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# Early Maya Astronomy and Urban Planning at El Mirador, Peten, Guatemala

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## ABSTRACT

Archaeoastronomical studies conducted thus far have shown that many important buildings of prehispanic Mesoamerican cities were oriented on an astronomical basis, predominantly to sunrises and sunsets on particular dates, allowing the use of observational calendars that facilitated an efficient scheduling of agricultural and associated ritual activities in the yearly cycle. The alignments in the urban layout of El Mirador, the largest Late Preclassic site in the Maya Lowlands (ca. 300 B.C.–A.D. 150), represent the earliest evidence of the use of such observational schemes in the Maya area, and exemplify the significance of astronomical and calendrical factors in the concepts dictating architectural design and urban planning. Also relevant, particularly to the issues of cultural interaction in Mesoamerica, is our finding that the so-called 17° family of orientations, the most widespread Mesoamerican alignment group, did not originate in the central Mexican city of Teotihuacan, as commonly held, but rather in the Maya area, most likely at sites within the Mirador Basin.

**KEYWORDS:** Maya archaeology, archaeoastronomy, architectural orientations, urban patterning.

## Introduction

Archaeoastronomical studies carried out in recent decades in different parts of Mesoamerica have revealed that the orientations in monumental architecture exhibit a clearly non-random distribution, indicating that civic and ceremonial buildings were oriented predominantly on an astronomical basis. While some research has been conducted in the Maya area, the most important early urban centers located in the Mirador Basin in northern Guatemala so far have not been studied from this point of view. Our research at El Mirador, the largest site

in the area (Matheny 1980; Hansen 1990; 1998; 2000; 2001; Hansen et al. 2008) (Figure 1), has detected regularities in architectural orientations and urban layout, demonstrating that complex rules related to astronomy and calendrics, and similar to those dictating urban planning in other parts of Mesoamerica in later times, were already fully developed in the central Maya Lowlands by the Late Preclassic period (ca. 300 B.C.–A.D. 200).

Most buildings of El Mirador are earthen and stone mounds covered by dense tropical vegetation; their sizes, irregular shapes and vegetative cover do not allow architectural orientations to be easily determined and the alignments in urban layout to be detected and measured in the field. However, the recently elaborated site map based on total-station surveying (Hansen et al. 2006; Morales-Aguilar and Morales López 2005) is sufficiently accurate for archaeoastronomical considerations. In order to obtain true (astronomical) azimuths necessary for this type of research, the map's orientation has been rectified to true north: during field measurements in 2007, theodolite readings were taken along several long sight lines connecting points easily and accurately identifiable on the map, employing astronomical fix and methods described elsewhere (e.g.: Aveni 2001: 120–124; Ruggles 1999: 164–171).



Figure 1: Location of El Mirador and some other major archaeological sites in the central Maya Lowlands

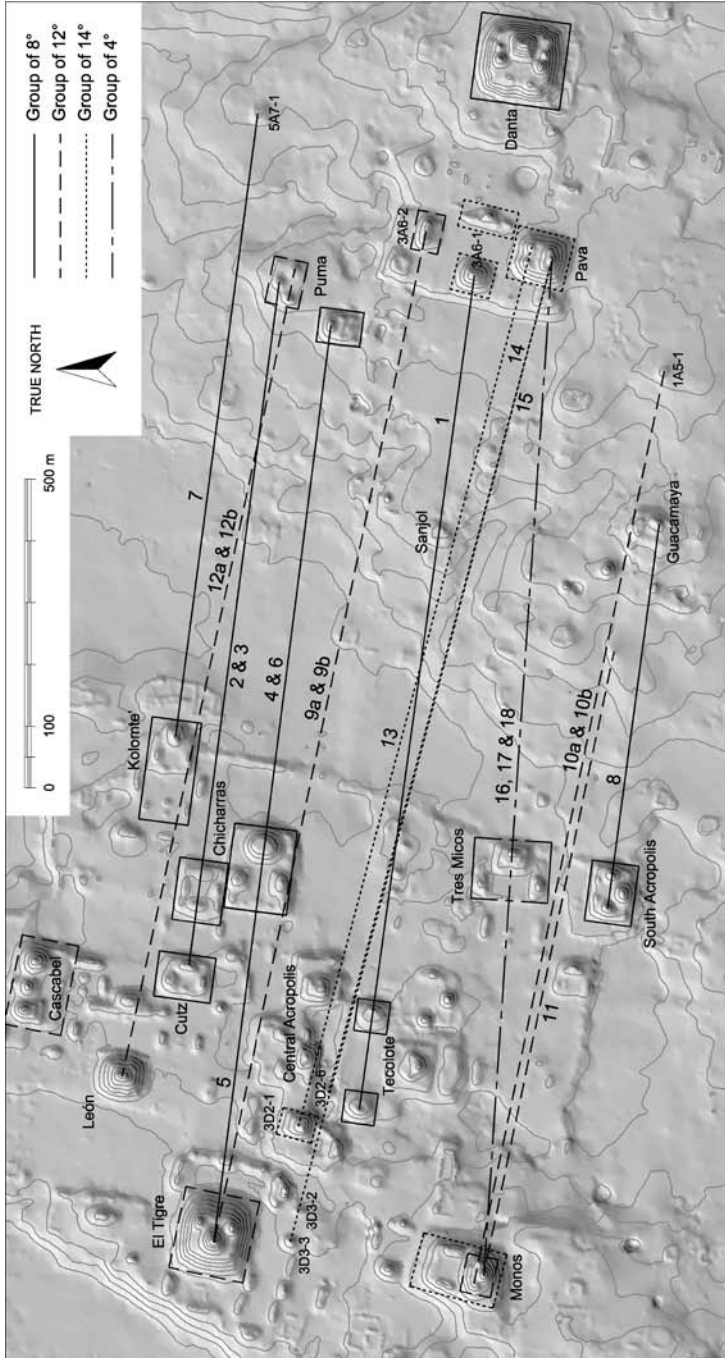


Figure 2: Digital surface model and a contour map of El Mirador, Peten, Guatemala, showing the orientations and alignments discussed in the text and pertaining to different groups (contour interval: 5 m; map by Depic-Guatemala & C. Morales-Aguilar; digital model by C. Morales-Aguilar; © FARES – Mirador Basin Project, Project Director: Richard D. Hansen).

