



## **THE MESOAMERICAN 6,940-DAY CYCLE RECONSIDERED**

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### **ABSTRACT**

In 1931 John Teeple first proposed that the dates recorded on Stela A at Copán evidenced the Classic Maya knowledge of the Metonic cycle. While his Determinant Theory has long been fully discredited, scholars' explanations of a 6940-day period have been diverse (e.g. Morley, 1920; Spinden, 1924; Chambers, 1965; Alexander, 1988). The information, however, is not self-evident. At best, the use of the 235-lunar month cycle may only be inferred from a limited corpus of documents, but cannot be confirmed (Bricker and Bricker, 2011). While it may be imprudent to firmly dismiss the hypothesis concerning the Maya awareness of the Metonic cycle, it seems that even if the Maya has some knowledge of it, in practice this knowledge had never been consistently used or disseminated.

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**KEYWORDS:** Metonic Cycle, Lunar Series, Maya astronomy, Nahua astronomy

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## 1. INTRODUCTION

The Metonic cycle is a well-known calendaric device in which 19 solar (tropical) years are equal to 235 lunations and 6,940 days. Discovered in the latter half of the fifth century BCE by the Athenian astronomer Meton, the cycle was used to help to determine the length of the year. The relationship of 19 solar (tropical) years with 235 synodic months ( $19 \times 365.2423 = 6,939.6$  days,  $235 \times 29.530584 = 6,939.69$  days) gives a year length of  $365 + 5/19$  days ( $6,940 : 19 = 365.26316$  days; see Dicks, 1970: 87-89; Goldstein and Bowen, 1983: 337-338; Hannah, 2005: 52-58; Lehoux, 2007: 88-93; and Neugebauer, 1975: 622-623). For present purposes it is irrelevant whether Meton and Euctemon invented the 19-year cycle independently or borrowed it from the Babylonians (Bowen and Goldstein 1988; Hannah 2007: 85).

All Greek calendars of that epoch were lunar and the beginning of the new month was defined, at least in theory, by the visibility of the first lunar crescent. In practice, however, lunar-based periods followed a fixed sequence of "full" (30-day) and "hollow" (29-day) months rather than relying on current observations. Calendars of diverse city-states were not synchronized with each other, and decisions made to start a new month or to intercalate an additional month were determined by various religious and political circumstances (see Dicks, 1970: 89; Hannah, 2007: 73-82; Stern 2012: 29-35, 62-70).

## 2. THE CLASSIC PERIOD EVIDENCE

The Maya did not develop lunar or luni-solar calendars, but instead utilized the Long Count system consisting of five basic units denoting days (*k'in*), 20 days (*winal*), 360 days (*haab'* or *tuun*),  $20 \times 360$  days (*winkhaab'* or *k'atun*), and  $400 \times 360$  days (*pik* or *bak'tun*). The Long Count system operated with the 260-day and 365-day components of the Calendar Round ( $73 \times 260 = 52 \times 365$  days) and counted days elapsed from the chronological base-date at 13.0.0.0.0 4 *Ajaw* 8 *Kum'ku*. The most significant stations of the Long Count system were period end-

ings (*tuun*, *k'atun* and *bak'tun* endings falling on 5, 10, 13, 15 and 0), often celebrated by rulers in public ceremonies. *K'atun* endings (7,200-day cycles) were easily identified by juxtaposed Calendar Round components and named by their ending day, always a day *Ajaw* (e.g. *k'atun* 4 *Ajaw*). A full cycle of 13 *k'atuns* served to make prophecies.

Maya year (called *haab'*) consisted of 18 units of 20 days plus 5 added days, for a fixed total of 365 days. Because there were no leap years, their 365-day year shifted in relation to the tropical year at a rate of about 1 day in 4 years. It is generally assumed that the Maya year followed this shifting course until the Spanish Conquest in early 16<sup>th</sup> century (Bricker and Bricker, 2011: 489-690).

According to Geminus, a Hellenistic astronomer and mathematician living in the first century BCE, each round of the Metonic cycle contains 110 "hollow" and 125 "full" lunar months ( $110 \times 29 + 125 \times 30 = 6940$  days) (see Dicks, 1970: 87-88; Hannah, 2007: 56; Lehoux, 2007: 91-93). The Classic Maya (200-1000 CE) texts incorporated the lunar cycle into the Long Count in the form of the Lunar Series, representing a continuous lunar count and consisting of alternating 29-day and 30-day units, a rough correspondence with hollow and full lunar months. The ancient Mesoamericans, who did not write fractions, would have observed that the time interval of 235 lunar months would be either 6,939 or 6,940 days (the nearest integral numbers).

