Lunar alignments in Mesoamerican architecture

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Abstract
Systematic archaeoastronomical research recently conducted in several regions of Mesoamerica has revealed the existence of architectural orientations corresponding to major and minor extremes of the Moon (also known as standstill positions) on the horizon. Particularly indicative are the results of quantitative analyses of alignment data from the Maya Lowlands, disclosing a prominent group of orientations that can be convincingly related to the major lunar extremes. The astronomically-motivated intentionality of these alignments is additionally supported by contextual evidence, particularly significant being the fact that most of them are concentrated along the northeast coast of the Yucatán peninsula, where the lunar cult is known to have been important. Since the lunar orientations are regularly associated with those corresponding to the solstitial positions of the Sun, it is very likely that particular attention was paid to the full Moon extremes. This contribution also presents some independent evidence that sheds light on the cultural significance of lunar orientations.

KEYWORDS: Mesoamerica, archaeoastronomy, architecture, orientations, Moon, standstills

Introduction
Archaeoastronomical studies carried out in recent decades in different parts of Mesoamerica have shown that the orientations in civic and ceremonial architecture exhibit a clearly non-uniform distribution, i.e. concentrations around certain azimuthal values. The presence of such orientation groups at a number of sites spread far apart in space and time can only be explained with the use of astronomical objects on the horizon as reference objects (cf. Aveni & Hartung 1986: 7f). The prevailing orientation patterns indicate that most buildings were aligned to sunrises and sunsets on particular dates; some orientations to Venus extremes were also identified (e.g. Aveni 2001; Aveni & Hartung 1986; Aveni et al. 2003; Galindo 1994; 2009; Tichy 1991; Šprajc 1993a, 1996, 2001), whereas the relationship of alignments with other celestial bodies was much less certain. While it was observed that some buildings in the Maya area may have been oriented to the standstill positions of the Moon (Aveni & Hartung 1978, 1979; Sletteland 1985), only recent research in various parts of Mesoamerica has disclosed a considerable number of structures that can be reliably related to these phenomena (Sánchez & Šprajc 2015;

ANTHROPOLOGICAL NOTEBOOKS 22 (3): 61–85.
ISSN 1408-032X
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Sánchez et al. 2016; Šprajc & Sánchez 2015; Šprajc et al. 2016). The present contribution summarises the analyses that led to this conclusion and presents contextual data that elucidate the significance of lunar alignments.

Lunar standstills

If observed on consecutive days at the moment of rising or setting, the Moon moves along the horizon between its extreme northerly and southerly positions, taking one month to complete the circuit. However, since the Moon's orbit is inclined to that of the Earth (the ecliptic) at an angle of 5.145° (i), and because the lunar nodes, i.e. intersections of both orbits projected on the celestial sphere, move gradually along the ecliptic, completing the whole circle in 18.6 years, the extreme declinations[1] of the Moon differ from those reached by the Sun at the solstices by up to ±5.145°, exhibiting variations with the same periodicity. Considering an approximate value of ±23.5° for the obliquity of the ecliptic ε (inclination of the Earth's equator to the ecliptic), the extreme declinations of the Moon in an 18.6-year cycle vary between $\pm(\varepsilon + i)$ (ca. ±28.5°) and $\pm(\varepsilon - i)$ (ca. ±18.5°); the corresponding moments are known as major and minor lunar standstills, respectively, each of the two occurring at 18.6-year intervals. Consequently, at a major standstill the rising and setting Moon reaches its greatest extremes, i.e. the farthest northerly and southerly points on the horizon, while the smallest (innermost) extremes can be observed after 9.3 years (cf. Thom 1971: 15ff; Morrison 1980; Ruggles 1999: 36f, 60f; Aparicio et al. 2000: 32ff; González-García 2015).

The apparent motion of the Moon is quite complicated. Due to its relative proximity to the Earth, the positions of the Moon, as seen from the Earth, are affected by the parallax, which must be taken into account in calculating geocentric lunar declinations corresponding to alignments (Hawkins 1968: 51f; Thom 1971: 34; Ruggles 1999: 36f).[2] The exact values of standstill declinations of the Moon are subject to a number of parameters, which vary as a function of time. As already mentioned, the differences between the extreme declinations of the Moon and those reached by the Sun at the solstices can be up to about ±5.145°; however, due to secular variations of the obliquity of the ecliptic (cf. Ruggles 2015: 479f), the exact values of lunar standstill declinations also vary in time. Furthermore, the mean

[1] Whereas the azimuth is the angle measured in the horizontal plane clockwise from the North, having values from 0° to 360°, the declination is the celestial coordinate expressing the angular distance of a point projected on the imaginary celestial sphere from the celestial equator, which can be imagined as a projection of the Earth's equator on the celestial sphere. Declinations are measured perpendicularly to the celestial equator to the north and south, having values from 0° to ±90°. Possible astronomical referents of an alignment can only be identified by calculating the declination of the corresponding horizon point (considering its altitude above the horizon plane corrected for atmospheric refraction, the geographic latitude of the observation point, and the alignment's azimuth) and matching it with declination values given for celestial bodies in astronomical sources (ephemerides, star atlases, etc.).

[2] The declinations of the Moon given in astronomical ephemerides are geocentric (i.e. valid for an observer in the center of the Earth). For an observer on the Earth's surface, however, the apparent declination of the Moon is slightly different (unless the Moon is in zenith, which means that the observer is located exactly along the line connecting the Moon and the Earth's center). The difference between the two values (the parallax) thus depends on the position of the observer relative to the Earth's center and the Moon. For determining the parallax needed in our calculations of geocentric lunar declinations, the mean values of the Earth's radius and of its distance from the Moon have been considered, as well as the concrete horizon altitudes along the alignments.

value of the inclination of lunar orbit to the ecliptic (5.145°) exhibits periodic variations of up to ±0.15° or 9 arc minutes. Additionally, the parallax of the Moon, depending on its changing distance from the Earth, manifests periodic variations of a few arc minutes. Another factor to be considered is that (strictly speaking) a lunar standstill corresponds to the moment in which the nodes of the lunar orbit coincide with the equinoctial points on the ecliptic, but this instant rarely coincides with the extreme declination reached by the Moon in a month. Moreover, if we assume that the ancient observers paid particular attention to the Moon's northernmost and southernmost excursions on the horizon, it is important to consider that the moment the Moon attains its extreme declination only exceptionally coincides with the time of its rising or setting; due to its relatively fast movement with respect to the starry background (ca. 13° per day), its declination at the moment of rising or setting can differ by a few arc minutes from the maximum/minimum declination reached in that particular month. Likewise, the need to postpone observations because of unfavourable weather conditions can additionally contribute to errors in determining the northernmost or southernmost position of the Moon.

Owing to these and other variables, discussed by Ruggles (1999: 36f, 60f) and, in greater detail, by Morrison (1980), the extremes of the Moon determined through the observation of its risings and settings will tend to be smaller than those resulting from calculations based on the true standstill declinations. In other words, it can be expected that the declinations corresponding to the directions determined this way will be larger for southern standstills (negative declinations) and smaller for northern standstills (positive declinations); this is precisely what is observed in our data.