As one can observe on the site map (Figure 2), the architectural orientations manifest a consistent clockwise skew from cardinal directions, prevailing throughout Mesoamerica (cf. Aveni 2001: 233; Aveni and Hartung 1986, 2000: 55; Šprajc 2001; Tichy 1991). Also evident are several groups of orientations dominating different sectors of the city layout. In general, Mesoamerican architectural alignments clearly cluster around certain azimuthal values, a pattern for which ‘there can be no conceivable way of actually laying out the chosen direction other than by the use of astronomical bodies at the horizon as reference objects’ (Aveni and Hartung 1986: 7–8).<sup>1</sup>

Furthermore, some geometrical patterns in the distribution of structures were observed, including alignments running mostly in an east-west direction (Morales-Aguilar and Hansen 2005; Morales-Aguilar and Morales López 2005: 74, Fig. 69). In other words, a number of buildings and architectural groups are oriented to others. Upon closer inspection of the map, we have found out that the azimuths of these alignments, rather than being distributed randomly, cluster around the same values as the orientation groups we have identified (Figure 2). Both the east-west direction of the alignments we detected and the disposition of the whole city along an east-west axis indicate a special importance of the two directions or sides of the world (Hansen 2005; Morales-Aguilar et al. 2007). It has been argued, on several grounds, that Mesoamerican architectural orientations are related, in most cases, to the Sun’s positions on the horizon. One circumstance supporting this conclusion is the fact that most of the east-west orientation azimuths lie within the angle of annual movement of the Sun along the horizon (Aveni and Hartung 1986: 59–60; 2000: 55; Šprajc 2001: 25–26). At El Mirador, all of the east-west alignments are placed within this angle, suggesting they refer to sunrises and sunsets on particular dates.

Since archaeoastronomical studies conducted in several Mesoamerican regions have shown that the sunrise and sunset dates recorded by orientations at a particular site tend to be separated by multiples of 13 and 20 days, which are basic periods of the Mesoamerican calendrical system, it has been argued that the alignments allowed the use of observational calendars composed of calendrically significant intervals. Furthermore, the correspondence between the most frequently recorded dates and crucial moments of the maize cultivation cycle suggests that the reconstructed observational schemes facilitated a proper scheduling of agricultural activities and associated ceremonies (Aveni and Hartung 1986; Aveni et al. 2003; Šprajc 2000a; 2000b; 2001; 2004b; 2008). It should be recalled that, since the Mesoamerican calendrical year of 365 days, due to the lack of intercalations, did not maintain a perpetual concordance with the tropical year of 365.2422 days, astronomical observations were always necessary. The orientations, marking critical and canonized moments of the year of the seasons, not only allowed their determination by means of direct observations; if the observational schemes were composed of elementary periods of the formal calendrical system, it was relatively easy to *anticipate* the relevant dates, knowing the structure of a specific observational calendar and

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<sup>1</sup> While the astronomical motives represent the only viable rationale for the widespread orientation groups, they are not sufficient for explaining the characteristic clockwise skew of Mesoamerican architectural orientations from cardinal directions. As argued elsewhere (Šprajc 2001: 88–91; 2004a), this tendency derives from a combination of astronomical considerations and the symbolism related to world directions or parts of the universe.

the mechanics of the formal one. Particularly important for these purposes must have been the 260-day calendrical count, in which the cycles of 13 and 20 days were intermeshing, so that every date had a name composed of a number from 1 to 13 and a sign in the series of 20. Given the structure of this calendrical count, the sunrises and sunsets separated by 13-day intervals and their multiples occurred on the dates with the same numeral, while the events separated by periods of 20 days and their multiples fell on the dates having the same sign.<sup>2</sup>

In this paper, we argue that the alignments at Late Preclassic El Mirador reflect the use of observational calendars that were, both in structure and practical function, analogous to those attested in other parts of Mesoamerica in later periods.

## Alignment groups and their astronomical referents

The following analysis is based on the alignments connecting two or more prominent buildings or architectural groups, because they are much more convenient for a reliable astronomical assessment than the orientations of particular structures. While the latter, due to the present state of most buildings, cannot be accurately determined, the alignments connect structures and compounds placed relatively far away from each other; consequently, the astronomically relevant alignment data can be determined with considerable precision from the map. For each alignment, we have chosen the most appropriate observation point and the point on the target structure assumed to have served as a marker of an astronomical event (i.e. sunrise or sunset); both points always correspond to the uppermost parts of structures, while for determining the direction in which an alignment must have been functional we assumed that the target point needed to be higher than the background natural horizon line.

In order to identify astronomical phenomena possibly related to an alignment, the corresponding declination ( $\delta$ ) must be calculated, based on the observer's geographic latitude, the alignment azimuth ( $A$ ) and the angular altitude ( $h$ ) of the observed point above the horizontal plane (on calculation procedures see: Aveni 2001: 119–120; Šprajc 2001: 45–51).<sup>3</sup> The alignment data for El Mirador are listed in Table 1, arranged in groups whose labels refer to the approximate clockwise azimuthal skew from cardinal directions. Declinations of the points viewed to the east ( $\delta_e$ ) and west ( $\delta_w$ ), as well as the corresponding

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<sup>2</sup> The importance of intervalic time reckoning in Mesoamerica is attested both in central Mexican (Siarkiewicz 1995) and in the Maya codices (Aveni et al. 1995; 1996); hence the patterns of dates separated by certain intervals must have been well known to astronomers-priests. The mechanics of the 260-day count, as well as some mnemotechnic aids that facilitate determination of dates on the basis of intervals separating them, are even nowadays familiar to indigenous calendar-keepers in the Guatemala highlands, who use no written records; the knowledge possessed and the procedures employed by prehispanic full-time specialists were obviously far more sophisticated (see the whole argument and the corresponding bibliography in Šprajc 2001: 99–100, 151–155).