The Maya Lunar Series go back to mid-fourth century CE, but evidence of how they were structured starts in the seventh century CE. The Lunar Series registered three types of information about the lunar cycle: the age of the current moon, the number of lunar months completed in 6 and/or 18 differentiated months, and the alternating of 29 and 30-day formal months (Aldana, 2006; Linden, 1996; Rohark, 1996; Schele *et al.*, 1992). During the Late Classic period (ca. 600-900 CE) the sequence of 6 and/or 18 months was fixed and represented by the so-called Glyph C, which was

composed of two variable elements: numerical coefficients running from 1 to 6 and three head variants: skull(s), a young female (f) and a young male or mythological being (m). This provided the following sequence: 1-6Cs, 1-6Cf and 1-6Cm, meaning that 6 lunar months patronized by a skull were followed by 6 lunar months under the auspices of a young female and followed by 6 lunar months governed by a young male or a mythological being. According to the Metonic Cycle rule, the Moon should recur to the same phase, or the same moon age, after each round of this cycle (after either 6,939 or 6,940 days).

### 2.1 A 6,940-day cycle on Stela A at Copán

The use of a 6,940-day cycle in Mesoamerica is inferred from a hieroglyphic text displayed on Stela A at Copán. The text opens with the Initial Series date of 9.14.19.8.0 12 *Ajaw* 18 *Kumk'u* (date 1, 731 CE) and moves 60 days backward to 9.14.19.5.0 4 *Ajaw* 18 *Muwan* (date 2, 730 CE). Sylvanus Morley (1920: 221-223) was first to notice that the second date occurs 6,940 days after the *k'atun* ending on 9.14.0.0.0 6 *Ajaw* 13 *Muwan*, not cited in the text (reconstructions in brackets):

$$\begin{array}{l} [9.14.0.0.0 \ 6 \textit{ Ajaw} \ 13 \textit{ Muwan}] \\ [+ \quad \underline{19.5.0.0} \ ] \ [6,940 \ \text{days}] \\ = 19.14.19.5.0 \ 4 \textit{ Ajaw} \ 18 \textit{ Muwan} \end{array}$$

Finding the same time interval on Stela I (wrongly reconstructed), Morley (1920: 178-180; 222) proposed that subtracting 260 days from the nearest *k'atun* date would have marked the start of the ceremonies dedicated to the end of that *k'atun*, that is, 6,940 = 7,200 - 260 days. A few years later Herbert J. Spinden (1924: 143) noticed that this cycle corresponded to a whole number of solar years and suggested that the Maya utilized a rule of thumb saying that "one *k'atun* less a *tzolk'in* equals 19 tropical years". The Metonic cycle was not identified with this interval yet (Spinden, 1924: 175).

John Teeple (1931), who believed that Maya astronomy reached the level of competence comparable with that of the Old

World, first proposed that the 6,940-day interval inferred from the text recorded on Stela A reflected the knowledge of the Metonic cycle. This finding allowed Teeple to show that the Maya calculated the length of the tropical year. His theory of determinants holds that some dates displayed in Maya monuments represent corrections between the wandering 365-day solar year and the true tropical year computed from the start of the Long Count date at 13.0.0.0.0 4 *Ajaw* 8 *Kumk'u*. Maya "determinants" express the accumulated error of days since the start of the Long Count. Today we know that "determinant" dates are in fact historical dates.

Since then, Stela A has served as an emblematic monument evidencing the Maya knowledge of the Metonic cycle. This, however, needs to be treated with great caution, since Teeple's theory of determinants, used to reconstruct astronomical methods of the Maya, has long been proved wrong (e.g. Satterthwaite, 1947: 135-142; Berlin, 1986: 50-51; Coe, 1994: 126-127,168).

To begin let me note that Stela A was erected in 731 CE by Waxaklaju'n U B'aah K'awiil, the 13<sup>th</sup> ruler of Copán, who reigned between 695 and 738 CE (Martin and Grube, 2008: 203-205). The monument was set up in one of the most important public spaces at Copán, the Great Plaza, to commemorate the *k'atun* ending of 9.15.0.0.0 4 *Ajaw* 13 *Ya'ax* (731 CE). The ceremony was attended by noblemen representing the four most important Maya polities: Tikal, Calakmul, Palenque and Copán. The stela portrays the ruler, shown in the guise of a deity (Copán's patron god?), in a ritual performance to ensure the renewal of life on earth and the fertility of maize (Reents-Budet, 2010: 59, 62). The hieroglyphic text contains four dates (see Table 1):

1) 9.14.19.8.0 12 *Ajaw* 18 *Kumk'u*, which refers to the planting of the stela, its erection.