Orientations to major lunar extremes

The most compelling evidence for the existence of lunar orientations comes from the Maya area, whereas their occurrences elsewhere in Mesoamerica are rather sporadic. Figure 1 presents relative frequencies of declinations corresponding to the east-west azimuths of 305 architectural orientations measured at 106 sites in the Maya Lowlands (for detailed alignment data, see Sánchez & Šprajc 2015; Sánchez et al. 2016). To illustrate the difference between lunar declinations, which are, on average, about 0.37° greater than 'normal' declination values (calculated without taking into account lunar parallax and employed for determining other possible celestial referents of alignments), the distribution of both types of declinations is shown. To facilitate further references, the declinations marked on the eastern and western horizon are designated briefly as east and west declinations, respectively. For obtaining the curves, the method known as kernel density estimation (KDE) was employed, taking into consideration the errors assigned to each value on the basis of the present state of the buildings observed in the field and the estimated uncertainties regarding the originally intended azimuths. For the error assigned to each declination value, a normal distribution centred on the nominal value and with a standard deviation of the specified uncertainty was assumed, and all normal distributions were totaled to obtain the data for the curves (for details see Sánchez & Šprajc 2015: 49f). It can thus be expected that the most prominent peaks of the curves closely correspond to the values targeted by particular orientation groups.

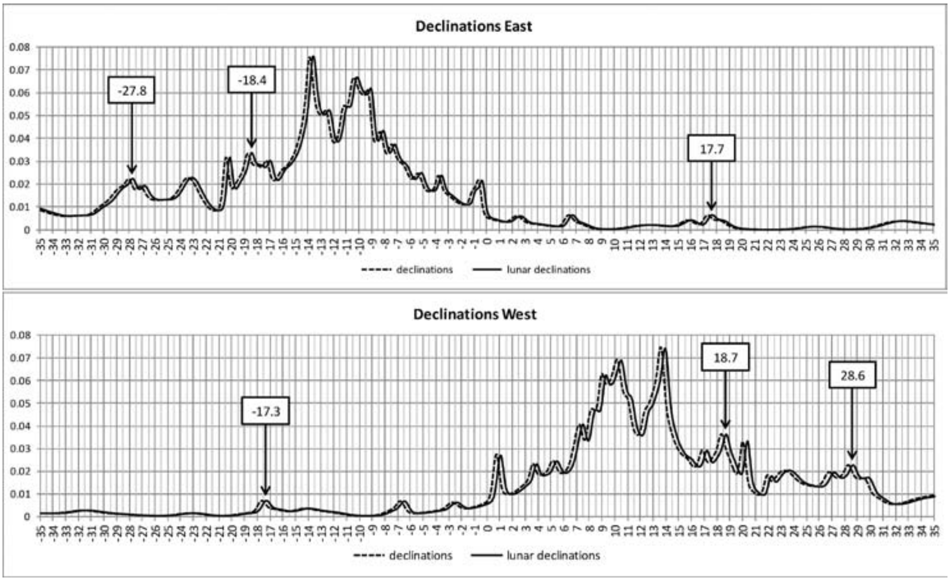

Figure 1: Relative frequency distribution of declinations corresponding to the east-west azimuths of orientations in the Maya Lowlands

Since most of the buildings that have been measured are skewed clockwise from cardinal directions, which is a prevalent characteristic of Mesoamerican architectural orientations, the east/west declinations are predominantly negative/positive. Most of the prominent declination peaks correspond to solar orientation groups, being related to particular sunrise and sunset dates (Sánchez & Šprajc 2015; Sánchez et al. 2016). In the curves presenting lunar declinations, however, the two peaks corresponding to declinations of -27.8° (east) and 28.6° (west) can be related to the major lunar standstills. The structures involved in the two orientation groups, which have been shown to be statistically significant (González-García & Šprajc 2016), date to the Classic and Postclassic periods. The chronological placement of these buildings is relevant because (as already mentioned) the maximum/minimum declinations of the Moon vary in time as a consequence of secular variations in the obliquity of the ecliptic ε. Since the values of ε around the beginning of the current era and around A.D. 1500 were 23.695° and 23.504°,[3] the major standstill declinations ($\varepsilon + i$) at the two epochs were 28.84° and 28.65°, respectively, their mean being 28.745°, very close to the peak among the western lunar declinations (28.6°), whereas the eastern peak (-27.8°) differs by 1° from the negative value of this mean (Figure 1). In both cases, the absolute values of declination peaks are smaller than the 'ideal' mean, as was to be expected in view of the observational complications mentioned above, but a better agreement with the western peak suggests

[3] The values of ε for certain past epochs can be found, for example, in Aveni (2001: 103) and Ruggles (2015: Table 31.3). For our purposes, the formula presented by Meeus (1991: 135) was employed.

that the orientations of this group in the Maya area were intended to record the *settings* of the Moon at its major *northern* standstills.

Because of the complexities of the apparent motion of the Moon and observational problems referred to above, we can assume that an alignment aiming at a standstill position on the horizon may be in error of up to ±0.5° relative to the exact standstill declination. In order to find the buildings that could have been oriented to major lunar standstills, the estimated errors of declinations calculated for the Moon and corresponding to the orientations that have been measured in Mesoamerica were, therefore, incremented by this value. Selecting the lunar declinations that, considering the range of these incremented errors, match the major standstill values given above and valid for the periods in which the structures were built, the orientations listed in Table 1 were obtained, where the declinations that (taking into account these criteria) may refer to major lunar standstills are written in bold characters. We can see that, in various cases, it is impossible to determine whether an orientation was functional to the east or the west.

Table 1: Orientations corresponding to the major lunar extremes; δ_E: declination east; δ_W: declination west; EC: Early Classic; LC: Late Classic; EPC: Early Postclassic; LPC: Late Postclassic

Site, structure	**Period**	**Lunar δ_E**	**Error δ_E**	**Lunar δ_W**	**Error δ_W**
Buena Vista (Quintana Roo, Mexico), Structure C18-1-a	LPC	**-27.353**	**1.5**	**27.647**	**1.5**
Cobá (Quintana Roo, Mexico), Xaibé	LC	**-29.898**	**2.5**	**30.202**	**2.5**
El Altar (Quintana Roo, Mexico), Structures III and IV	LPC	**-28.881**	**1.5**	**29.161**	**1.5**
Iglesia Vieja (Chiapas, Mexico), Structure B-1	EC	**-30.380**	2.5	31.364	2.5
Iglesia Vieja (Chiapas, Mexico), Structure B-3	EC	**-29.309**	**2.5**	**30.364**	**2.5**
Izamal (Yucatán, Mexico), Chaltunhá	EC/EPC	**-28.009**	**2.0**	**28.313**	**2.0**
La Campana (Colima, Mexico), Structure 2	EC-LC	-25.525	1.5	**27.834**	**1.5**
La Expedición (Quintana Roo, Mexico), Structures C25-1-a, 1-b, 1-c	LPC	**-29.025**	**1.5**	**29.326**	**1.5**
La Quemada (Zacatecas, Mexico), Plaza of the Sacrifices	LC	**-28.812**	**1.5**	31.412	1.5
Lagartero (Chiapas, Mexico), Mound 2	LC	-26.867	1.5	**28.691**	**1.5**
Nuevo Chetumal (Chiapas, Mexico), Structure 1	LC	33.685	3.0	**-29.235**	**2.5**
Paamul (Quintana Roo, Mexico), Two-Storey Temple	LPC	**-27.722**	**1.5**	**28.019**	**1.5**
Palenque (Chiapas, Mexico), Temple of the Cross	LC	-23.561	2.5	**28.569**	**1.5**
Recodo San Juan (Quintana Roo, Mexico), temple	LPC	**-28.685**	**2.5**	**28.936**	**2.5**
Sabana Piletas (Campeche, Mexico), Columnitas group, upper str.	LC	**-27.681**	**1.5**	**28.405**	**1.5**
San Gervasio (Quintana Roo, Mexico), El Ramonal group, Acropolis	EC	**-27.860**	**1.0**	**28.069**	**1.0**
Tancah (Quintana Roo, Mexico), Structure 12	EPC	**-27.464**	**1.5**	**27.693**	**1.5**
Tulum (Quintana Roo, Mexico), Structure 25	LPC	-27.700	**0.8**	**28.658**	**0.8**
Vega de la Peña (Veracruz, Mexico), Edificio del Dintel, southern part	EPC	**29.482**	**1.5**	-20.074	1.5
Xamanhá (Quintana Roo, Mexico), Structure C-1	LPC	**-27.450**	**2.5**	**27.755**	**2.5**
Xcalacoco (Quintana Roo, Mexico), Structure B-II	LPC	**-29.035**	**1.0**	**29.369**	**1.0**
Xcalacoco (Quintana Roo, Mexico), Structure B-IV	LPC	**-28.768**	**1.8**	**29.117**	**1.8**
Xcalumkín (Campeche, Mexico), North Hill Group, South Building	LC	**-28.429**	**1.0**	**29.621**	**1.0**
Xelhá (Quintana Roo, Mexico), Palace, northern part	EC-LC	**-28.294**	**1.0**	**28.525**	**1.0**
Xelhá (Quintana Roo, Mexico), Structure of the Pillars	EC-LC	**-29.697**	**1.5**	**29.932**	**1.5**
Yaxchilán (Chiapas, Mexico), Structure 40	LC	32.793	1.5	**-31.052**	**2.5**

