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# The Astronomical Significance of the Clockwise Misalignment from Cardinal Directions in the Maya Lowlands

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**Abstract**

In this paper we outline the results of our archaeoastronomical study dealing with a number of Mayan settlements located in the lowlands of Campeche, Yucatan and Quintana Roo (Mexico), in order to try to explain the well- known clockwise misalignments with respect to the astronomical cardinal directions. In this work we present the results of our analysis and propose a solution of this problem. The methodology followed in our study is based on statistical methods as well as on the astronomical computations. In a preliminary research we at first analysed the topographic maps of the Mayan sites checking that the deviation of the main axes of the cities is always rotated by few degrees in a clockwise direction from the astronomical North, but with different azimuths. We have successfully tested various hypotheses on the astronomical criteria applied by the Mayan people in order to build and orient their cities, and we are able to show that exists a strict relationship between the architectural alignments and the astronomical observations of the most important stars in the framework of the Mayan religion.

**Keywords**: Maya, star, Orion, Archaeoastronomy, Astronomy

## Introduction

The Maya were great observers of the sky and of the motions of celestial bodies. The exponents of their priestly class were invariably focused in the pursuit of so-called "time measurement". For them, the time was not understood in a linear pattern as in our modern sense, that is a straight line from the past and continues into the future, but according to a cyclic applicant as was typical for

all ancient peoples. The rigorous repetition of celestial phenomena fully supported a conception of this kind. Systematic studies made recently in some regions of Mesoamerica have revealed that the distribution of monumental architectural guidance is not uniform but exhibits distinct groups, namely concentrations azimuths around certain values [1, 2, 3, 4, 5, 6].

The objective of this research is to study the architecture and urbanism of 60 Mayan cities located in the lowlands of Campeche, Yucatan and Quintana Roo (Mexico), from an archaeoastronomical point of view and in a systematical way, using a rigorous methodology. Among the possible symbolic aspects related with the foundation of a city and to be considered in the analysis of a town's project is, of course, the orientation. In particular, it has been repeatedly suggested that several Mayan towns, whose orientation does not conform to peculiar features of the landscape, were oriented in accordance with astronomical, rather than utilitarian, criteria.

It is the aim of the present paper to defend the idea that this orientation was deliberate and to set up some hypotheses in order to explain it.

## Methodology

In a preliminary research we at first analysed the topographic maps of the Maya sites checking that the deviation of the main axes of the cities is always rotated by few degrees in a clockwise direction from the astronomical North, but with different azimuths. For each site we have traced the orthogonal axes passing through the city and in each case there is a skew from north to east, ranging from 3° up to 18°, but the most are rotated slightly on its base of 14°. Mesoamerican architectural orientations tend to be skewed clockwise from cardinal directions, east of north [1, 2, 3, 4, 5, 6]. Figures 1 and 2, reproduced below, show the results obtained for the city of Becan, located in Campeche, Mexico.

Afterwards we applied different statistical techniques to many measured data kindly supplied by Prof. I. Sprajc [7]. We took into account 204 values among the 214 of the measured azimuths towards the east direction related to the structures of the 60 sites considered in our work (Fig. 1, Fig. 2).

