henriksson 1999).

We are hampered by the lack of written records to fill out this aspect of Minoan culture, but we find that the Minoans had constructed a cosmos with close relationship of their buildings and towns to celestial phenomena. We have found such relationships, sometimes several, of all the buildings that we have investigated.

work there. For efforts on our behalf we have been indebted to the late Berit Wells, former director, and also to Bodil Nordström, secretary, at the Swedish Institute in Athens.

We thank Allan Klynne for the drawing for Figure 8. For permission to publish material for our figures, we are grateful to J.W. Myers, E.E. Myers, and G. Cadogan (figure 1), S. Hood and W. Taylor (figure 2), J. Driessen (figure 4) and two anonymous referees.

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