It should be noted that some of the orientations given in Table 1, considering the estimated errors, might refer to the maximum extremes of Venus as an evening star (Šprajc 1993a, 1996, 2015). The existence of both lunar and Venus orientations in the Maya Lowlands is indicated by two distinct peaks in the distribution of declinations on the western horizon (Figure 1), the lower one (at 26.8°) corresponding to the maximum northerly extremes of Venus as evening star (the corresponding peak among the east declinations, -27.2°, cannot be related to the morning star extremes, due to the asymmetry of Venus extremes visible on the eastern and western horizon: Šprajc 1993a: 20f, 1996: 33ff, 2015). Due to the small difference between the extreme declinations reached by Venus and the Moon, and considering the errors estimated for individual alignment data, it is often impossible to reliably establish the intended celestial referent of a particular orientation; for the alignments discussed below, however, a lunar interpretation is particularly likely in the light of contextual data.

At Sabana Piletas and Xcalumkín, Campeche, Mexico, stone sculptures of a seated anthropomorphic figure known as *la vieja* (or *xnuc*, in Yucatec Maya) were found (Benavides 2010: 31, Fig. 15; Benavides & Novelo 2015: 67f); if these images represent the old Moon goddess, as one can surmise (cf. Milbrath 1999: 141ff; Benavides n.d.), the cult of this deity would have been consistent with the presence of lunar orientations at both sites (Table 1).

The idea that one group of orientations in the Maya architecture marked the major lunar standstills of the Moon is most convincingly supported by the fact that the main concentration of these orientations has been found on the north-eastern coast of the Yucatan peninsula, i.e. in the area where the worship of the goddess Ixchel is known to have been crucial during the Postclassic period (Sánchez & Šprajc 2015: 62ff; Sánchez et al. 2016). It is a rather common opinion that Ixchel, associated at the time of the Conquest with pregnancy, childbirth, medicine, divination and weaving (Thompson 1939: 166; Tozzer 1941: 9f, 129f, 154; Cruz 2005), was the Maya goddess of the Moon, identical to Goddess I, which in codices appears associated with weaving. Taube (1992: 64ff, 99ff), however, argues that there is little evidence allowing the relation of Goddess I to the Moon and that Ixchel corresponds rather to Goddess O, associated with water, weaving, childbirth, medicine and divination, but not explicitly with the Moon. Even though also Thompson (1939: 133, 166, 1975: 296) admits that there are no direct proofs about Ixchel being a Moon goddess, his extensive comparative study clearly shows that Mesoamerican lunar goddesses were generally associated with earth, water, weaving, childbirth, procreation, medicine, and diseases; therefore, his conclusion that Ixchel, in view of her functions and attributes, must also have been a lunar deity is compelling. In her exhaustive presentation of iconographic, epigraphic, historical and ethnographic data about the Maya Moon deities and the concepts related to this celestial body, Milbrath (1999: 27–34, 105-156) arrives to the same conclusion and suggests that the evidently related deities (such as Goddesses I and O in the codices, which sometimes even appear in hybrid forms) correspond to different aspects or phases of the Moon, one of their manifestations being Ixchel. Arguments about the identity of Goddesses I and O had also been presented by Montolíu (1984).

In view of the evident lunar nature of Ixchel, we can conclude that the popularity of her cult on Isla Mujeres and Cozumel, where her temples were centres of massive pilgrimages (Tozzer 1941; 9f, 109; De la Garza 1983: 187; Sierra 1994: 18f, 101), as well as representations of Goddess O, identified with Ixchel, in mural paintings of Tulum, reflect the importance of the lunar cult along the northeast coast of the Yucatan peninsula during the Postclassic period (Miller 1974, 1982: 85f; Freidel 1975; Freidel & Sabloff 1984; Milbrath 1999: 147f). It may be added that the maritime environment could have been perceived as particularly appropriate for worshipping the goddess related to water and fertility. Furthermore, as noted by Davidson (1975: 58f), in the specific coastal setting some lunar phenomena arouse very special feelings, which could well have inspired, at least in part, the attention paid to this celestial body.

Whatever the underlying causes may have been, the area in which the cult of the Moon goddess is known to have been important agrees with the concentration of orientations matching the major lunar standstills: to date, they have been identified at Buena Vista, La Expedición, and San Gervasio on the Cozumel Island, as well as at Cobá, Xelhá, Tancah, Tulum, Paamul, El Altar, Recodo San Juan, Xamanhá, and Xcalacoco along the northeast coast.

Another notable fact is that the orientations to major lunar standstills are very often associated with solstitial alignments. They occur together at Buena Vista, San Gervasio, Tancah, Tulum, Xelhá, El Altar, Xamanhá, Xcalacoco, Iglesia Vieja, Lagartero, Vega de la Peña, La Campana and La Quemada, whereas the Temple of the Cross at Palenque may have been oriented both to the major northern standstills of the Moon on the western horizon and (due to a considerable altitude of the nearby eastern horizon line) to the December solstice sunrise (Table 1; Sánchez & Šprajc 2015: 63–65; Sánchez et al. 2016: 36f; Šprajc & Sánchez 2015: 22; Šprajc et al. 2016: 14f). At La Expedición, in the north-eastern part of Cozumel, no structure with a solstitial orientation has been detected in the immediate vicinity of the main group, but it may not be fortuitous that such an alignment is embedded in Structure C8-2-a of Janán I, located on the north-eastern coast of the island, 650 m east of La Expedición. It can be added that, if Structure 40 of Yaxchilán was oriented to major southern lunar standstills on the western horizon (Table 1), Structure 39, notably skewed relative to the adjacent Structures 40 and 41, possibly incorporated a poor-precision solstitial alignment (Sánchez & Šprajc 2015: 164, 212).