<sup>3</sup> The *azimuth* is the angle measured in the horizontal plane clockwise from the north, having values from 0° to 360°, while the *declination* expresses the angular distance measured from the celestial equator (imaginary circle on the celestial sphere, placed in the plane of the Earth's equator) to the north and south, having values from 0° to ±90°. Geographical coordinates of El Mirador were determined with a portable GPS receiver (El Tigre Pyramid: N17°45'21.8", W89°55'16.2"; Danta Pyramid: N17°45'05.6", W89°54'10.3"). Angular elevations or altitudes of the observed points were calculated from hypsometric data (contours at 1 m intervals) and distances on the original site map, employing the formula  $\Delta_{alt}/d = \tan h$ , where  $\Delta_{alt}$  is the difference in height above sea level between the observation and observed points,  $d$  is horizontal distance between both points, and  $h$  is angular altitude of the observed point.

sunrise and sunset dates,<sup>4</sup> appear in separate columns, making clearer the directionality of each alignment. Considering the degree of precision of the data obtained from the site map, we estimate that possible errors in declinations do not exceed  $\pm 10'$ , which means that the corresponding sunrise and sunset dates may have an error not greater than  $\pm 1$  day.

Our selection of the alignments connecting different buildings or architectural groups might be disputable from the methodological point of view, were it not supported by the orientations: in all cases, the direction (azimuth) of the alignment is indicated by

alignment group	no.	observation point (structure, group)	observed point (structure, group)	A	h	$\delta_E$	$\delta_W$	sunrise date	sunset date
group of 8°	1	3D2-10, Tecolote	3A6-1, Pava	97°50'	1°36'	-7°04'	-	Mar 3, Oct 11	-
	2	5D1-18, Cutz	4A6-1, Puma	97°36'	0°58'	-7°04'	-	Mar 3, Oct 11	-
	3	4A1-20, Chicharras	4A6-1, Puma	97°29'	1°20'	-6°49'	-	Mar 3, Oct 10	-
	4	4A-1, Chicharras	4A5-1, Puma	97°22'	1°05'	-6°48'	-	Mar 3, Oct 10	-
	5	4A-1, Chicharras	4D3-1, El Tigre	277°08'	2°41'	-	7°32'	-	Apr 9, Sep 3
	6	4A5-1, Puma	4D3-1, El Tigre	277°16'	0°32'	-	6°57'	-	Apr 7, Sep 5
	7	5A1-1, Kolomte'	5A7-1	97°30'	1°08'	-6°54'	-	Mar 3, Oct 10	-
	8	1A1-2, 1A1-3, South Acropolis	1A4-1, Guacamaya	97°38'	1°49'	-6°48'	-	Mar 3, Oct 10	-
group of 12°	9a	4D3-1, El Tigre	3A6-2, Pava	101°50'	-0°06'	-11°28'	-	Feb 19, Oct 22	-
	9b	3A6-2, Pava	4D3-1, El Tigre	281°50'	0°06'	-	11°08'	-	Apr 19, Aug 25
	10a	2D3-4, 2D3-5, Monos	1A5-1	101°46'	-0°02'	-11°23'	-	Feb 19, Oct 22	-
	10b	1A5-1	2D3-4, 2D3-5, Monos	281°46'	0°02'	-	11°02'	-	Apr 19, Aug 25
	11	1A3-1, Guacamaya	2D3-2, Monos	281°47'	1°33'	-	11°35'	-	Apr 20, Aug 23
	12a	4A6-2, 4A6-3, Puma	5D2-1, León	282°04'	0°00'	-	11°19'	-	Apr 19, Aug 24
	12b	5D2-1, León	4A6-2, 4A6-3, Puma	102°04'	0°00'	-11°39'	-	Feb 18, Oct 23	-
group of 14°	13	3D2-1, Central Acropolis	2A6-6, 2A6-7, Pava	104°51'	1°11'	-13°52'	-	Feb 12, Oct 30	-
	14	3D2-6, Central Acropolis	2A6-3, Pava	105°02'	2°23'	-13°38'	-	Feb 12, Oct 29	-
	15	3D3-3, El Tigre	2A6-3, Pava	104°55'	1°55'	-13°41'	-	Feb 12, Oct 29	-
group of 4°	16	2A1-1, Tres Micos	2A6-3, Pava	93°50'	3°09'	-2°45'	-	Mar 14, Sep 30	-
	17	2A1-1, Tres Micos	2D3-2, Monos	273°50'	2°55'	-	4°28'	-	Apr 1, Sep 11
	18	2D3-2, Monos	2A6-3, Pava	93°50'	0°38'	-3°36'	-	Mar 11, Oct 2	-

*Table 1: Data on architectural alignments at El Mirador.*

<sup>4</sup> The dates listed in Table 1 are valid for the most likely time-span in which the alignments were in use, and are given in the proleptic Gregorian calendar (i.e. reconstructed for the past before its actual introduction), because

the orientation of at least one of the structures or compounds involved. Figure 2 shows a map of El Mirador with the alignments pertaining to the identified groups; also marked are the buildings whose orientations belong to particular groups. While not every building whose orientation has been determined and marked in Figure 2 composes an alignment with another one, it should be underscored that the alignments we have in fact detected must have been designed intentionally: as our comments to each alignment group show (below), the orientations clustering around the same azimuthal values have been found in different parts of Mesoamerica.

### Group of 8°

Alignment 1 corresponds to the east-west axes of two structures of the Tecolote Group and, prolonged eastward, incorporates the Sanjol Group and Structure 3A6-1 of the Pava Group. Of the two buildings of the Tecolote Group, the western one is taller and thus constitutes a convenient observation point. Alignment 2 coincides with the east-west axis of symmetry of the Cutz Group and, almost perfectly, also with the east-west axis of Compound A of the Chicharras Group. Alignment 3 is nearly identical, but with a different observation point. Alignments 4, 5 and 6, almost superposed, agree with the east-west axis of Compound B of the Chicharras Group, as well as with the orientation of the south triadic compound of the Puma Group, involved in Alignments 4 and 6. Alignment 7 coincides with the east-west axis of the Kolomte' Group, while Alignment 8 is indicated by the line connecting lateral mounds of the South Acropolis, of which the western one is slightly taller, so that, observing there, the structure in front was probably lower than – but aligned with – the main building of the Guacamaya Complex in the background.