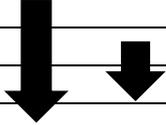
2) 9.14.19.5.0 4 *Ajaw* 18 *Muwan*, the date that describes the dedication of a skull and bones to honor K'ahk' U Ti' Chan Yo-paat, the 11th ruler at Copán (reigned 578-628 CE) and the grandfather of the present

ruler. The ruler's blood sacrifice and vision quest rituals are also recorded on Stela H.

3) 9.15.0.0.0 4 *Ajaw* 13 *Ya'ax*, a period-ending ceremony. The same period ending is commemorated on Stela B.

4) 9.15.3.0.0 12 *Ajaw* 13 *Mahk*, a final dedicatory ritual, in the presence of the noblemen from Tikal, Calakmul, and Palenque.

**Table 1. The 260-day cycles as displayed on Copán Stela A. *Ajaw* days are shown in bold. Symbols: LC - Long Count, CR - Calendar Round.**

Date	LC and CR dates	260-day cycles
1	9.14.19.8.0 <b>12 <i>Ajaw</i></b> 18 <i>Kumk'u</i>	
2	9.14.19.5.0 <b>4 <i>Ajaw</i></b> 18 <i>Muwan</i>	
3	9.15.0.0.0 <b>4 <i>Ajaw</i></b> 13 <i>Ya'ax</i>	
4	9.15.0.3.0 <b>12 <i>Ajaw</i></b> 13 <i>Mahk</i>	

## 2.2 Interpretations of Stela A dates

At first glance, recorded dates do not show astronomical cycles, but rather display calendrical series. First, it commemorates one of the major *k'atun* endings (divisible by 5, three-quarters of a *bak'tun* cycle), contains a Calendar Round date of 4 *Ajaw* presumably reminding Maya computists of the anniversary of the era date of 4 *Ajaw* 8 *Kumk'u*, and displays dates that mark two 260-day intervals (see Table 1; also Morley, 1920; Spinden, 1924). Celebrations of a 260-day sacred cycle are known from other Maya cities (Alexander, 1988; Berlin, 1986: 46; Schele and Grube, 1992), but their meanings are not well known.

Alternative interpretations of Stela A dates were offered by Alexander (1988) and Schele and Grube (1992) who aimed to link the dates from Stela A with the Venus cycle. However, this appears to be both very imprecise and doubtful (see Table 2).

By studying a pattern of dates in the life of Waxaklaju'n U B'aah K'awiil, Schele and Grube (1992: 11) correlated the second date on Stela A, 9.14.19.5.0, with a 4-*k'atun* (28,800 days) anniversary of the placement of Stela 3 at 9.10.19.5.0 12 *Ajaw* 3 *Kayab* (652 CE) by the twelfth Copán ruler, K'ahk' U Ti' Witz' K'awiil. *K'atun* anniversaries were important events to be recorded on monuments.

Furthermore, Schele and Mathews (1998: 156) argued that Waxaklaju'n U B'aah K'awiil selected the date of 9.14.19.5.0 in

order to have the Milky Way and the celestial vault in the same position as they were on the days referred to on Stela 3. The principal dates on Stela A (9.14.19.8.0 = Feb. 3, 731 CE) and on Stela 3 (9.10.19.5.10 = Feb. 7, 652 CE) are within a few days of February 5, one of the two dates related to the Maya Creation myth, and associated with important positions of Venus (see Table 2) (Schele and Mathews, 1998: 156-157). Interestingly, the hypothetical start of the Metonic Cycle at 9.14.0.0.0 (711 CE) denotes also the first *k'atun* ending ceremony celebrated by Waxaklaju'n U B'aah K'awiil (who acceded at 9.13.3.6.8 7 *Lamat* 1 *Mol*, or 695 CE).

Finally, Stela A records Glyph Y followed by K'awil, which resemble the glyphs representing either a 7-day cycle (Glyph Z is lacking) or the 819-day count (four or five glyphs are lacking). Since in both cases the phrase on Stela A is not complete, its meaning must be different, and is not necessarily a numerical (Yasugi and Saito, 1991: 10-11).

Dates on Stela A may also be used to track a solar anniversary of the era date 4 *Ajaw* 8 *Kumk'u*. The first date, 9.14.19.8.0 12 *Ajaw* 18 *Kumk'u*, falls only 10 days after this event (18 *Kumk'u* - 10 days = 8 *Kumk'u*; thus 9.14.19.7.10 = 1,403,790 days = 365 x 3,846). In a similar way the second date, 9.14.19.5.0 4 *Ajaw* 18 *Muwan*, marks a 260-day anniversary of a *tzolk'in* component of the era date.