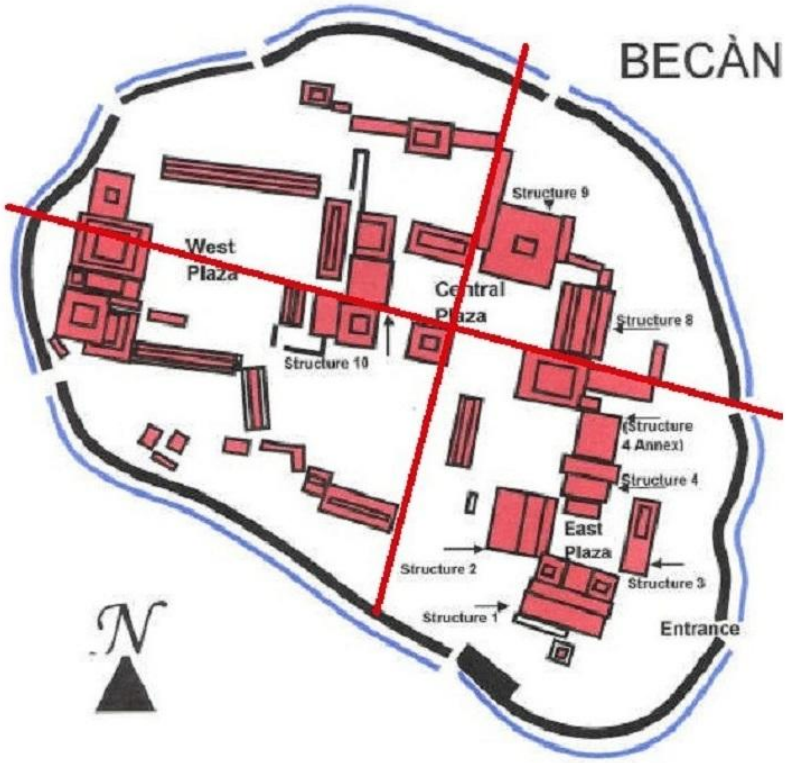

**Figure 1.** The main axes of the site Becan.


**Figure2.** Becan viewed with Google Earth. The yellow line is the azimuth West-Est

**Archaeoastronomical study**

Our first analysis of the histograms of the distribution of the azimuths in the direction east-west of all the structures, with a bin width of 1 degree, revealed the presence of two main peaks at the azimuths 99.9°±0.1° and 104.0°±0.1°, as shown in figure 3. A subsequent investigation has led us to set up different histograms for the main three periods: Preclassic, Classic and Postclassic. As the azimuths of the Preclassic structures are very few (13), the limit of the beginning and the end of the two epochs is weakly known and most of the buildings measured belongs to the Classic period, we decided to bring together Preclassic and Classic data in a single analysis. In figure 4 are highlighted the peaks of the Gaussian curves that best approximate the distribution of the azimuths