The orientations skewed about 8° clockwise from cardinal directions have been found both in central Mexico (Šprajc 2001: 57–64) and in the Maya area (Aveni and Hartung 1986: 12–14, 73–82; Nalda 2004: 78–80; Šprajc 2008). It may be mentioned that the orientations of the Danta Acropolis of El Mirador and of Structure 59 of Nakbe, a large Preclassic site located about 11 km southeast of El Mirador, seem to pertain to the same group (Šprajc and Morales-Aguilar 2007: 128–129). Since the association of Structure 59

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the Gregorian calendar maintains concordance with the tropical year for long periods and considering that, in our context, it is the moments of the tropical year that are relevant. Due to the intercalation system in the Gregorian calendar, as well as to precessional variations in the obliquity of the ecliptic and in the heliocentric longitude of the perihelion of the Earth's orbit (the latter element determining the length of astronomical seasons), one and the same solar declination does not necessarily correspond in any time span to exactly the same Gregorian date. The dates corresponding to the Sun's declinations in the past can be obtained, for example, with the ephemeris calculator of the NASA Jet Propulsion Laboratory, available online (<http://ssd.jpl.nasa.gov/?horizons>). The sunrise and sunset dates given in Table 1 were determined for the second century B.C., an epoch in which, according to the available datings, most buildings of El Mirador were in use (Copeland 1989; Forsyth 1989; 1993; Hansen 1990; 1992; Howell 1989; Matheny 1980; 1986). The exact dating of every structure or alignment does not have major relevance, because the dates corresponding to certain declinations remain the same during at least two or three centuries.



of Nakbe with an architectural assemblage resembling Group E of Uaxactun appears to be replicated at El Mirador, where the Danta Acropolis exhibits a similar spatial relationship with the same type of architectural compound on the Pava Acropolis (Figure 2), it seems significant that both buildings also appear to share the same orientation.

Inspecting the alignment data on this group at El Mirador (Tab. 1), we can notice that the difference between the extreme declinations of the points observed to the *east* ( $-7^{\circ}04'$  and  $-6^{\circ}48'$ ) is only  $16'$ , whereas the corresponding azimuths exhibit larger variations (from  $97^{\circ}22'$  to  $97^{\circ}50'$ ). This suggests that astronomical factors were more important for designing these alignments than geometrical ones; furthermore, if our supposition concerning the directionality of alignments, based on the altitude of the observed points with respect to natural horizon (see above), is correct, we can notice that most alignments of this group were functional to the *east*. Indeed, considering that only two possibly west-working alignments have been identified and that the corresponding declinations differ notably, it is possible that none of the two was observationally functional and that this group of alignments was intended to record sunrises only. The idea is supported by the corresponding dates and intervals: while the sunset dates (Alignments 5 and 6) are not separated by calendrically significant intervals, the east-working alignments appear to have been intended to record the dates separated by intervals of 143 (from October 11 to March 3) and 221 days (from March 3 to October 10), both of which are multiples of 13 days ( $143 = 11 \times 13$ ;  $221 = 17 \times 13$ ). Considering the estimated margin of error in the alignment data (see above), it is also possible that all alignments of this group recorded only one of the two pairs of dates.

### Group of $12^{\circ}$

Alignments 9a and 9b – identical, but functioning in opposite directions – coincide with the east-west axis of Structure 3A6-2 of the Pava Group, and possibly also agree with the orientation of the Tigre pyramid, even if the latter cannot be established with precision. Alignments 10a, 10b and 11 reproduce the east-west orientation of the triadic group on the Monos Pyramid; as one can observe on the site map, the orientation of this compound, clearly indicated by the array of its two lateral mounds incorporated in Alignments 10a and 10b (identical, but with different directionality), differs from the one manifested in the basal platform of the pyramid and pertaining to the group of  $14^{\circ}$  (see below). Most probably, the two distinct orientations belong to different construction phases, as suggested by Copeland (1989: 59). Alignments 12a and 12b (identical, differing only in directionality) correspond to the orientation of the northern triadic compound of the Puma Group, indicated by the two lateral mounds incorporated in both alignments.

The orientations of the group of  $12^{\circ}$  are found in both central Mexico and the Maya area (Šprajc 2001: 57–64; 2004b; 2008; Aveni et al. 2003). At Nakbe, one of the earliest urban centers of the Mirador Basin, such an orientation seems to be incorporated into Structure 47 (Šprajc and Morales-Aguilar 2007: 130–131). At El Mirador, some alignments of this group could have been functional to the east and others to the west. Significantly, the interval from October 22 to February 19 is 120 ( $= 6 \times 20$ ) days, while the

distance from August 23 to April 20 is 240 ( $= 12 \times 20$ ) days. It is worth noting that Aveni et al. (2003: 162) also found a concentration of dates around February 19 and October 22 in their analysis of orientations of Group-E-type architectural complexes. However, since the interval from October 23 to February 18 is 247 ( $= 19 \times 13$ ) days, it is not impossible that Alignment 12b was intended to record precisely this pair of dates.

### Group of 14°

Alignment 13 reproduces the orientation of the south pyramid of the Pava Acropolis, since it incorporates the two mounds aligned along the north edge of the upper level of its basal platform, and also coincides with the east-west axis of Structure 3D2-1, located in the western sector of the Central Acropolis. Alignments 14 and 15 are practically parallel to the former one, connecting the topmost structure (2A6-3) on the south pyramid of the Pava Acropolis with Structures 3D2-6 of the Central Acropolis and 3D3-3 of the Tigre Complex, respectively. Also the latter two buildings seem to have been oriented with their east-west axes along both alignments. This is suggested by their contours observed on the original site map, as well as by the spatial arrangement of structures in this part of the city: those enclosing the plaza northwest of Structure 3D3-3 and south of the Tigre Pyramid appear to be disposed along an axis parallel to Alignment 15, underscoring its importance, while immediately east of Structure 3D3-3, another structure (3D3-2) is placed along Alignment 15. Furthermore, the north-south axis of symmetry of the basal platform of the Monos Pyramid, prolonged northward, passes between the latter two buildings and perpendicularly to Alignment 15 (Figure 2). It should be recalled that, while the basal platform of the Monos Pyramid is skewed about 14° clockwise from cardinal directions, the upper triadic group possesses a different orientation pertaining to the group of 12° (see above).

The importance of orientations of the 14° group is attested in the distribution of architectural alignments in the Maya area in general: Aveni and Hartung (1986: 17; 2000: 55) observed a prominent peak centered at the clockwise skew of 14° from cardinal directions. This orientation group prevails in southeastern Campeche, Mexico, i.e. in the area just north of the Mirador Basin (12 of the 23 analyzed structures at 11 sites exhibit such orientations: Šprajc 2008), and it is also noteworthy that, according to Nalda (2004: 78-80), a major part of the urban layout of Kohunlich, Quintana Roo, Mexico, is dominated by orientations skewed about 13° east of north.