In the attempt to explain these occurrences, which can hardly be attributed to chance, it should be noted that the major/minor lunar standstills repeat at 18.6-year intervals, but in these moments the Moon is not always in the same phase. If particular attention was paid to the risings and settings of the full Moon near its standstills, we should recall that, due to celestial mechanics, the full Moon extremes always occur near the solstices, when the Sun also reaches the extreme points of its movement along the horizon, but an interesting contrast can be observed: the full Moon reaches its *northerly* extremes always around the December solstice, when the Sun rises and sets at its farthest *southerly* point, whereas around the June solstice, when the Sun attains its extreme *northerly* rising and setting points, the full Moon rises and sets at its farthest *southerly* points. Since the full Moon always rises approximately at sunset and sets at sunrise, this means that the extreme positions of the Sun and the Moon are observed on diametrically opposite sides of the horizon, and that the full Moon illuminates the night for the longest time precisely in the period of the year with the shortest days, and vice versa; obviously, the time span during which the full Moon is visible above the horizon is particularly long/short near its major standstills (cf. Thom 1971: 22f; Ruggles 1999: 149, 2005: 272f). In view of these facts, the aforementioned associations of solstitial orientations and those referring to the major lunar standstills suggest that the latter phenomena were, indeed, observed during the full Moon phase.

In the context of European prehistory, Sims (2006) argues that the associations of lunar and solstitial alignments reflect the observation of the dark (nearly new) Moon around the solstices; in this case, the Moon is very near the Sun and thus the extremes of both celestial bodies are observed on the same horizon. Such a scenario cannot be discarded in our cases; however, the available data from the Maya area, where most of the orientations to major lunar extremes have been documented, favour the idea that lunar and solstitial extremes were observed on opposite horizons, implying the importance of the full Moon. As already mentioned, the distribution of declinations in Figure 1 suggests that the orientations to major lunar standstills in the Maya Lowlands were functional predominantly to the west. In contrast, the solstitial orientations associated with those to major lunar extremes exhibit a better agreement with December solstice sunrises than with June solstice sunsets, suggesting that these orientations were functional mostly to the east (Sánchez & Šprajc 2015: 64f; Sánchez et al. 2016: 37f).

Nonetheless, in some cases, a different observation scheme is indicated. The characteristics and spatial relations of buildings at San Gervasio support the eastern directionality of lunar alignments, in combination with orientations to the summer solstice sunsets, while alternative interpretations can be offered for Tulum. Both cases are particularly interesting and are examined in greater detail below.

San Gervasio

Various sectors of the urban core of San Gervasio, the largest site on the Cozumel Island, are dominated by the direction approximately corresponding to the December solstice sunrise and the June solstice sunset. Most structures composing Groups I, II and III are arranged along this solstitial axis marked by Sacbé 2, which connects Groups I and III; running parallel to Sacbé 2 is Sacbé 7, in the compound southwest of Group I (Sabloff & Rathje 1975a: Fig. 15, map in pocket), and it may not be coincidental that Group IV (Murciélagos) and Structure C22-32-a (Nohoch Nah) are situated along an approximately parallel line. In Group VI, also known as El Ramonal, the orientations to the solstice positions of the Sun are associated with those marking major lunar standstills.[4]

[4] For designating the buildings at San Gervasio and other archaeological sites on Cozumel, I follow the nomenclature established by the Harvard-Arizona Project carried out in the 1970s, considering that it is based on uniform criteria valid for the whole island and explained by Gregory (1975: 91) and Freidel & Sabloff (1984: 5ff): the site code composed of a letter and number is followed by the number assigned to a structure. For architectural groups at San Gervasio, Gregory's (1975) Roman numerals are used. While other names have been introduced in more recent publications for some buildings and architectural groups at San Gervasio, no consistent and agreed-upon nomenclature has been established; therefore, I only use those newer names that have become rather popular, or I mention alternative labels in parentheses, in order to facilitate identifications in cited literature.

While many buildings of San Gervasio reproduce the solstitial direction only approximately, some orientations are quite precise and could have been astronomically functional. One of the buildings for which the observational function is particularly likely is Structure C22-41-a (Ka'na Nah), one of the tallest and most prominent buildings of San Gervasio (Gregory 1975: 105; Freidel & Sabloff 1984: 63ff, Figs. 14 & 15; Sierra 1994: 109, Fig. 38). The upper sanctuary, with a doorway facing west, was originally a single-room structure with an altar either against the back wall or set out a small distance from it, but was later modified by construction of a medial wall, which extends in the north-south direction, but does not reach the northern and southern walls, leaving narrow lateral access ways to the back part of the room. This wall, built over one part of the altar, also has a central opening or doorway. Having both the main stairway and the entrance to the upper shrine on the western side, the building was likely oriented to the June solstice sunsets. Since the entrance to the upper sanctuary is slightly wider than the doorway in the medial wall, a light-and-shadow effect could have been observed: the rays of the setting Sun, when aligned with the building at the summer solstice, would have cast shadows of jambs of the outer doorway on the medial wall, leaving illuminated strips of equal width on both sides of its doorway (Figure 2). Alternatively, if the rectangular altar protruding from the west base of the doorway in the medial wall[5] supported a statue of the deity worshipped in the temple (cf. Freidel 1975; Freidel & Sabloff 1984: 64), the rays of the setting solstitial Sun would have illuminated the idol, creating a solar hierophany that may have been observed by a wider audience. Freidel (1975) and Freidel and Sabloff (1984: 44, 63ff, 152f, 164) argue that Structure C22-41-a was a temple of Ixchel with a talking idol, because the characteristics of the upper shrine, particularly of its late stage with the medial wall and an altar in front, manifest a close correspondence with early Spanish descriptions of an oracle temple dedicated to the same deity and located on the coast, presumably in the settlement, now destroyed, near the modern town of San Miguel de Cozumel.[6]

[5] In the ground plans of this building published by Freidel (1975: Fig. 25) and Freidel & Sabloff (1984: Figs. 14 & 15), this altar is erroneously shown on the east side of the medial wall. An accurate plan of this structure was published by Sierra (1994: Fig. 38).

[6] Citing this information, Galindo (2002) maintains that Ka'na Nah is oriented, with the azimuth of 300°21', to major northern lunar standstills on the western horizon. However, the results of measurements presented in Table 1, as well as photographic records of the light-and-shadow effect on a day near a June solstice (Figure 2), demonstrate that the orientation of this building cannot be related to lunar standstills.

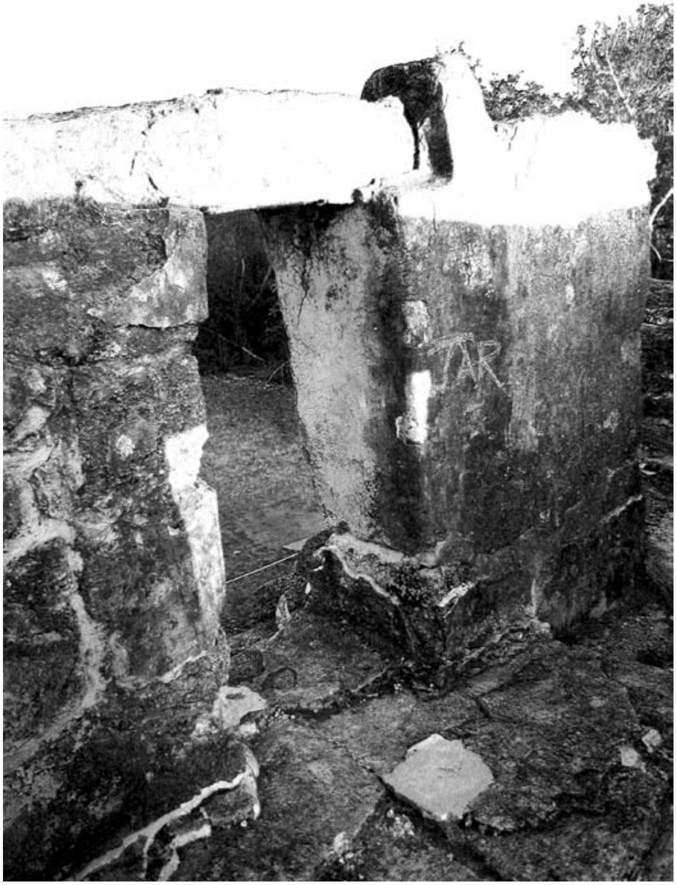

Figure 2: San Gervasio, Structure C22-41-a (Ka'na Nah), light-and-shadow effect on the west face of the medial wall in the upper shrine, before sunset on July 3, 2009; note that the illuminated strip on the left side of the central opening is considerably wider than on the right side, because the photo was taken 12 days after the summer solstice and, moreover, almost 20 minutes before sunset