**Table 2. Venus synodic cycle and the dates on Copán monuments. IS - Inferior Conjunction, SC - Superior Conjunction, correlation factor: 584,283. Venus dates according to Meeus (1995: 413-426).**

Monument	Date	Gregorian date	Days after conjunction	Important moments in the cycle
Stela 3	9.10.19.5.0 12 <i>Ajaw</i> 13 <i>Kayab</i>	26.01.652	59 days after the IC, Morning Star	Morning Star
	9.10.19.5.10 9 <i>Ok</i> 3 <i>Kumk'u</i>	5.02.652	69 days after IC, Morning Star	Morning Star, near to the max. western elongation
Stela A	9.14.19.8.0 12 <i>Ajaw</i> 18 <i>Kumk'u</i>	1.02.731	13 days after the SC	Invisible
	9.14.19.5.0 4 <i>Ajaw</i> 18 <i>Muwan</i>	3.12.730	47 days before the SC	Morning Star, last days of visibility
	9.15.0.0.0 4 <i>Ajaw</i> 13 <i>Ya'ax</i>	20.08.731	75 days before the IC	Evening Star near to the max. eastern elongation
	9.15.0.3.0 12 <i>Ajaw</i> 13 <i>Mahk</i>	19.10.731	15 days before the IC	Evening Star

Another explication of the dates displayed on Stela A was offered by Teeple (1931: 71-72). Teeple says that Maya “determinants” express the accumulated error of days since the start of the Long Count; for example, the date of 9.15.0.0.0 specifies 1,404,000 days elapsed from the “base-date”, which may be converted into 3,844 tropical years plus 9 days, or 3,846 365-day *haab'* years plus 210 days. The difference between these two numbers is  $2 \times 365 = 730 \pm 200$  (actually 201) days, indicating that the *haab'* years “moved” 2 years and 201 days along the tropical year. The first date displayed on Stela A, 9.14.19.8.0, remains 200 days before *k'atun*, ending at 9.15.0.0.0. The problem with Teeple’s theory is that it assumes *a priori* that the Maya already knew that their *haab'* had shifted in relation to the seasons by just **under one day** in four years, so they were able to compute how much the solar tropical year had exceeded their 365-day year. However, the Metonic Cycle used by Teeple to show that the Maya computed the length of the tropical year produces a year of  $365 + 5/19$  days, suggesting that the Maya *haab'* shifts **over one day** in four years in relation to the solar year defined by the Metonic Cycle.

The Maya calendar was invested with diverse symbolic meanings that could have been appropriated by Waxaklaju'n U B'aah

K'awiil to produce authoritative statements. The Stela A mentions the *k'uhul ajaw* of the four major Maya polities in the context of period-ending (= time-renewal) rituals. Following this line of argument, this may reflect the Maya model of an ordered quadripartite settlement space and the emergence of sentiments of a pan-Maya identity (Wagner, 2006: 15-17). On this basis it may be argued that the *k'atun* ending ceremony at 9.15.0.0.0 symbolically recreated or reordered concepts of space and time according to Copánec Maya cosmivision. The count of 260-day periods was part of this process.

### 2.3 Doubts about the Metonic Cycle

Now, let us adopt a more empirical approach, and attempt to assess whether there is any evidence in the sources themselves to support the regularity of the lunar cycle as provided by the calculation of the hypothetical Metonic Cycle on Stela A.

Date 1 on Stela A is followed by the Lunar Series, indicating that this was the “15<sup>th</sup> day [after the Moon] arrived, when the 6<sup>th</sup> [Moon of the] Jaguar God of the Underworld was tied. The holy name of this 29 [-day lunar month was]...” This expression may be recorded as 15D 6Cj A9. This is the only lunar data recorded on Stela A. If there is a fixed, schematic notation implied in the Lunar Series, then hollow and shal-

low months should be regularly sequenced. Therefore we can compute with reasonable accuracy the Lunar Series for the Date 2:

$$\begin{array}{r} 9.14.19.8.0 \text{ 12 } Ajaw \text{ 18 } Kumk'u \text{ 15D } 6Cj \text{ A9} \\ - \quad \quad \quad 3.0 \text{ [60 days]} \\ = 9.14.19.5.0 \text{ 4 } Ajaw \text{ 18 } Muwan \text{ 14D } 4Cj \text{ A9} \end{array}$$

We conclude that associated with the date 9.14.19.5.0 is the Moon Age of 14 days, the 16<sup>th</sup> Lunar Semester, and the current lunar month containing 29 days (14D 4Cj A9). The Dates 1 and 2 appear to refer to the day of the full moon (Milbrath, 1999: 106).