In southeastern Campeche, the orientations of this group correspond to sunrises around February 12 and October 30 (Šprajc 2008: 235). This pair of sunrise dates is marked also by Structure I of Becán, in the Río Bec region, as well as by a number of orientations in central Mexico (Šprajc 2000a; 2001; 2004b). In the light of these analogies, and considering that at El Gallinero and Yaxnohcah, in southeastern Campeche, two pairs of structures skewed around 14° clockwise from cardinal directions compose alignments marking sunrises on February 12 and October 30 with accuracy (Šprajc 2008: 238–239), it is highly likely that also the alignments at El Mirador, functional to the east (Tab. 1), were intended to record precisely this pair of dates. Significantly, the interval from February 12 to October 30 is 260 ( $= 20 \times 13$ ) days, equivalent to the length of the Mesoamerican ritual calendrical cycle.

### Group of 4°

The axis of symmetry of the Tres Micos Group, prolonged eastward and westward, passes over the tops of Structure 2A6-3 of the Pava Acropolis and of Structure 2D3-2 of the Monos Pyramid, respectively. Depending on the placement of observation and observed points, we are actually dealing with three alignments (16, 17 and 18; Table 1).

The intervals separating the dates corresponding to the 4° group of alignments suggest that only Alignments 16 and 18 were observationally functional: the distance from March 14 to September 30 is 200 (=  $10 \times 20$ ) days, while the interval between October 2 and March 11 is 160 (=  $8 \times 20$ ) days. The intentionality of these alignments, even if we have not identified others with similar azimuths at El Mirador, is supported by the fact that one concentration of dates recorded by the Group-E-type complexes analyzed by Aveni et al. (2003: 162) is centered on March 11 and October 2.

## Observational calendars and their use

As already mentioned, the sunrise and sunset dates corresponding to architectural orientations in Mesoamerica tend to be separated by multiples of 13 and of 20 days (elementary periods of the Mesoamerican calendrical system), and this peculiarity also characterizes the dates marked by most of the alignments we have detected at El Mirador. For a number of sites in central Mexico, it was possible to reconstruct observational calendars composed of calendrically significant intervals between the dates recorded by different alignments (Šprajc 2000a; 2000b; 2001). Two such observational schemes that may have been in use at El Mirador are shown in Table 2. In the first scheme, all of the intervals, except the one of 125 days, are multiples of 20 days, while the second one incorporates multiples of 13 days, being the one of 118 days the only exception.<sup>5</sup>

It may not be a coincidence that the two reconstructed observational calendars are associated with different buildings: none of the structures incorporated in the alignments appearing in one scheme is involved in those listed in the other one. One possible explanation is that different observational schemes were in use simultaneously, perhaps related to distinct social groups; another possibility is that they were used at different times, which could be verified only with more precise dating of the buildings involved. Notably, the dates recorded by the 14° group of alignments are not included in any of the two schemes, because they are not separated from those marked by other alignments by calendrically significant intervals. Considering that the interval from February 12 to October 30 equals the length of the 260-day calendrical cycle (multiple of both 13 and 20 days), the two dates may have composed an observational calendar of its own, but it is also possible that we have simply failed to recognize alignments marking dates that could be combined with those corresponding to the group of 14°.

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<sup>5</sup> Since the length of the tropical year is 365.2422 days, while the sum of all intervals in each observational scheme is 365 days, the observer would obviously have noted a one-day increment in one of the intervals approximately every four years.

Comparative data from other parts of Mesoamerica reveal that the observational calendars based on architectural orientations and composed of calendrically significant intervals were used for determining the most important moments of the annual climatic cycle and, consequently, for a proper scheduling of agricultural activities (cf. Aveni and

alignment	event	date	interval (days)	date
Alignments 9a and 10a (group of 12°)	sunrise	Feb 19	120	Oct 22
Alignment 18 (group of 4°)	sunrise	Mar 11	20 20	Oct 2
Alignment 11 (grupo of 12°)	sunset	Apr 20	40 40	Aug 23
			125	

alignment	event	date	interval (days)	date
Alignment 12b (group of 12°)	sunrise	Feb 18	118	Oct 23
Alignments 3, 4, 7 and 8 (group of 8°)	sunrise	Mar 3	13 13	Oct 10
			221	

Table 2: Schemes of two possible observational calendars of El Mirador (dates and intervals are to be read in the counter-clockwise direction).

Hartung 1986; Aveni et al. 2003; Šprajc 2001). The most compelling evidence supporting this affirmation is, beyond doubt, the large number of orientations recording the dates February 12 and October 30.

The alignments of this group belong to the so-called 17° family of orientations, widely spread throughout Mesoamerica. A systematic research accomplished in central Mexico disclosed that this alignment family is actually composed of two groups of orientations recording two slightly different sets of dates.<sup>6</sup> Both groups occur simultaneously at several sites, most prominently at Teotihuacan and Xochicalco. The sunrise/sunset dates recorded by one group tend to be February 12 and October 30/April 30 and August 13. In view of abundant evidence suggesting an agricultural significance of the four dates, they must have marked four critical moments in the maize cultivation cycle, corresponding to the preparation of fields (February), the onset of the rainy season and the time of planting (around May 1st), the appearance of the first corn cobs or *elotes* (August), and the end of the rainy season and the beginning of harvest (around November 1st). However,

<sup>6</sup> Depending on the dates they record, and geographic latitude and horizon altitude, the azimuths of these alignments exhibit considerable variations, mainly between 104°/284° and 108°/284°. Even if, therefore, their mean clockwise skew from cardinal directions is not 17°, the designation for the '17° family of orientations' has become conventional (cf. Aveni 2001: 234; Šprajc 2001: 27).

an additional peculiarity of the four dates is that they delimit intervals of 260 days (from February 12 to October 30, and from August 13 to April 30), equivalent to the length of the Mesoamerican ritual calendrical cycle. It has thus been argued that these dates must have been crucial moments of a *ritual* or *canonical* agricultural cycle (Šprajc 2001: 79–88, 107–120). Among ethnographic data supporting this conclusion, we can mention the popularity, among present-day indigenous communities, of Candlemas (February 2), Holy Cross (May 3), Virgin of Assumption (August 15) and All Saints and All Souls (November 1 and 2) festivals, whose ritual contents are patently agricultural; furthermore, a canonical agricultural cycle of 260 days continues to be in use among the K'iche' of Momostenango, Guatemala (Tedlock 1991).