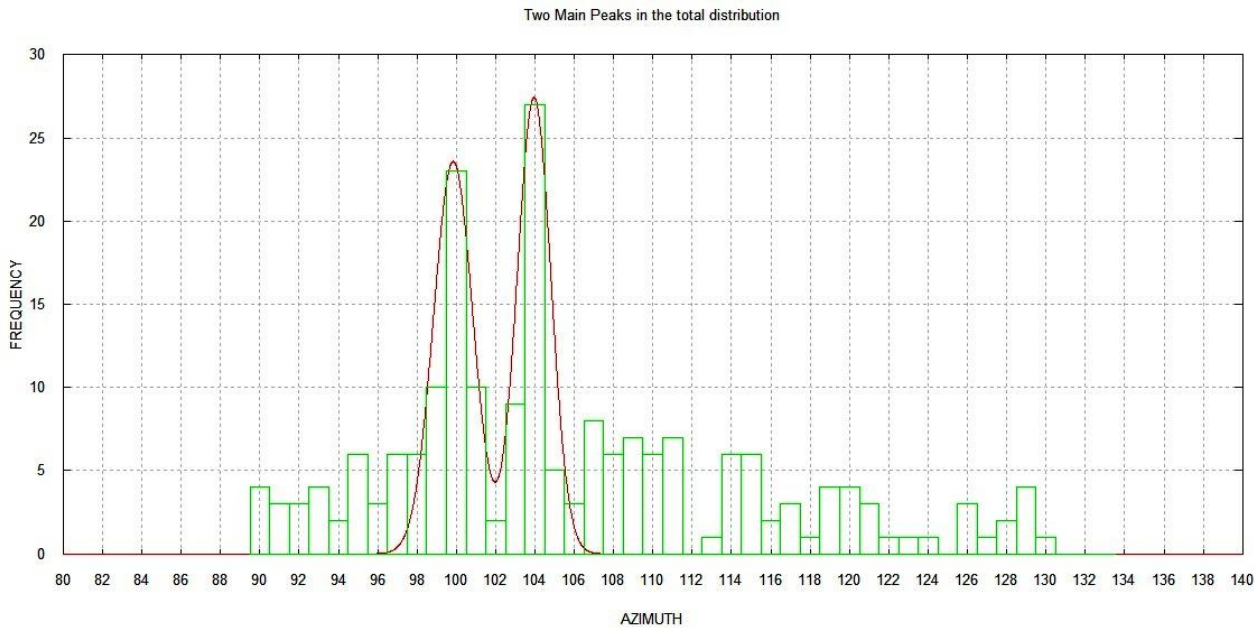


**Figure3**. Peaks of the total distribution of the azimuths in the direction east-west

whose values are 99.8°±0.2° and 104.0°±0.8°. The distribution of the azimuths of the Postclassic period shows a greater number of peaks in which the most marked correspond to the values 100.2°±0.2°,103.8°±0.2° and 107.4°±0.2°. Significant is the fact that the south-of-east skews are particularly consistent in the orientations of ceremonial structures, for which practical considerations must have been less relevant than in the case of housing units [2].

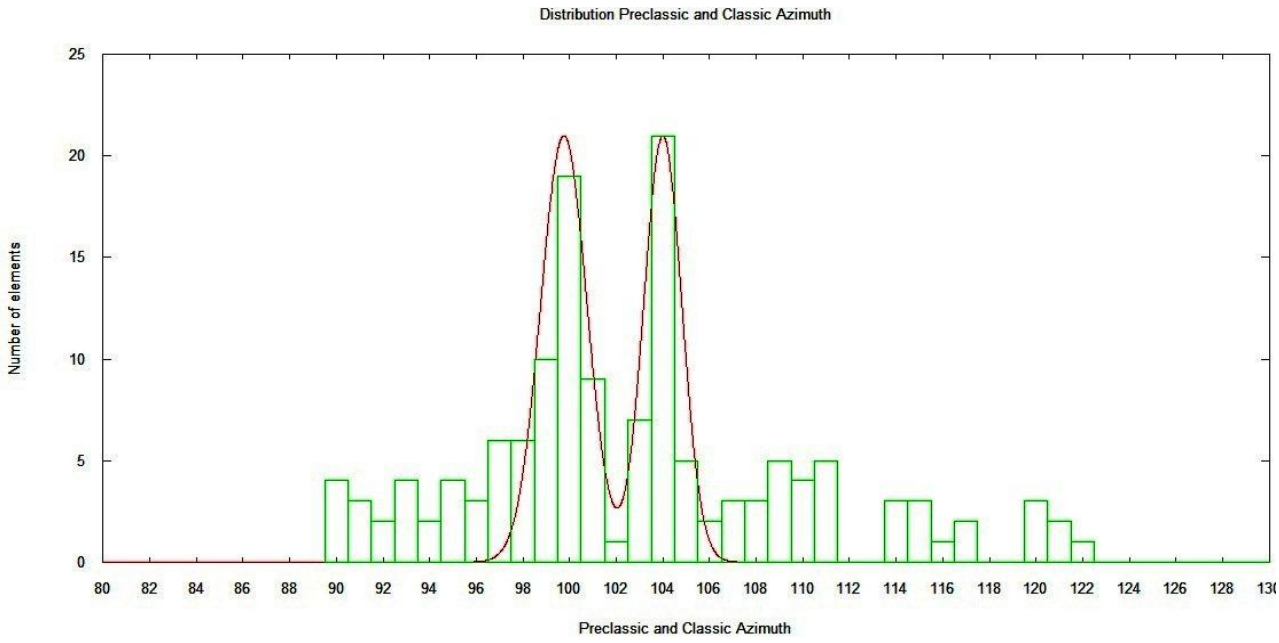


**Figure4**. Peaks of the Gaussian curves in the Preclassic and Classic Period.

Particularly revealing are the results of a recent study in southeastern Campeche, Mexico, i.e. in the central part of the Yucatan peninsula. Orientations were determined for 23 Late Preclassic and Classic structures (300 BC – 900 AD) at 11 archaeological sites [8, 9]. The most numerous orientations (12) cluster around the azimuth of 104°/284°. We have to notice that, in the distribution of architectural alignments in the whole Mayan area, Aveni & Hartung [2, 10, 11] in a previous work observed a prominent peak right around 14° clockwise from cardinal directions.

When a deliberate astronomical alignment is proposed, it is of course fundamental to investigate on the possibility of a mere coincidence. If the sample under exam is wide enough, a statistical analysis can be applied to evaluate the probability of casual alignments [12, 13].