Structure C22-41-a is located immediately southeast of the Acropolis of Group VI or El Ramonal (Sabloff & Rathje 1975a: Fig. 15, map in pocket; Freidel & Sabloff 1984: Fig. 22; Robles 1986a: Figs. 5 & 6, 1986b: maps in annex; Azcárate & Ramírez 2000: Fig. 3; Ramírez & Azcárate 2002: 48), characterised by a combination of lunar and solstitial alignments. The east-west azimuth of the Acropolis corresponds to lunar declinations of -27.860° on the eastern horizon and 28.069° on the western horizon (Table 1), both quite close to the major standstill values, but it should be noted that this azimuth was measured along the southern wall of the supporting platform and the access stairway, which are the only excavated elements of the Acropolis. According to the maps published by Azcárate and Ramírez (2000: Fig. 3) and Ramírez and Azcárate (2002: 48), the orientation of this part of the Acropolis agrees with the orientation of most buildings on the platform (Figure 3), but quite likely does not reproduce it accurately; the corresponding declinations thus do not allow any reliable conclusion regarding the directionality of the orientation. As mentioned above, the alignment data from the Maya area suggest that the orientations to the major standstills of the Moon were predominantly functional to the west, recording its northerly extremes. In the case of El Ramonal, however, a different scenario seems to be more likely. If we consider that, among the buildings on the Acropolis sharing the orientation possibly related to lunar standstills, the tallest one is Structure C22-54-a, situated on the western side of the Acropolis and facing east, it is conceivable that this building served for observing moonrises on the eastern horizon: when the Moon reached its major southern extreme, it appeared not only along the central east-west axis of this building but also over the centre of Structure C22-49, standing on the opposite side of the Acropolis. On the other hand, Structure C22-48a, on the plaza immediately south of the Acropolis, is oriented solstitially, and the same orientation seems to be also shared by Structure C22-47 to the west, as well as by Structures C22-49 and C22-50-a on the eastern flank of the Acropolis (Figure 3; Azcárate & Ramírez 2000: Fig. 3; Ramírez & Azcárate 2002: 48). It can thus be supposed that the orientation of most buildings on the Acropolis, dominated by Structure C22-54-a, referred to the southernmost rising position of the full Moon, while the solstitial orientations marked the northernmost setting point of the Sun. Indeed, the western directionality of solstitial orientations is supported by the west-facing Structure C22-41-a (Ka'na Nah), located immediately southeast of El Ramonal Acropolis and arguably oriented to the June solstice sunsets (see above).

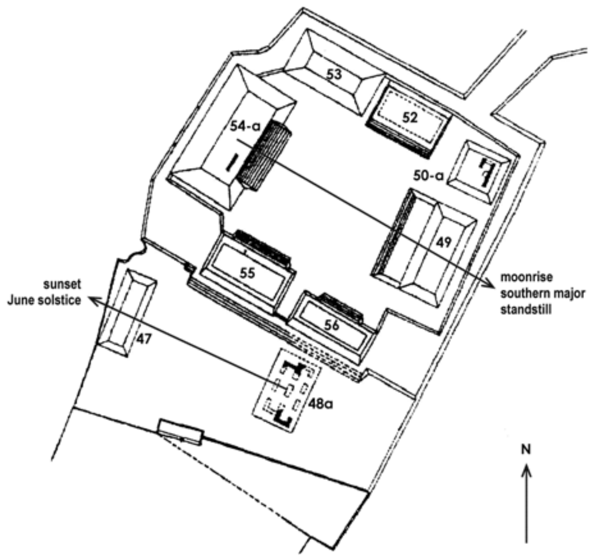

Figure 3: San Gervasio, map of Group VI (El Ramonal) (after Azcárate & Ramirez 2000), with alignments discussed in the text

Even though the latest construction stage of Structure C22-41-a was shaped in the Late Postclassic, while all the remaining monumental architecture of El Ramonal dates to the Classic period (some substructures might be even earlier: Gregory 1975: 103ff; Freidel & Sabloff 1984: 151ff; Sierra 1994: 109; Azcárate & Ramírez 2000: 15; Ramírez & Azcárate 2002: 48), it is reasonable to suppose that the observational scheme described above was in use in both the Classic and Postclassic periods. On the one hand, Structure C22-41-a, interpreted as a temple of Ixchel, has several earlier phases (Freidel & Sabloff 1984: 153), which may also have been functional to the west. On the other, Freidel and Sabloff (1984: 151ff) argue that the civic and ceremonial precinct of the El Ramonal group (labelled District 2 in their nomenclature), being the centre of the settlement during the Classic period, functioned as the original focus of the oracle cult; in the Postclassic period there was no construction activity in the sacred precinct, but the archaeological evidence (particularly the characteristics and contexts of ceramic material found in Structure C22-48a: *ibid.*: 151f; Gregory 1975: 103) indicates it was used for worship. Consequently, if El Ramonal continued to be the stage for ritual activities, it probably also conserved its astronomical function; while the ancient ceremonial precinct served for observing both the southernmost rises of the Moon and the northernmost settings of the Sun, the latter phenomena could now be sighted also in Structure C22-41-a, apparently the only one built (or remodelled) during the Late Postclassic.

The fact that Structure C22-41-a marks solar rather than lunar events does not necessarily weaken its identification with the temple of Ixchel, based on the comparison of its architectural characteristics with historical descriptions of the shrine that was probably located in the vicinity of modern San Miguel Cozumel (Freidel 1975; Freidel & Sabloff 1984: 44, 152f, 164). In view of Ixchel's attributes referred to above, the idea that the Sun was observed in her temple is not implausible: in the Mesoamerican world view, the Moon was closely related to the night Sun, and both were associated with water, earth, and fertility (Klein 1976: 97; 1980; Milbrath 1999: 105ff; Šprajc 1993a: 37f; 1996: 187f); furthermore, Xbalanqué, one of the twin heroes of the *Popol Vuh*, represents both the night Sun and the full Moon (Baudez 1985: 33ff; Tedlock 1985: 296ff; Rivera 1988; Milbrath 1999: 130; cf. Christenson 2007: 94f). Since the transformation from the daytime to the nocturnal Sun occurred at the horizon (Klein 1980: 165ff), it is not unreasonable to imagine that the solstitial solar hierophany produced in Structure C22-41-a was conceived as a liminal moment in which the setting Sun was acquiring the powers it shared with Ixchel and with her other celestial avatar, observed in her ancient shrine. The relation of her sanctuary with sunsets also agrees with the symbolism of the western side of the universe, associated with water, maize, and fertility (Šprajc 1993a; 1993b; 1996; 2001: 88ff; 2004).

While the practice of orienting certain buildings to major lunar extremes may be included among the cultural traits that reflect a 'homogeneous development' on the northeast coast during the Postclassic period (cf. Robles 1986a: 11f), the use of lunar alignments since the Classic period, attested in El Ramonal of San Gervasio, reinforces the idea that the Ixchel temple, instead of becoming important in the Late Postclassic, 'might have been a much older shrine which was initially responsible for Cozumel's increasing importance from Florescent [i.e. Terminal Classic] times onward' (Sabloff & Rathje 1975b: 27).