However, while in central Mexico, in some cases, one and the same orientation records both sunrises on February 12 and October 30 and sunsets on April 30 and August 13, such alignments have not been found in the Maya area. For the four dates to be recorded by one and the same orientation, appropriate horizon altitudes are required, such as those found in mountainous regions of central Mexico; in the Maya Lowlands, however, where horizon elevations are close to 0°, these four dates cannot be marked by a single alignment. In southeastern Campeche, Mexico, the sunrise dates recorded by the most numerous orientations tend to be February 12 and October 30, whereas the sunset dates corresponding to the same orientations do not cluster around April 30 and August 13 but rather around April 26 and August 18. Since the intervals separating April 26 and August 18 (114/251 days) do not seem significant, these orientations were likely intended to record only the sunrises on February 12 and October 30, separated by 260 days. The hypothesis is reinforced by two pairs of structures at El Gallinero and Yaxnohcah, skewed around 14° clockwise from cardinal directions and composing alignments whose azimuths and, therefore, the corresponding sunrise and sunset dates can be accurately determined: both alignments record the dates February 12 and October 30 on the eastern horizon, and April 26 and August 17 on the western horizon (Šprajc 2008: 238–239). Even if the possibility that these alignments were functional (also) in the western direction cannot be discarded, analogous cases from other parts of Mesoamerica do not support the idea: while numerous orientations in central Mexico record sunrises on February 12 and October 30, the importance of the dates April 26 and August 17 has not been attested (cf. Šprajc 2001).

In the light of this evidence, it is highly likely that, also at El Mirador, the alignments of the 14° group were functional only to the east, and this conclusion is further supported by their directionality: the structures on their western ends, due to their low heights (Figure 2), would have hardly served as appropriate markers of astronomical phenomena.

Ethnographic analogies suggest that the dates corresponding to other alignment groups at El Mirador (late February and early March, April, September, October: Table 1) may have also been related with the agricultural cycle. For modern descendants of the ancient Maya, such as the Q'eqchi' and the Lacandonés, February and March are the months for preparatory works in cultivation plots and the corresponding rites, April is the time when planting starts, while the first young corn cobs appear in August or early September (Hatse and De Ceuster 2001: 89–124, 159–164; Marion 1999: 343, 356).

It should be emphasized that the dates recorded by alignments, assuming they were related to agriculture, must have had a *canonical* importance; while they probably marked critical moments for performing appropriate ceremonies, the exact scheduling of agricultural labors depended on additional, both practical and religious considerations. Modern ethnographic evidence indicates that exact moments of planting and harvesting vary from year to year, depending not only on specific climatic circumstances and maize varieties but also on the lunar phases and – where fragments of prehispanic calendar survive – even on the auguries of particular days. The canonical or ritual meaning of the dates recorded by alignments is attributable both to their approximate concomitance with important phases of agricultural year and to the properties of the intervals separating them: the multiples of 13 and 20 days not only facilitated manipulation of observational calendars; the fact that they were constitutive periods of the sacred 260-day cycle must have been the motive for which also the dates separated by these intervals became sacralized (Šprajc 2001: 79–88, 107–120, 151–155).

However, not necessarily all of the dates marked by alignments had an immediate relationship with crucial moments of the agricultural year. Some of them may have had the role of facilitating *prediction* of the most important days by means of easily manageable intervals. As the studies accomplished thus far suggest, the most important feature of observational calendars was precisely their *anticipatory* aspect related to their practical function (Aveni et al. 2003: 162–163; Šprajc 2001: 79–88, 107–120, 151–155; for illustrative ethnographic analogies from the US Southwest, see Zeilik 1985: S3, S17, S21): if the astronomers-priests could rely on various alignments, they had a better chance to accurately predict the ritually important moments of the agricultural cycle, even if direct observations of the Sun on the key dates were hindered by unfavorable weather conditions. Quite obviously, the dates appropriate for performing certain agricultural labors and related ceremonies had to be determined with due anticipation.

As argued for central Mexico (Šprajc 2001: 106), different versions of observational calendars were likely in use also in the Maya area; while based on the same principles and serving the same practical needs, they had slightly different structures and canonical dates. Discussing observational calendars in the Maya area, Aveni and Hartung (1986: 57) comment that local variants can be understood in terms of a relative autonomy of political entities, as well as of environmental variations. Considering that contemporary buildings frequently exhibit differing orientations, it can also be assumed that, even in one and the same community, different observational calendars were in use simultaneously, involving a broader range of dates and allowing a more reliable scheduling of activities in the seasonal cycle. Consequently, the presence of different orientations at one and the same site does not necessarily mean that they belong to different periods. On the other hand, it is also likely that time-dependent variations observed in orientation patterns reflect changes in observational practices, which can be accounted for by both cultural interaction among different regions and innovations imposed by rulers or the priestly class. The Great Temple of the Mexica capital of Tenochtitlan represents an illustrative example. The change in orientation of this building, observed since its Phase III commissioned by Itzcoatl, can

be understood as forming part of the ambitious program of reforms for which this ruler is well known (Šprajc 2000b; 2001: 390).

In relation with the calendrical interpretation of alignments, it should be noted that, according to Aimers and Rice (2006: 83), the Mayas had no need to rely on astronomical phenomena to determine precise agricultural dates, because 'weather and visible growth cycles clearly indicate when it is time to perform certain tasks'; a similar opinion had been expressed formerly by Thompson (1974: 94–95; cf. Aveni and Hartung 1986: 8). Nonetheless, the following ethnographic record obtained among the Mayas of Quintana Roo casts doubt on such affirmations, suggesting that seasonal changes in the nature are not sufficiently exact and reliable indicators of the moments appropriate for initiating certain activities:

El agricultor, por su parte, ha de procurar que la quema se lleve a cabo antes de que lleguen las primeras lluvias, pues, de lo contrario, quedaría imposibilitado para hacerlo, perdiendo así la ocasión de usar el terreno talado. Para preservarse de este peligro, el milpero suele acudir a alguno de los dos escribas que hay en el cacicazgo, el cual, usando un almanaque impreso en Mérida, le puede anunciar la clase de tiempo que ha de hacer en cada uno de los meses venideros (Villa Rojas 1978: 315–316).