How significant are the alignments? That is, how likely are the claimed alignments to have arisen by chance alone with no astronomical intention or knowledge? Can we reject that null hypothesis that the claimed alignments are consistent with the number expected by chance? If we find that the null hypothesis adequately explains the data, then any case for intentional alignment must necessarily be too weak to allow any mention of the claim, unless significant and specific archaeological or ethnographic evidence is proven.

While single sites can't be statistically significant, the use of multiple sites can yield very strong rejection of the "*null hypothesis*", relating to the orientation by chance, so we are able to demonstrate the intentional orientation. Although we need information coming from archaeological, historical and ethnographical data, to prove the knowledgeable intent of the builders.

We therefore applied the Schaefer test [14, 15], which is a probabilistic analysis of the results of the archaeoastronomical research carried out in an archaeological site. It is the estimation of the probability that one or more lines found in a site are not astronomically significant but due only to a relevant combination of some random events. Our software performs the Schaefer "$3\sigma$ Gaussian test" [14, 15]. We assumed that the "*null hypothesis"* Ho is the random orientation and the alternative hypothesis *H1* is the deliberate orientation along the inferred directions. The decision criterion *Ho* has to be rejected if $z>3$, that is equivalent to say $Pn(random)<P(3\sigma)$ and where "z" is a standard Normal random variable, *Pn(random)* is the probability that the direction of the orientation is chance, $P(3\sigma)$ is the tabulated integral of the Gaussian Function. Adopting a 99.73 confidence level the value is $P(3\sigma)$=0.0027 and corresponds to a probability that the alignment is intentionally oriented. For the average value of the azimuth 99.8° we obtained a random probability *Pn*=0.0004 and then a probability of genuine anthropic line *Po*=99.96%; for the average value of the azimuth 104.0° a random probability *Pn*=0.0004 which implies a probability of genuine anthropic line *Po*=99.96% again. These data confirm that the measured misalignment passed the "$3\sigma$ Schafer test".

In this way we have calculated, and we emphasize, that the predominant orientation of the monuments in the Mayan cities studied here present two significant values of the azimuths, but this result alone doesn't mean that these two peaks are correlated with the values of the azimuths of any star of the Orion Constellation. It just means that the Gaussian distribution that approximates the distribution of the azimuths is correct.

From an ethnographic point of view in the Maya culture the Orion Constellation is associated with the Creation Myth in the Popol Vuh [16, 17] and in the *Chilam Balam Book of Chumayel [18]*. The stars of Orion are visible at this latitude for many months in the year, from mid - June until the following May.

With this work we assume that the target which sought the global orientation of the principal axes of the Mayan cities were two stars of the Orion Constellation.

We considered the values of the azimuths of the stars of the Orion Constellation and we studied if there is a correlation between the peaks of the data obtained with the measurements and the values of the azimuths of Orion.

In the reference pattern 3 stars are involved: Rigel (β Ori), Alnitak (ζ Ori),Saiph (k Ori) which are the three stars that symbolize the Mayan hearth, while ι Orionis, that is near the Nebula M42, represents the flame and the smoke. The hearth was and is the very foundation of the Maya home. The orientations of the monumental architectures, leading to the orientation of the main axes of the sites, reveal that the 2 main peaks with a value of 100° and 104°, indicate a well-defined, delineated and exact area of the sky.

We have considered that in the Mayan culture it is very important the time of the year when the stars ι Orionis and ζ Orionis are rising for the first time and can be seen from the horizon up to the sky, as explained below in the paragraph of cultural relics and evidence.

Using astronomical simulation software (Skymap) and software specially developed by us (A.Gaspani), our computations show that the heliacal risings of these stars always occur, over the centuries between 200 A.D. and 600 A.D., in days whose dates are contained between June 29 and July1 for ι Orionis and between June 22 and June 24 for ζ Orionis. Furthermore we have calculated the first visibility azimuths of the heliacal rising and the last visibility azimuths of the heliacal setting of the stars ι Orionis and ζ Orionis (Alnitak) in different historical periods at different values of latitude and we have obtained for ι Orionis a variation of the values of the

azimuths approximately of 1.0° in a period of 400 years, from 200 AD with an azimuth of 104°37' to 600 A.D. with an azimuth of 103°31' and also for ζ Orionis the variation is of almost 1°, in 200 AD with an azimuth of 100°27' and in 600 AD the azimuth is 99°20'. Considering that the main and most important buildings were built in the period between 200 AD and 600 AD, it is possible to bethink the orientation of the sites along almost the same direction. As we can argue from Tab.1 the most important structures of the Early Classic period, that overlaps with the Preclassic, and Late Classic Period have been built in order to be oriented at 100° and 104°. It is remarkable that these values of the azimuths are predominant and recurring.