Can we reconstruct the Lunar Series of the hypothetical starting point of the cycle at 9.14.0.0.0? Unfortunately, at Copán there are no monuments recording the Lunar Series at 9.14.0.0.0. The nearest Lunar Series (18D 1Cs A10) is displayed on Stela J, erected on 9.13.10.0.0 7 *Ajaw* 3 *Kumk'u* (731 CE), a half-*k'atun* (3,600-day) interval before arriving at 9.14.0.0.0:

$$\begin{array}{r} 9.13.10.0.0 \text{ 18D } 1Cs \text{ A10} \\ + \quad \quad \quad 10.0.0 \text{ [3,600 days]} \\ = \quad 9.14.0.0.0 \text{ [17D } 3Cj \text{ A10]} \end{array}$$

Within a half-*k'atun* interval the only possible combination is the sum of 62 30-day months and 60 29-day months ( $62 \times 30 + 60 \times 29 = 3,600$  days). This includes two intercalary months and leads to 17D 3Cj A10. It can be inferred that Glyph D records two different moon ages in the supposed Metonic Cycle.

Now, it is important to notice that the dates recorded on Stelae J and A belong to Teeple's (1931: 54-61) and Aldana's (2006: 240, 248) "Periods of Uniformity", during

which all Maya polities recording the Lunar Series kept the same count. Taking into account more lunar data from other sites, we can compare them with the Lunar Series from Copán. In Table 3 are brought together all the monuments that have their lunar count either at 9.14.0.0.0 or at 9.14.19.5.0. Our reconstructed Lunar Series at 9.14.0.0.0 at Copán agrees with most dates in Table 3. While there are observed small deviations from the Moon Age values (Glyph D) that may be attributed to the regional differences in defining the start of the lunar month, there is a perfect accordance in Glyph C variants.

The idea behind the concept of the Metonic Cycle is that the Maya Lunar Series is able to maintain standardized and fixed sequences of 29-day and 30-day months. The evidence from Table 3 shows that in the first half of the 8<sup>th</sup> century CE the Maya political fragmentation did not lead to major differences in the Lunar Series (see Glyph C). The degree of uniformity shown in Glyph C variants clearly shows that the Maya skywatchers mastered a calculation that produced the Lunar Series. But they were not able to ensure uniformity in their Moon Age records, nor to synchronize the values assigned to Glyph A (the 29-day or 30-day months). It demonstrates that the Late Classic Lunar Series was not as calendrically exact as astronomical cycles. Therefore, the probability that the Maya utilized the Metonic Cycle in their texts displayed on monuments is very low. It therefore appears that most of the Copán readings are over-interpretations and are determined by the assumption that the lunar observations of the Maya were both regular and precise.

**Table 3. The Lunar Series from different Maya polities compared. Lunar data compiled from Aldana (2006: Table 17-2). Reconstructed data are in brackets.**

Polity	Monument	Date 9.14.0.0.0	Date 9.14.19.5.0	Comments
Dos Pilas	Stela 14	16D 3Cj		
Calakmul	Stelae 71 and 73	15D [3Cj]		1 day off the Metonic Cycle
Calakmul	Stela 51		14D 4Cj A10	

Piedras Negras	Stela 3 left side	17D 3Cj A10		
Uaxactun	Stela 1	17D 3C[j] A9		
Copán	Stela A reconstructed	[17D 3Cj A10]	[14D 4Cj A9]	3 days off the Metonic Cycle

### 3. POSTCLASSIC EVIDENCE

#### 3.1 A 6,939-day interval in the Dresden Codex

First, we deal with the interval of 6,939 days. It is found in the Maya Dresden Codex Eclipse Table (Dresden 51-58). Here, the groups of intervals are recorded by five and six lunar months (containing 29 or 30 days). Each such cycle is individually specified either through the number of 148 days (5 months) or through the number of 177 or 178 days (6 months) and used to predict eclipses of the sun and the moon. Juxtaposed to them are numbers recording the days elapsed from the starting date of the table. Page 52 (bottom) records numbers of 6,408, 6,585, 6,762, and 6,939 days. The Saros (= 6,585 days) and Metonic (= 6,939 days) intervals are represented, but not specially marked. "The Metonic cycle appears to have attracted no particular attention. It is too there, as it has to be (at 235

lunations), but again only as one of many eclipse possibilities" (Lounsbury, 1978: 804). This evidence cannot help to resolve the question of the deliberate use of the Metonic Cycle. I am not aware of any other evidence for the use of a 6,939-day interval in Mesoamerica.

#### 3.2 The Paris Codex

Celebrations of *k'atun* endings (7,200-day periods) are depicted in the Maya Postclassic Paris Codex. On pages 2 to 11 (of 13 original pages only 11 have survived; see Love, 1994: 18) these different *k'atuns* are depicted as personified entities, perhaps gods, seated on thrones, being attended to by another individuals, also gods. *K'atun* periods started on *Imix* days and ended on *Ajaw* days; for example, the *k'atun* ending 9.17.0.0.0 13 *Ajaw* 18 *Kumk'u* refers to the period that starts on 9.16.0.0.1 3 *Imix* 14 *Tzek*.