If modern peasants, in spite of their knowledge about cyclical changes in the natural environment, use a published almanac, it is obvious that in prehispanic times, in the absence of a formal calendar maintaining a permanent concordance with the tropical year, the regulation of agricultural works must have been based on astronomical observations. Currently, when practically all indigenous communities use Christian calendar, whose saints and feasts constantly mark the dates at which certain labors and associated ceremonies must be carried out, it may be difficult to assess or understand adequately the importance that astronomical observations must have had in the practical life of prehispanic societies. However, the K'iche' of Momostenango continue to regulate their agricultural cycle by observing celestial bodies (Tedlock 1991), and there are other ethnographically documented examples of the same practice (see bibliography in Šprajc 2001: 151–155).

## **Other implications of the alignments at El Mirador**

The alignment patterns detected at El Mirador shed light on an important, though little studied problem of astronomical practices in Mesoamerica. Clearly, various buildings and architectural groups were not only oriented but also located with respect to each other deliberately, in order that, by observing from one, the other one situated sufficiently far away could have served as an exact marker of the Sun's position on important dates. In mountainous regions, prominent peaks on the natural horizon were used in a similar way: in central Mexico, for example, a number of astronomically oriented buildings have been found to be aligned to hilltops on the local horizon, which facilitated observations and even conditioned the selection of localities for construction of the most important temples (Šprajc 2001: 57). The inhabitants of El Mirador, and probably of other cities in the Maya

Lowlands, where few natural features offer such possibilities, apparently found a solution in the appropriate distribution of buildings that shaped an artificial horizon. While further systematic studies are required to establish how common this practice was, it has already been mentioned that two alignments of this kind have been found at El Gallinero and Yaxnohcah, important Maya centers in the neighboring southeastern Campeche, Mexico (Šprajc 2008: 238–239). Another example is the Governor's Palace at Uxmal, Yucatán, Mexico, oriented to the main pyramid of Cehtzuc, a small site lying about 4.5 km southeast of Uxmal: observing from Cehtzuc, Venus as the evening star, whenever it reached northerly extremes, which heralded the onset of the rainy season, could be seen setting behind the Governor's Palace of Uxmal (Šprajc 1993: 45–47; 1996: 173–178).

The fact that several buildings of El Mirador do not face in directions we have assumed to have been astronomically functional (Figure 2) agrees with analogies from central Mexico and southeastern Campeche, which allow us to conclude that the placement of the main façade or access to a building does not indicate the direction in which its astronomical orientation was functional, but was rather dictated by the symbolism and ritual associated with a particular structure, as well as by general factors of urban planning (cf. Šprajc 2001: 69–71; 2008: 240–241).

Indeed, the astronomical alignments embedded in Mesoamerican architecture and urban layouts must be interpreted as having not only a practical function but also a very important symbolic significance. The mere objective of measuring time by means of observation of celestial bodies could have been achieved without constructing monumental buildings and orienting them accurately. Hence, the astronomically oriented buildings should not be interpreted as observatories, in the modern sense of the word; while they did serve for monitoring certain celestial events, these buildings were, more than instruments for observation, a *result* of astronomical knowledge and, considering their political and ritual significance, must have had an important place in the world view and even in the cosmologically substantiated political ideology. Since the celestial order, apparently immutable and perfect, was viewed as superior to the one reigning on the earth, the parallelism between the motion of celestial bodies and cyclical changes in natural environment was interpreted in terms of cause and effect, giving rise to the beliefs according to which the events in the sky conditioned seasonal transformations in the nature. Since architectural orientations to significant rising and setting points of celestial bodies represented spatial referents of the most important moments of cyclical time, they reproduced the ideal cosmic order that guaranteed the survival of humans and of which the rulers, as men-gods, pretended to be responsible. Consequently, the astronomical alignments incorporated in temples, elite residences and other monumental buildings can be understood as a manifestation of the attempts of the rulers to recreate and perpetuate the divine heavenly order in their earthly environment. If astronomical phenomena were observed on predicted dates, they sanctioned the ideology of the ruling class and contributed to the legitimation of its power and the preservation of the existing political order (Aveni 2001: 217–222; Aveni and Hartung 1986: 8; Broda 1982; 1991; Iwaniszewski 1989: 30–31; Šprajc 1996: 21–22, 198–203; 2001: 121–122, 154–155, 411–415; 2005).



Apart from disclosing the astronomically-derived practical and symbolic motives underlying urban planning at El Mirador, the results of our analysis have another very important implication. In southeastern Campeche, Mexico, some orientations of the 14° group are embedded in the so-called triadic groups, dated to the Late Preclassic period; it has therefore been suggested (Šprajc 2008: 238–239) they predate the urban layout of Teotihuacan, designed at the beginning of the current era and so far considered as a prototype of the so-called 17° family, to which this orientation group belongs (Aveni 2001: 234; Šprajc 2000a; 2001: 203–231).<sup>7</sup> Now that these alignments have been found at El Mirador, involving structures securely dated to a time no later than the second century B.C., and in the absence of earlier cases elsewhere in Mesoamerica, it is much more likely that their origin was, in fact, in the Maya area, possibly at El Mirador itself, pending our studies of even earlier centers within the region.

The chronological priority of the alignments of this group in the central Maya Lowlands agrees with what has been stated about their directionality. If both at El Mirador and in the neighboring southeastern Campeche they were functional only to the east, as argued above, they allowed the use of a relatively simple observational calendar, which may well have been the earliest version of complex observational schemes developed later and materialized in the widespread 17° family of orientations, whose most prominent examples are found at the central Mexican sites of Teotihuacan and Xochicalco (Šprajc 2000a; 2001). Such a scenario is supported by the fact that, according to the available data, the alignments corresponding to sunsets on April 30 and August 13 appear in the Maya area only in later periods, being incorporated, for example, in the Late Classic Structure X of Chicanná (Šprajc 2004b) and in Terminal Classic and Postclassic architecture of Chichén Itzá and Mayapán (Aveni et al. 2004).<sup>8</sup>