In order to estimate the cross correlation between the orientation and the direction of the visibility of the target stars we applied some techniques dealing with the statistical Analysis of Circular Data (Azimuths) [19].

Von Mises distribution (also known as the circular normal distribution or Tikhonov distribution) is a continuous probability distribution on the circle. It is a close approximation to the wrapped normal distribution, which is the circular analogue of the normal distribution for data defined with directional coordinates. We can represent the azimuths defined on the horizon as vectors of unit module with different directions, therefore we can't integrate the Gaussian function from minus infinity to plus infinity as the horizon is circular. We must apply the "normal distribution of circular data", or Von Mises distribution, where we integrate the distribution function over the range $[0,2\pi]$. We have calculated the probability that there is a correlation between the values of the peaks obtained with the measures, called A2, and the values of the azimuth of Orion, called A1, our target. Relative to the star ζ Orionis, where A1 is 99.84° and A2 is 100.45°, we have achieved a value of probability of 0,006% that is random and that matches to the probability of 99.994% of cross correlated alignments; while for the star ι Orionis where A2 is 104.18° and A1 is 103.96° we had a probability of a random alignment of 0.001% that is the 99,999% of intentionality. In both cases since the probability of an intentional alignment is greater than the standard reference level of 99,73% corresponding to a $3\sigma$ level on the wrapped Gaussian distribution, we accept these results as significant.

These important results allow us to support the thesis that the orientation of the principal axes of the Mayan cities were deliberately clockwise skewed as to collimate the position of the two stars in the sky.

**Ethnographic and culture evidence**

A means of proving intention is whether there is any ethnographic information that indicates similar practices or knowledge within associated communities. So the question is then whether we can find any such evidence for the key features of the claimed alignment.

The rite of worship the Creation and the Gods of the Creation was strongly felt by the ancient populations. Maya people demonstrated their veneration building imposing structures aligned with the direction of the celestial bodies that symbolized that event.

The Maya have extensive written texts that now have been translated [20] and they have cultural descendants well-studied by ethnographers.

The Maya would study the heavens for divination purposes [21]. The celestial bodies exert direct control over the affairs of man [22] and as far as the Maya were concerned, astronomy was astrology [23]. As Thompson [24] stated, "astronomy is the handmaid of astrology." From the above we can get confirmation of our statements from the tradition passed down in their lyrics. People of strong religious traditions and a highly conservative spirit such as that of the

Mayas could not do without their sacred books, the crux of their identity and that is why some noble Mayas, that were educated by Spanish friars, that had learned the Latin alphabet were determined to preserve their traditions, history and religious beliefs by writing books in their own languages, but with the new form of writing brought by the conquerors, so during the 16th century indigenous books came out in communities in Guatemala as well as in Chiapas, Yucatán and Tabasco.The "*Books of Chilam Balam*" are handwritten, and preserving important traditional knowledge in which indigenous Maya and early Spanish traditions have coalesced. One of the most important is "*Los libros de Chilam Balam de Chumayel".* Here we can read: «Y fue creada la Piedra que fundó las piedras, las Tres Piedras que fueron a asentarse a los pies de la *Sustinal Gracia....» (pag.57, Anonimo).* «And was created the Stone that founded the stones, the Three Stones which were to settle at the foot of the Sustinal Grace ....». In these words we can find references to Three Stones fundamental to the Mayan culture.

The most complete description of the beginning of human life is given in the Popol Vuh of the Postclassic K'iché Maya, but the Murals recently discovered in the Pre Classic (250 BC) site of San Bartolo in Guatemala, confirm that the Popol Vuh, is the true and Original Maya creation Myth. The Popol Vuh, literally as "Book of the People", is the most important sacred book of the Maya and was preserved by the Postclassic K'iche' Maya, in the Guatemala Highlands. The book itself dates to the mid-16$^{th}$ century and it probably was originated as a transcription in Spanish alphabet of an older pre-Hispanic text. In the 18$^{th}$ century the Spanish friar Francisco Ximenez translated the document into Spanish. It is the creation story of the Maya and recounts the first attempts of the Creator, Heart of Sky to make humans. In this book, Orion was seen as the First Father, the Maize God.