**Table 4. The hypothetical Metonic Cycle used to predict lunar eclipses from page 10 of the Paris Codex. The data are after Bricker and Bricker (2011: 363). Correlation factor: 584,283. The lunar eclipse of 633 CE (saros 88) was total; the lunar eclipse of 652 CE was barely visible (partial, saros 98). It is not certain whether this second eclipse was perceived by the Maya.**

Long Count date	Calendar Round date	Gregorian calendar date, GMT2 correlation	Days after 9.10.0.0.0
9.10.0.0.0	1 <i>Ajaw</i> 8 <i>Kayab</i>	25 January 633 CE	0
9.10.0.0.1	2 <i>Imix</i> 9 <i>Kayab</i>	26 January 633 CE	1
9.10.0.7.16	1 <i>Kib</i> 19 <i>Xul</i>	30 June 633 CE eclipse	156
9.10.19.12.16	12 <i>Kib</i> 4 <i>Yaxk'in</i>	30 June 652 CE eclipse	7,096
9.11.0.0.0	12 <i>Ajaw</i> 8 <i>Keh</i>	12 October 652 CE	7,200

Page 10 of the Paris Codex represents a *k'atun* ending on the day 12 *Ajaw*. There are two eclipse glyphs (the solar and lunar ones) below the *Kawak* glyph, with numerical coefficients attached, referring to a time period. Scholars read this period variously. For example, Severin (1981: 51-52) reads the glyph to the left as the larger period, getting 5.0.19, or 1819 days (in fact Severin reads  $5 \times 365 + 19 = 1,844$  days), while others (Kelley, 1983: S71; Bricker and

Bricker, 2011: 363-364) read it as 19.5.0, or 6,940 days, and identify it with the Metonic Cycle. Based on their earlier interpretations, Bricker and Bricker infer that the page refers to the period that was initiated on 9.10.0.0.1 2 *Imix* 9 *Kayab* (633 CE) and closed on 9.11.0.0.0 12 *Ajaw* 8 *Keh* (652 CE) and observed that lunar eclipses were observed in the Maya region on June 30, 633 CE and June 30, 652 CE (see Table 4), both dates being separated by the 6,940-day in-

terval inferred above, and suggested that the Metonic cycle could have been used by the Maya to commensurate “not only the lunar cycle with the tropical year, but also the *k’atun* with eclipse seasons” (Bricker and Bricker, 2011: 363).

We see that the evidence for the awareness of the Metonic Cycle in the Codex Paris is ambiguous. What is interesting here is the possibility of using the interval of 6,940 days to track the lunar eclipses. Naturally, it cannot be used to predict eclipses for a longer time; rather it may serve as an *ad hoc* technique for eclipse predictions.

### 3.2 Codex Fejérváry Mayer

This manuscript was manufactured in Central Mexico, somewhere between the Puebla-Tlaxcala region and the Mexican Gulf. The document bears Nahuatl, Mixtec, and Gulf Coast cultural features and emphasizes merchant activities (Boone, 2007: 229), or more specifically, divinatory rituals designed for the *pochtecas* (León Portilla, 2005: 9-10). Codex pages display sections that describe specific rituals and ceremonies involving great quantities of counted offerings. Calendrical elements are greatly reduced to one or a few day names associated with specific rituals, supernaturals invoked, “actions to be performed, and the objects to be manipulated” (Boone, 2007: 160).

For a long time, the strings of numbers displayed on manuscript pages have been considered as having something to do with astronomy. Brotherston (1982: 115-116) proposed that the numbers displayed on the manuscript pages 15-22 were running Aztec calendar feasts from lesser *Micailhuitl* to *Atemoztli* and together yielded the number of 6,940 days (without hollow dots). Brotherston considered that numbers in bundles were counted as units while other numbers written at a 90° angle were multiplied by 10. Developing a very peculiar numerological and iconographic approach to interpret the content of pre-hispanic codices, Brotherston (1982: 129)

concluded that the codex recorded “the lunar-solar cycles of 8 and 19 years”.

Current interpretations define codex pages 15-22 as representing “protocols for rituals” (Boone, 2007: 157). Offered items are carefully counted, bound into bunches, and arranged in rows and columns to form a square on altars. Numbers of items are selected in accordance with their mantic meanings. They correspond to specific ritual actions and domains rather than to calendric or astronomical cycles. The evidence for the record of the Metonic cycle on codex pages 15-22 appears to be absolutely negative.