Tulum

While Structure 1 (El Castillo) of Tulum seems to have dictated the orientations of many surrounding buildings (Sánchez & Šprajc 2015: 200), Structures 21 and 25 exhibit different orientations, which can be related to the solstices and major lunar standstills, respectively.

Figure 4: Tulum, Room A of Structure 25, looking northeast; note the Diving God figure above the central doorway, and the aperture in the east (right) wall

On the south side of Structure 25, in front of its principal entrance, is a stairway leading to Room A, which has two openings in its east and west walls (Lothrop 1924: 102ff, Fig. 87), the western one being higher above the floor than the eastern one (Figure 4). The eastern wall divides Room A from a smaller Room D, which has two columns on the east side (Figure 5). The fact that, observing from the eastern opening, the visual line through the western opening passes exactly over the western segment of the wall enclosing the urban core of the site (Figures 5 and 6) suggests the possibility that the two holes served for astronomical observations. Therefore, and considering that the alignment along the two apertures is parallel to other east-west lines (walls, colonnades) of the building, its azimuth was measured with precision and assumed to be representative of the structure's east-west orientation (Table 1). The lunar declination corresponding to the line from the eastern to the western orifice (28.658°) is equal to the maximum declination reached by the Moon in the Late Postclassic period. Due to its inclination, the alignment could not have served for observing southern major standstills on the eastern horizon: observing through both holes in the opposite direction, one cannot see the horizon but rather the natural ground some 20 m east of the structure.

Figure 5: Tulum, Room D of Structure 25, looking west along the apertures in the eastern and western walls of Room A; note the height of the orifices with respect to the segment of the defensive wall visible in the background to the left

Figure 6: Tulum, Structure 25, looking west through the aperture in the east wall of Room A

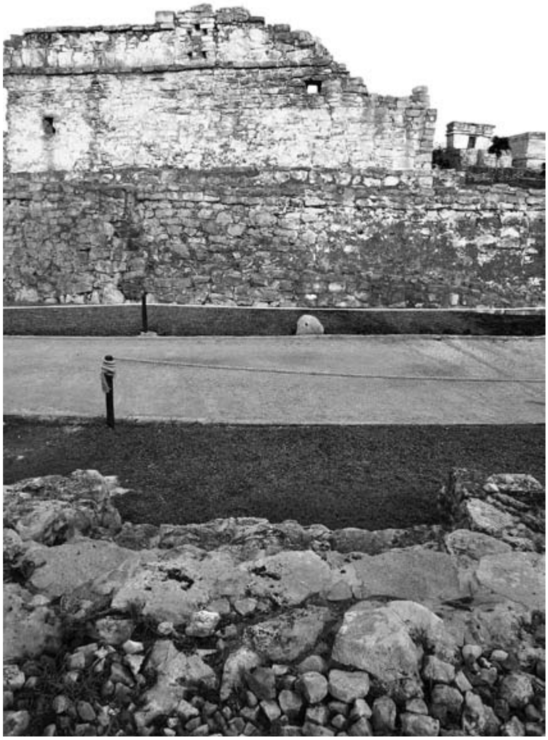

Figure 7: Tulum, west facade of Structure 25, looking east from the stairway of Structure 29

Figure 8: Tulum, small stairway located in the western segment of the defensive wall along the alignment of apertures in Room A of Structure 25; view to the northwest

The idea that the alignment of the two vents in Room A of Structure 25 had a special significance is reinforced by its relationship with other architectural elements.[7] Immediately west of the building is Structure 29 (Lothrop 1924: 108), a low platform with a small stairway whose midpoint is located exactly along the direction marked by the two orifices in Structure 25 (Figure 7); extended further west, the same alignment passes exactly over a small stairway in the west arm of the defensive wall of the city (Figure 8). It seems significant that this line coincides precisely with the two openings in the east and west walls of Room A, rather than with the central east-west axis of Structure 25.[8]

Although the alignment defined by the two apertures in Structure 25 corresponds to northern major lunar standstills on the western horizon with precision, it is not impossible that the stairway in the defensive wall marked the point for observing southern major standstills on the eastern horizon, approximately in the direction marked by Structure 25 (Table 1).

Above the central doorway communicating Room A with the central sanctuary of Structure 25 (cf. ground plan in Lothrop 1924: 104, Fig. 87), there is a stucco figure representing the Diving God. Although a similar plunging figure appears on page 58 of the Dresden Codex with a Venus glyph substituting its head, the fact that this page belongs to the lunar table, or table of the eclipses, indicates that this deity was also associated with the Moon. A fusion of Venus and lunar attributes does not come as a surprise, considering the relationships observed between the Dresden Codex Venus table and eclipse cycles (cf. Bricker & Bricker 2011: 180f, 214f), as well as Closs's (1989) argument about Venus being an eclipse agent. On the other hand, if the diving deity on Structure 25 of Tulum refers to eclipses, it should be recalled that the periodicity of both lunar standstills and eclipses depends on the lunar nodal cycle of 18.6 years. In the absence of any further evidence, however, the question whether the observation of lunar extremes had any relation with eclipse predictions (cf. Thom 1971: 18ff) will not be pursued here.

The orientation of Structure 21, immediately south of Structure 25 (Lothrop 1924: 99ff), corresponds to the June solstice sunsets (Sánchez & Šprajc 2015: 205f).[9] Although it is not impossible that Structure 25 marked southern major lunar standstills on the eastern horizon, various circumstances mentioned above favour the idea that it was oriented to the major northern standstills on the western horizon. If the standstill positions were observed during the full Moon, we would expect Structure 21 to be oriented to the December solstice sunrises. In this direction, the northern annexes of the architectural complex of El Castillo block the view to the horizon, forming an artificial horizon line whose altitude depends on the exact observation point and thus cannot be

[7] While another aperture perforates the west wall of Room C of Structure 25 (Figure 7), it has no counterpart in the east wall of the room (cf. Lothrop 1924: 104, Fig. 87).

[8] Lothrop's (1924: Pl. 25) map of Tulum is incorrect in showing the stairway of Structure 29 aligned with the central east-west wall of Structure 25. It seems significant that another small stairway in the west segment of the defensive wall is located exactly along the axis of symmetry of El Castillo; Structure 8, a rectangular platform in the center of the interior precinct, is placed along the same axis, evidently stressing its importance (cf. Vargas 1995: 61f). Although there are several stairways in the west arm of the defensive wall (cf. Lothrop 1924: 72), it is hardly fortuitous that two of them are located exactly along the axes also marked by other architectural elements.

[9] On Lothrop's (1924: Pl. 25) map Structure 21 is inaccurately shown as having the same orientation as Structure 25.

reliably determined. However, if these buildings are later than Structure 21, or if the Sun's appearance above them was observed, it is entirely possible that the orientation of Structure 21 was functional to the east, marking sunrises at the winter solstice. Another possibility is that Structures 21 and 25 were both functional to the west, marking summer solstice sunsets and the approximately concomitant northern major standstills of the dark (nearly new) Moon, respectively. In light of the above-mentioned comparative data, however, the first alternative seems more likely.