The most interesting data concerning Mayan constellations are contained in the prehispanic manuscript known as the *Paris Codex*. The images on pages 23 and 24, mostly representing animals hanging from celestial bands and accompanied by dates, have been interpreted by various researchers as a Maya zodiac, even if there is no agreement about the functioning of the table and the identity of constellations represented by different images [1, 25, 26, 27, 28].

In the Madrid Codex Orion is depicted as a turtle with three tun ("stone") glyphs on its back. The turtle shell is an earth symbol; this is the place of Creation, where the sky will rise and saw the nearby ecliptic constellation of Gemini as the mother peccary and the belt stars are her children (Schele). Because the sky has not yet been raised, the hearth is a location in both earth and sky. In addition, the Maya used three stars in the constellation Orion: the great blue giant, Rigel, β Orionis; the star Saiph, K Orionis, and the belt star, Alnitak, ζ Orionis. These three stars form an equilateral triangle called, "The Three Stones of the Hearth". They represent the Maya hearth, made of three stones placed in a triangular pattern. In the center of the Three Stones of the Hearth, there is the Orion nebula, M42, and it acts as the flame. Toward dawn on the Creation night of Aug 13, the constellation Orion moves toward the zenith. The K'iche' people still refer to a triad of three bright stars in Orion as "the hearth stones", and the hazy nebula below Orion's belt is called "the smoke from the hearth". In figure 5 there is the reconstruction of the Mayan "hearth" preserved in the Maya Museum of Chetumal, while in figure 6 is shown the triangular pattern.