While we can offer no definite answer concerning the place of origin of the 14° group of orientations, an allusion to it may be materialized at the huge Classic period metropolis of Calakmul, located in southeastern Campeche, about 40 km north of El Mirador. Structure I, the second highest pyramid of Calakmul, is skewed 14°19' clockwise from cardinal directions; its east west orientation corresponds to sunrises on February 12 and October 30 (Šprajc 2008: 235), whereas its north-south axis prolonged southward passes exactly over the colossal Danta pyramid of El Mirador, visible from Calakmul as a small bump on the southern horizon. If there was a purpose underlying this alignment, it must have influenced the location of Structure I of Calakmul, which obviously postdates the Preclassic Danta Complex of El Mirador: in order to incorporate both the astronomically

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<sup>7</sup> Recent excavations in the Moon Pyramid of Teotihuacan have revealed that the orientation of the earliest building, constructed around A.D. 100, differs radically from the alignments of the 17° family adopted by the later overall grid system (Sugiyama and Cabrera Castro 2007: 116). Malmström (1981: 251–252; 1997: 91–95) and Tichy (1991: 99) suggested an earlier origin of these alignments at other sites; however, since they give no precise alignment data, their affirmations cannot be confirmed.

<sup>8</sup> According to Malmström (1981; 1997), the Pyramid of the Sun of Teotihuacan and other buildings oriented to sunsets on August 13 were intended to commemorate the initial date of the Maya Long Count in 3114 B.C. However, the hypothesis is weakened by the fact that, in the Maya area, no early orientations have been found that could be confidently related to this date.

functional east-west orientation and the alignment to the Danta pyramid of El Mirador into a structure with a rectangular ground plan, i.e. with its north-south and east-west axes intersecting at right angles, the builders had to find an appropriate spot where the two relevant directions were perpendicular to each other. In fact, such a design, possibly intended to indicate the place of origin of the astronomical orientation embedded in Structure I, is not unlikely, considering that comparable symbolic alignments are found in central Mexico: many buildings with astronomical east-west orientations have their north-south axes aligned to prominent hilltops on the northern or southern horizon (Šprajc 2001: 57), reflecting the importance of mountains and of their aquatic and fertility symbolism in the Mesoamerican worldview (cf. Broda 1991).

Regarding the possible intentionality and meaning of the alignment discussed above, there is yet another piece of evidence worth mentioning. It has been argued that the Kaan dynasty, ruling in the Late Classic period from Calakmul, originally had its seat at El Mirador (Hansen and Guenter 2005: 60–61; Hansen et al. 2008; Martin 1997; Šprajc and Grube 2008: 273–274). Was the north-south alignment of Structure I of Calakmul intended to memorialize not only the source of innovations in astronomical practices but also the homeland of one of the most powerful dynasties of the Maya world?

## **Final remarks**

The analysis and arguments exposed above lead to the conclusion that the alignment patterns found in the urban layout of El Mirador represent a material remnant of observational calendars whose function can be interpreted in terms of a proper scheduling of agricultural and related ritual activities. While more elementary astronomical orientations, particularly to solstitial sunrises and sunsets, were incorporated in Mesoamerican architecture from earlier times (Aveni and Hartung 2000; Aveni et al. 2003: 163; Tichy 1991: 55–56; Šprajc 2001: 74–75; 2008: 236–237), the regularities detected in the Late Preclassic urban pattern of El Mirador constitute the earliest evidence known so far of the use of complex observational schemes attested in other parts of Mesoamerica in later periods. While some of the dates recorded by alignments marked crucial moments of a canonical agricultural cycle, others may have had an auxiliary function; since the intervals separating them were multiples of basic periods of the calendrical system, it was relatively easy to predict the most important dates, knowing the sequence of intervals involved and the mechanics of the formal calendar. This anticipatory aspect of observational calendars must have been of foremost importance, considering that cloudy weather occasionally impeded direct observations of sunrises and sunsets and that the agricultural activities and ceremonies needed to be scheduled ahead of time.

However, the astronomical alignments cannot be adequately understood only in terms of their practical function. Both at El Mirador and elsewhere in Mesoamerica they are incorporated in important civic and ceremonial buildings, revealing that the utilitarian function of astronomy was embedded in ritual and intimately related with social life, religion, and political affairs of prehispanic societies.

Archaeoastronomical investigations offer answers to a number of questions con-

cerning the nature of the concepts underlying Mesoamerican architecture and urbanism, their meaning with respect to the specific natural environment and cultural context, and their consequent role in the world view and political ideology (cf. Šprajc 2005). Moreover, as exemplified by the problem of origin of the 14° orientation group, the study of alignment patterns and their development and similarities in different Mesoamerican regions can also contribute to the understanding of processes of cultural interaction, i.e. to the solution of questions of broader significance and general interest in Mesoamerican archaeology. If further research confirms that the orientations to sunrises on February 12 and October 30 had their origin, indeed, in the Maya Lowlands, as their early appearance at El Mirador suggests, they will have to be added to the corpus of data that, as Marcus (2003: 91) points out, require a reconsideration of the alleged Teotihuacan influences in the Maya area.

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## **POVZETEK**

Doslej opravljene arheoastronomske študije so pokazale, da so bile mnoge pomembne stavbe v predšpanski Mezoameriki astronomsko usmerjene, predvsem proti Sončevim vzhodom in zahodom na določene datume, tako da so omogočale uporabo observacionalnih koledarjev, ki so olajševali učinkovito načrtovanje poljedelskih in s temi povezanih obrednih dejavnosti v letnem ciklu. Orientacije v urbani trasi El Miradorja, največjega poznopredklasičnega mesta v majevskih nižavjih (ok. 300 pr. n. št. – 150 n. št.), predstavljajo najzgodnejši dokaz uporabe takšnih opazovalnih shem na območju Majev in ponazarjajo pomen astronomskih in koledarskih dejavnikov v pojmovanjih, ki so narekovala arhitektonsko in urbano načrtovanje. Prav tako pomembno, predvsem za razumevanje kulturne interakcije v Mezoameriki, je naše odkritje, da izvor t. i. družine 17°, najbolj razširjene mezoameriške skupine orientacij, ni bil v osrednjemehiškem mestu Teotihuacanu, kot je bilo doslej splošno mnenje, temveč na območju Majev, najverjetneje prav v Miradorskem bazenu.

**KLJUČNE BESEDE:** arheologija Majev, arheoastronomija, orientacije v arhitekturi, urbanizem

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