Orientations to minor lunar standstills

Since the existence of orientations to major lunar standstills is, in view of the above arguments, hardly disputable, can we suppose that there were also alignments recording the minor standstills? Between the years 500 B.C. and A.D. 1500, the mean values of minor standstill declinations of the Moon varied from ±18.61° to ±18.36°, hence the peaks in Figure 1 on the values -18.4° and 17.7° (east declinations) and -17.3° and 18.7° (west declinations) might be related to these phenomena; the two smaller peaks (17.7° on the east and -17.3° on the west) are produced by the few orientations skewed counter clockwise from cardinal directions. In order to find the buildings that may have been oriented to minor lunar standstill positions, the estimated errors of lunar declinations were increased, as in the case of major standstills, by an arbitrary value of 0.5°; selecting those that, taking into account these errors, fit the extreme lunar declinations at the time of construction of particular buildings, the orientations listed in Table 2 were obtained, where the values of declinations and errors possibly related to minor standstills are marked in bold type.

It should be underscored, however, that the relation of these orientations with the Moon is less certain than of those corresponding to major standstills, because their other astronomical referent could have been the Sun. Indeed, several of these orientations in the Maya Lowlands pertain to one of the solar groups that have been identified (Group 10: Sánchez & Šprajc 2015: Table 7). Others, however, do not correspond to any prominent solar group. Among them are, significantly, Structure C15-1-a of El Cedral, Structure C22-32-a (Nohoch Nah) of San Gervasio, the Temple of Kisim at Calica, Structures 35 and 45 at Tulum, and the temple at Tulum Playa: the fact that these buildings are located along the northeast coast of the Yucatan peninsula, i.e. in the region with the greatest concentration of orientations to the major lunar standstills (Table 1), makes their relation with minor standstills more likely. Furthermore, it may be indicative that the orientations of the two main buildings of Paxil both correspond to minor lunar extremes, though on opposite horizons (Table 2), and that some orientations compatible with these phenomena are associated with solstitial alignments, e.g. at Caballito Blanco, La Quemada, Toniná, Tulum, and Xamanhá (Šprajc & Sánchez 2015; Šprajc et al. 2016; Sánchez & Šprajc 2015; Sánchez et al. 2016).

The association with these phenomena is, in the absence of independent evidence, much less certain for other buildings listed in Table 2, but some information regarding the pyramid known as *La Vieja* or *Vieja Hechicera* at Edzná is worth mentioning. Malmström (1991: 45, 1997: 145, 149f) claims that this building, for an observer on the Five-Storey

Table 2: Orientations corresponding to the minor lunar extremes; δ_E: declination east; δ_W: declination west; MP: Middle Preclassic; LP: Late Preclassic; EC: Early Classic; LC: Late Classic; EPC: Early Postclassic; LPC: Late Postclassic; NA: not applicable (view to the horizon is blocked by another structure)

Site, structure	Period	Lunar δ_E	Error δ_E	Lunar δ_W	Error δ_W
Acanmul (Campeche, Mexico), Palace	LC	**-17.814**	**2.0**	**18.068**	**2.0**
Caballito Blanco (Oaxaca, Mexico), Structure O	LP	22.111	2.0	**-19.625**	**2.0**
Calica (Quintana Roo, Mexico), Temple of Kisim	LPC	**18.519**	**1.5**	**-18.241**	**1.5**
Cempoala (Veracruz, Mexico), Temple of Ehécatl	LPC	**-18.411**	**1.5**	**19.265**	**1.5**
Dagamal Santa Rosa (Veracruz, Mexico), main group	LC	-16.914	1.5	**19.112**	**1.5**
Edzná (Campeche, Mexico), Temple of the Masks	EC	**-18.694**	**1.5**	**19.217**	**1.5**
Edzná (Campeche, Mexico), South Temple (Structure 421)	EC-LC	**-18.227**	**1.5**	**18.742**	**1.5**
Edzná (Campeche, Mexico), Vieja Hechicera	LPC	**-18.817**	**1.5**	**19.327**	**1.5**
El Cedral (Quintana Roo, Mexico), Structure C15-1-a	EPC	-16.688	1.5	**16.960**	**1.5**
La Blanca (Petén, Guatemala), Structure 6J2, south wing	LC	**18.467**	**1.0**	-16.664	1.2
La Quemada (Zacatecas, Mexico), Plaza de los Maestros	LC	**-16.954**	**2.0**	**18.484**	**2.0**
Malpasito (Tabasco, Mexico), Acrópolis	LC	**-17.372**	**2.5**	21.311	2.5
Oxtankah (Quintana Roo, Mexico), Plaza Abejas, Structure IV	EC-LC	**-19.893**	**1.5**	20.099	1.5
Palenque (Chiapas, Mexico), Temple of the Inscriptions	LC	**-18.628**	**1.5**	22.206	0.7
Paxil (Veracruz, Mexico), Building A (of the Tunnel)	EPC-LPC	-15.122	1.5	**17.634**	**1.5**
Paxil (Veracruz, Mexico), pyramid (La Palma building)	EPC-LPC	**-18.643**	**1.2**	21.389	1.3
Quiahuiztlán (Veracruz, Mexico), Structure 4	LPC	NA	NA	**19.054**	**1.5**
San Claudio (Tabasco, Mexico), Structure 1	EC	-15.392	2.5	**16.080**	**2.5**
San Gervasio (Quintana Roo, Mexico), Str. C22-32-a (Nohoch Nah)	LPC	**17.625**	**0.8**	-17.349	0.8
Sayil (Yucatán, Mexico), South Palace	LC	-16.571	1.5	**17.476**	**1.5**
Tingambato (Michoacán, Mexico), East Structure	LC	-14.847	1.5	**19.316**	**1.5**
Tipikal (Yucatán, Mexico), Structure 6	MP/EC	**-20.015**	**2.0**	**20.407**	**2.0**
Toniná (Chiapas, Mexico), Temple I (Structure D5-2)	LC	**-17.848**	**1.0**	**18.643**	**1.0**
Tulum (Quintana Roo, Mexico), Structure 35 (Casa del Cenote)	LPC	**-17.545**	**1.0**	**18.198**	**1.0**
Tulum (Quintana Roo, Mexico), Structure 45	LPC	**-18.558**	**2.0**	**18.787**	**2.0**
Tulum Playa (Quintana Roo, Mexico), temple	LPC	**-17.460**	**1.0**	**18.085**	**1.0**
Uxmal (Yucatán, Mexico), House of the Turtles	LC	**-18.279**	**1.0**	**18.556**	**1.0**
Uxmal (Yucatán, Mexico), Great Pyramid	LC	**-18.733**	**1.0**	**19.012**	**1.0**
Xamanhá (Quintana Roo, Mexico), Structure C-4a	LPC	**-18.882**	**1.5**	**19.169**	**1.5**
Xlapak (Yucatán, Mexico), Structure B	LC	**-16.637**	**2.5**	**18.037**	**2.5**
Xlapak (Yucatán, Mexico), Palace	LC	**-18.403**	**1.5**	19.783	1.5
Yaxchilán (Chiapas, Mexico), Structure 42	LC	-16.052	1.5	**17.110**	**1.5**
Zaachila (Oaxaca, Mexico), Mound A	LPC	-16.789	1.2	**19.243**	**1.2**

Pyramid, marked the moonsets at major northern standstills. Indeed, this alignment, according to our measurements, corresponds to the lunar declination of 28°25', very close to the maximum declination attainable by the Moon. Since the orientation of neither of the two buildings matches the alignment, there is no indication suggesting its intentionality, but the fact that the orientation of *La Vieja* corresponds to minor lunar standstills is noteworthy. Moreover, according to a local legend summarised by Benavides (n.d.), the peasants taking a rest at the base of *La Vieja* used to receive little *cocoyol* bowls of water from an old woman, in exchange for coins they would leave there. Recalling aquatic attributes of the old

Moon goddess in prehispanic times (Milbrath 1999: 141ff), the old lady of the legend may well be related to this celestial body, as supposed by Benavides (n.d.); if the story, indeed, represents a survival of the prehispanic importance of the Moon at the site, it lends some support to the lunar interpretation of the alignments mentioned above.