**Figure 5.** Mayan "hearth" preserved in the Maya Museum of Chetumal.

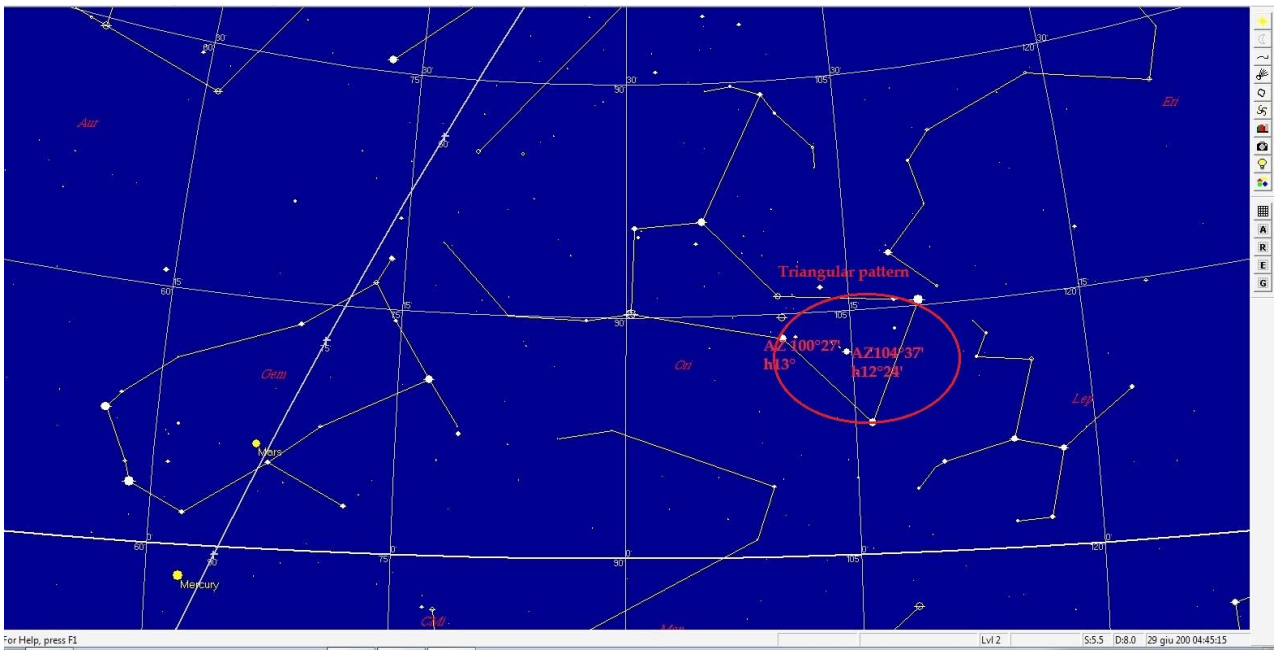


**Figure 6.** The triangular pattern of the "hearth" in the sky.

Furthermore the story of creation is depicted on Stela C, an immense stone monument in the center of the city, Quiriguá, in Izabal (Guatemala), and gives us the most detailed information about the first moment. This monument bears the longest single hieroglyphic description of the Maya Creation Myth, noting that it took place on the Maya calendar's day 13.0.0.0.0, 4 Ahaw, 8 Kumk'u, a date corresponding to August 11, 3114 BC (-3113) on our calendar in Gregorian date, using the GMT correlation constant 584283. On that day the Creator Gods set Three Stones or mountains in the sky after lifting it with the sacred tree of life, from the dark waters that once covered the primordial world. These three stones formed a cosmic hearth at the center of the universe. The gods then struck divine new fire by means of lightning, which charged the world with new life.

In Maya iconography, the Orion's Belt asterism is linked to a turtle , which is also linked to the creation, "probably because of the appearance of the swampy, watery world in which [the turtle] dwells" [29] and in the *Madrid Codex*, the turtle is seen bearing "the three hearthstones of creation on his back as he descends from heaven" [29], as shown in figure 7. It is from the back of a turtle, representing the earth, that the Maize God, or First Father, arises [30]. Thus, the turtle is important in that it simultaneously represents the underworld, the earth, and the sky, a tri-level symbolism linking all three realms of the cosmos, which in itself correlates with the trinity of stars in the Orion's Belt asterism.