### 3.3 Codex Zouche-Nuttall

This manuscript was probably made in 14<sup>th</sup> century, in the Mixteca Alta (Highland Mixteca) region in the state of Oaxaca. It records the political history, genealogy, biography, military and ritual events important for the establishment of the small Mixtec polity of Tilantongo (*Nuu Tnoo*), in highland Oaxaca. In particular it describes the political biography of the famous Mixtec ruler and cultural hero, Lord Eight Deer “Jaguar Claw”.

In his paper Brotherston (1982: 116-117) noticed that the birthdate of Eight Deer happened 19 years after the first marriage of his father, Lord 5 Crocodile “Sun of Rain”, high priest of Tilantongo. On manuscript side two, page 42, this ruler is depicted as wearing the mask of a Rain god, and Brotherston proposes that the 19-year cycle was symbolized by this “nosed” mask for a day-sign Rain. The author followed Kelley (1980: S38) in emphasizing that the return to the same position in the tropical and sidereal years after 6,940 days should be represented by an indigenous symbolic depiction.

Now, knowing the date of the first marriage of Lord 5 Crocodile, it is easy to compute the second date that falls after a 6,940-day interval. In Nuttall (Nuttall 26, 42, Anders *et al.*, 1992a: 147, 181) we are told that the marriage took place in the year 6 Flint (knife) day 7 Eagle (1044 CE) and that the birth of Lord 8 Deer occurred

in the year 12 Reed (Nuttall 26, 43; Anders *et al.*, 1992a: 148, 182 also in Vindobonensis 7, 1063 CE; see Anders *et al.*, 1992b: 202).

Computing one Metonic cycle (of 6,940 days) from year 6 Flint day 7 Eagle backwards, we arrive at year 12 Reed (correct) 5 Eagle (not written):

$$\begin{array}{r} \text{Year 6 Flint day 7 Eagle} \\ + \quad \underline{6,940 \text{ days}} \\ = \text{Year 12 Reed day 5 Eagle} \end{array}$$

Now, though the complete birthdate of Lord 8 Deer is not given, we know that in Mesoamerica people were usually named from their "birth-dates", in the *tonalpohualli* cycle (Pharo, 2012: 190). Thus Eight Deer's name is also his birthday (see Anders *et al.* 1992b: 48; Corona Núñez 1964: 42).

$$\begin{array}{r} \text{Year 6 Flint day 7 Eagle} \\ + \quad \underline{7,112 \text{ days}} \\ \text{Year 12 Reed day 8 Deer} \end{array}$$

The date of the marriage of Lord 5 Crocodile is also not verisimilar, since Vindobonensis 6 and Bodley 7 report it happened on year 5 Reed day 7 Eagle (=1043 CE, Anders *et al.*, 1992b: 201; Corona Núñez, 1964: 42) which is 260 days earlier. I think these facts definitely rule out any possibility of linking the lives of Mixtec rulers with the Metonic cycle.

#### 4. COLONIAL EVIDENCE

A variant of the Metonic cycle, adapted to the Julian calendar, has widely been used in medieval *Computus* to predict the date of the Paschal full moon (after each round of the 19-year cycle the Moon recurs to the same phase). The position of the given year in the Metonic cycle of 19 years was kept by the Golden Number, with the Full Moon day falling on the same solar day every 19 Julian years ( $19 \times 365.25 = 6939.75$ ). A greater Paschal Cycle of ( $19 \times 28$ ) 532 years was designed to commensurate all the possible permutations of weekdays and leap days (both defined by a 28-year cycle of Dominical Letters) and embo-

lisms (Metonic Cycle). This European calendrical influence is evident in the use of almanacs found in Colonial manuscripts written by native intellectuals and priests between the 16<sup>th</sup> and 19<sup>th</sup> centuries.

##### 4.1 *Codex Mexicanus 23-24*

*Codex Mexicanus 23-24* is an early Colonial (made in late 16<sup>th</sup> century; Prem 2008:153) native pictorial manuscript that contains diverse information on calendrics, astrology, and history. The Julian calendar is represented by a string of Dominical Letters that mark the days of a given month; under and in parallel run the so-called "lunar letters". On the left side of each page are placed the signs of the zodiac, moon cycles, etc. that usually appear in European repertoires. Finally, linked to the Dominical Letters are images representing Christian feasts and Catholic saints' days (above) and indigenous months and feasts (below). Julian calendar months are systematically juxtaposed to the months of the indigenous year (Mengin, 1952; Prem, 1978).