Cultural significance of lunar orientations

As is well known, the Maya were acutely aware of many regularities of the apparent motion of the Moon, including the eclipse patterns (e.g.: Thompson 1939; Milbrath 1999: 105ff; Cruz 2005; Bricker & Bricker 2011). The orientations discussed above indicate that they also perceived the periodic oscillations of its extreme rising and setting points. This sophisticated astronomical knowledge, possessed by astronomer-priests, was lost soon after the Conquest, when its bearers, pertaining to the highest layer of the vanquished society, were subject to an intensive Christian indoctrination.[10] However, the attention paid to this celestial body was largely motivated by the beliefs that were widely shared among people and which persist, although impoverished and modified, among the present-day communities. The Moon is associated with water, earth, and fertility, and its phases still represent an important factor in scheduling agricultural activities (Thompson 1939; Neuenswander 1981; Montolíu 1984; Báez-Jorge 1988; Köhler 1991; Atran 1993: 678f; Milbrath 1999: 27ff; Bassie-Sweet 2008: 33ff; Redfield & Villa Rojas 1962: 205f; Iwaniszewski 1992, 2006; Vogt 1997: 112).

The aquatic connotations of the Moon and its relations with fertility, found not only in Mesoamerica but also in many other cultures (cf. Eliade 1972: 150ff), can be largely accounted for by observational facts. The parallelism between the synodic month, the tides, and women's menstrual cycle must have called attention in distant times. Furthermore, various researchers have noted a correlation between certain phases of the Moon and rainfall, hurricanes, tropical storms, temperatures, and the germination of certain plants (e.g.: Carpenter et al. 1972; Balling & Cerveny 1995; Cerveny et al. 2010; González 2001: 171f). Specifically, for North America and New Zealand, it has been demonstrated that heavy rains tend to occur more frequently in the first and third weeks of the synodic month (Bradley et al. 1962; Adderley & Bowen 1962; Brier & Bradley 1964). Interestingly, and in agreement with these findings, Judith Remington (1980: 112) was told, during her ethnographic research in Guatemala Highlands, that during the rainy season 'llueve más cuando la luna está tierna que cuando está madura', while Diego de Landa reported that 'towards the end of January and in February, there is a short summer, with a burning sun; and during this time it does not rain except at the time of the new moon' (Tozzer 1941: 4). If the analyses of rainfall data from two widely separated regions resulted in the same conclusion, we can assume that it also applies to the Mesoamerican latitudes, thus being highly likely that the above-cited ethnographic and Landa's reports are based on observational reality.

[10] An informant from Chan Kom reported to Redfield & Villa Rojas (1962: 206) that 'every eighteen years the moon passes under the sun covering the earth with its shadow'. Although this seems to be a reference to the eclipse cycle known as saros (18.03 years), it should be recalled that the periodicity of the eclipses depends on the nodal cycle of 18.6 years, which is also the cycle of lunar major/minor standstill declinations. Citing this piece of information, Nahm (2004: 50) remarks that 'a survival of knowledge about such an astronomical period among rural Maya is unlikely, but it is hard to think of an obvious alternative'. A possible alternative is, of course, that the informant was 'contaminated' by modern astronomy.

While the significance of lunar orientations can be understood in the light of the above-mentioned concepts, it may have been related to even more specific observational facts. According to several recent studies (Agosta 2014; Baart et al. 2012; Currie 1993, 1995; Currie & Vines 1996; Haigh et al. 2011; Manzi et al. 2012; Mitra & Dutta 1992; Oost et al. 1993), a correlation exists between tides, rainfall patterns and temperatures, on the one hand, and the lunar nodal cycle of 18.6 years, on the other. These correspondences, in spite of the lack of evidence that they were actually perceived, offer an attractive basis for interpreting the meaning of orientations to lunar standstills, whose periodicity obeys the node cycle.

Finally, if the associations of lunar and solstitial orientations reflect the observation of standstill phenomena during the full Moon phase, they can be explained not only in terms of the attractiveness of the opposite positions of the Sun and the full Moon and the contrasting roles of the two luminaries during the shortest/longest days/nights of the year, but also in the light of their closely related symbolism. Since the orientations pointing to the Sun on the horizon may refer to its nocturnal aspect, let us recall that the night Sun was closely related to the full Moon; both were personified by Xbalanqué, one of the twin heroes of the *Popol Vuh*, and associated with water, earth and fertility (Baudez 1985: 33ff; Klein 1976: 97, 1980; Milbrath 1999: 105ff, 130; Rivera 1988; Šprajc 1993a: 37f, 1996: 187f; Tedlock 1985: 296ff).

Summary

The orientations of a significant number of civic and ceremonial buildings in various parts of Mesoamerica correspond to major lunar extremes on the horizon. An interpretation other than astronomical can hardly account for their occurrence in different periods and places, and their association with the Moon, specifically, is supported by the absence of other celestial candidates of comparable importance. Another significant fact is that most of these alignments are found along the north-eastern coast of the Yucatan peninsula, i.e. precisely in the area where the cult of the Moon goddess is known to have been particularly important. While there are a number of orientations matching minor lunar standstills, the intentionality of these correspondences is less certain, because an alternative celestial referent of these alignments may have been the Sun. Nonetheless, as indicated by contextual data, the Moon does seem to have been targeted by some of these orientations.

The buildings oriented to lunar extremes are, in many cases, in the immediate vicinity of those aligned to solstitial sunrises or sunsets. The analyses of the alignment data suggest that these associations, which are hardly coincidental, reflect the observation of full Moon extremes nearest to the standstills and always occurring around the solstices: the northernmost positions of the full Moon approximately coincide with the southernmost positions of the Sun, and vice versa.

The significance of lunar orientations can be accounted for by the widespread concepts associating the Moon and related deities with water, earth, and fertility. There is evidence indicating that these ideas were motivated by observational facts. Moreover, in light of several recent studies demonstrating interrelationships between the lunar nodal cycle, which determines the periodicity of standstills, and oscillations in rainfall, temperatures, and sea level, it is tempting to suggest that the alignments to lunar standstills reflect, specifically, the observation of these correlations.

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Povzetek

Sistematična arheoastronomska raziskava, nedavno opravljena na več območjih Mezoamerike, je razkrila obstoj arhitekturnih usmeritev, ki ustrezajo velikim in malim ekstremom Lune na horizontu. Posebno pomenljivi so rezultati kvantitativnih analiz podatkov o orientacijah v majevskih nižavjih; ti so pokazali, da je mogoče eno od izrazitih skupin usmeritev prepričljivo povezati z velikimi lunarnimi ekstremi. Astronomsko motivirano namernost teh orientacij dodatno podpirajo kontekstualni podatki; posebno pomembno je dejstvo, da je največ teh usmeritev koncentriranih vzdolž severovzhodne obale polotoka Jukatana, kjer je imel lunarni kult velik pomen. Ker lunarne orientacije pogosto nastopajo skupaj s tistimi, ki ustrezajo solsticijskim položajem Sonca na horizontu, je zelo verjetno, da je bila posebna pozornost namenjena ekstremom polne Lune. Članek predstavlja tudi neodvisne podatke, ki osvetljujejo kulturni pomen lunarnih orientacij.

KLJUČNE BESEDE: Mezoamerika, arheoastronomija, arhitektura, orientacije, Luna, ekstremi

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