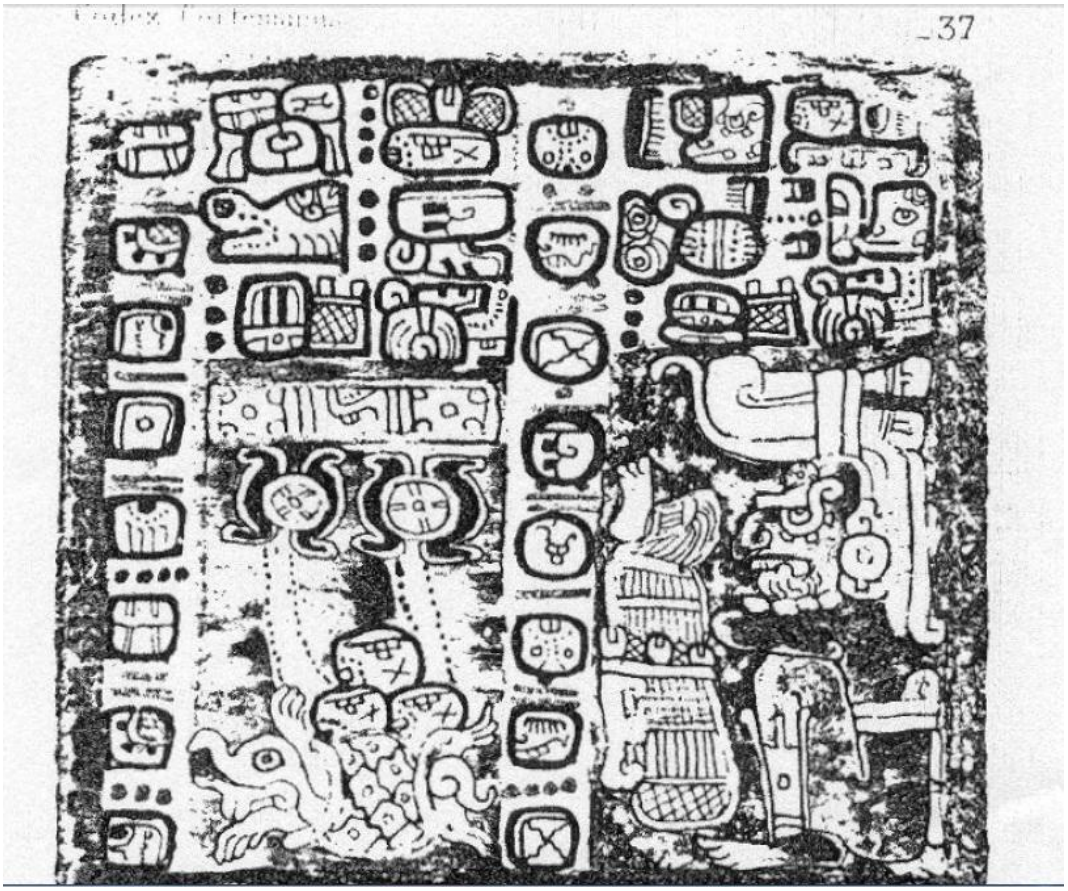


**Figure 7.** Madrid Codex. The turtle and the three stones

At Quirigua and Palenque, the scribes specified further that the place where these stones were set was "Lying-down Sky First Three-Stone-Place". Years ago it was recognized that this First-Three-Stone-Place had to refer to the three thrones, and [31, 32] further associated these stones with the descriptions of the creation in the Book of the Chilam Balam of Chumayel.

A study based on a number of sites with monumental architecture in central Mexico has revealed that the alignments allowed the use of observational calendars [7]. We can say that the alignments with the clockwise skew from cardinal directions, recording the dates in the dry season on the eastern horizon and those in the rainy season on the western horizon, reconciled observational necessities with the symbolism associated with the eastern and western parts of the universe. The correspondence between the most frequently recorded dates and the crucial moments of the cultivation cycle suggests that the observational schemes, reconstructed for a number of sites, served for predicting important seasonal changes and for an efficient scheduling of the corresponding agricultural and associated ritual activities [2, 6, 8, 9, 33, 34, 35].

If this interpretation is correct, it represents a cosmological rationale for one of the most pervasive features of architectural planning in the Maya area and in Mesoamerica in general [7, 36].

**Figure 8**. Orion above a pyramid at Tikal.

Even if the observational function of architectural orientations indicates their relationship with practical needs, which is in accordance with what we know about the adaptive value of astronomical knowledge and its consequent importance in archaic civilizations [2, 37, 38, 39], the alignments cannot be understood in purely utilitarian terms. As the repeatedly occurring directions are most consistently incorporated in monumental architecture of civic and ceremonial urban cores, entailing considerable effort, they must have had an important place in the worldview and even in the cosmologically substantiated political ideology.

## Conclusions

Planning the construction of a city in ancient populations is a ritual of religious, astronomical, environmental, landscape and knowledge and required to have a select few who were the keepers of these secrets. The orientation and location of the cities, from a symbolic point of view, were crucial to the development and prosperity of the people and it was important to make sure it was born under the protection of the gods.

As we said before Maya priests were obsessed with knowing time. They believed that time was cyclical and the events in the past were the same as events in the present or future, that there were good days and bad; the best way to cope with the bad days was to keep records and search those records for similarities. That way, a proper ritual could be followed to mitigate the bad effects; furthermore for them the conditions in the heavens were a portent of situations on earth. Careful

observation, record keeping, and experimentation are a major part of scientific investigation and the Maya priest kept records of celestial observations to make predictions.

That's why it should be very important to build a new city under the best auspices. To align a city towards the stars of Orion constellation, the Creator of the Humanity, represented thus the greatest protection.

We wish to stress that our work is focused on the explanation of the clockwise misalignment of the orientation of the whole city, not of each structure, which individually can have its one alignment, as for example the "E-Group" structures which could be used to in order to mark the rising points of sun, the moon at the standstills and the rising points of the five naked-eye planets [7, 40, 41, 42, 43].We suggest that a possible model of the orientation of a Maya city could include the following steps: selecting the right place, to proceed with the deforestation of the area, to define the line of orientation of the main axes of the city towards the point of rising of Orion Nebula (the fireplace), as in figure 8.

In conclusion we strongly believe that the clockwise misalignment of the Mayan cities is due to the desire to align the main axes of the cities to the rising of Orion constellation.

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