On manuscript page 9 we see calendar cycles represented in the form of two wheels. One of them displays a cycle of 28 Julian years, represented by Dominical Letters used in the *Computus*, while the other represents a native Calendar Round cycle (of 52 365-day years). Both calendar wheels are juxtaposed, suggesting that the manufacturers of the codex realized that the days of the week marked by Dominical Letters acted as year-bearers in a 28-year *computus* cycle in a similar way as year-bearers acted in a 52-year *xiuhmolpilli* cycle. This type of indigenous computational formula reveals some ignorance in calendars, inscribing the sequence of 28 Julian calendar years of 365.25 days against the sequence of 52 solar years of 365 days (Prem, 2008).

The next page (10) displays a lunar table that contains 19 columns representing Golden Numbers and 28 rows containing so-called "lunar letters". The "lunar letters" specify the positions of the Moon in 12 zodiac signs on the days determined by the Golden Number of the 19-year Metonic cy-

cle. This table displays a sequence of lunar letters derived from a perpetual canon used to perform computations; similar, for example, is the Lunar Table printed in *Repertorio de los tiempos* by Andrés de Li (1999: 82). The absence of any indigenous commentary or counterpart calls for an explanation.

#### 4.2 *Chilam Balam of Ixil*

The Book of Chilam Balam of Ixil belongs to the indigenous Mayan literary genre specific to Yucatán. The sacred texts known as the Books of Chilam Balam were believed to be written by jaguar priests (*chilanoob*) who predicted the arrival of the Spaniards and the end of a native religion. In general, the purpose of the Book of Chilam Balam “was to reconcile unfamiliar European concepts, such as the calendar, with the pre-existing Maya system. A second purpose was evidently to preserve pre-Hispanic ritual knowledge...” (Paxton, 1992: 241). Like other books of this genre, the Book of Chilam Balam of Ixil also contains astrological predictions, auguries and popular medicine and is heavily influenced by European calendrics and astronomy. The manuscript was manufactured in 18<sup>th</sup> century, but probably is a copy of an earlier document (Caso Barrera, 2011: 16).

More than half of the manuscript consists of translations into Mayan of Spanish almanacs or *reportorios*, and other European sources. Calendar sections displayed on pages 23a-40r show Maya and Christian calendars separately. Each Christian month is depicted on a separate page. The days are arranged in columns and show the Epact, a Dominical Letter, the day of the month and a Catholic saint’s day. It seems to represent a type of perpetual calendar because there are no movable feasts marked. The Maya months are also arranged in columns and structured in accordance with Christian months, starting in January. The columns are as follows: a day of the month, a Dominical Letter, a *trecena* day, a *tzolk’in* name day, the nature of each day (i.e. whether good or bad), the start of a Maya month (*veintena*) and additional information. The Dominical Letters

scheme is the same as in the list of Christian months and is also perpetual.

At the end of the manuscript the lunar table is inserted. First, on pages 43a-43r the lunar letters are associated with days arranged in columns for each month. Page 44a depicts 19 Golden Numbers and zodiacal signs. Finally on page 44r are depicted the lunar letters arranged in rows in accordance to the zodiacal signs. The scribal errors in this table were already observed by Aliphath (2011:74), though he did not notice that the table lacks two rows. Lunar letters seem to be arranged horizontally (in rows) rather than vertically (in columns). There is no indigenous counterpart to this lunar information. The table starts with the column belonging to the 19<sup>th</sup> year and ends with the 4<sup>th</sup> year.

When it is used as a concept, the cycle of 19 tropical years equating 235 synodic months is virtually absent from passages and places where its mention would have been most expected: in computations of the tropical year and in predictions of the Easter date (*argumentum e silentio*). This suggests that the cycle of 19 years manifested in *Computus* and corresponding to the Metonic Cycle was alien to early Colonial native priests or intellectuals.

## 5. CONCLUSIONS

The ancient Maya skywatchers devised a formalized (mathematized) system to track and observe the cycles of the Moon. That they partially succeeded in this is shown in their Lunar Series system. However, the evidence discussed above does not suggest that the Lunar Series was designed to keep track of the solar tropical year, which at first glance suggests awareness of the Metonic Cycle. Evidence in support of this is weak, and perhaps influenced by the Eurocentric bias against non-Western astronomical traditions (see Chambers 1965).

The calendar system brought to sixteenth century Mesoamerica was based on a 28-solar year cycle and a 19-year Metonic cycle necessary to calculate the days of the week and the Easter Sunday. The examples

presented above show that while the 28-year cycle represented by the continuous shift of Dominical Letters was understood as being relatively similar to the shift of indigenous year-bearers, the 19-year cycle was rather overlooked by Mesoamerican calendar specialists. My argument is that if Mesoamericans discovered and used the Metonic cycle in the past, they would immediately recognize its presence in the structure of European calendars.

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