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► **To cite this version:**

| Thomas Chanier. The Mayan Long Count Calendar. 2014. hal-00750006v7

**HAL Id: hal-00750006**

**<https://hal.science/hal-00750006v7>**

Preprint submitted on 28 Apr 2014 (v7), last revised 16 Dec 2015 (v12)

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# The Mayan Long Count Calendar

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The Maya were known for their astronomical proficiency. Whereas Mayan mathematics was based on a vigesimal system, they used a different base when dealing with long periods of time, the Long Count Calendar (LCC), composed of different Long Count Periods (LCPs) (i.e., the Tun of 360 days, the Katun of 7200 days and the Baktun of 144000 days). There were two other calendars used in addition to the LCC, a civil year Haab' of 365 days and a religious year Tzolk'in of 260 days. Based on astronomical argument, we propose here an explanation of the origin of the LCC. This interpretation links the LCC to the religious calendar. We then examine the relationships among the LCP, Tzolk'in, Haab', and planet cycles, which correspond to the various religious cycles in use in Mayan religion.

The Maya had a very elaborate and accurate Long Count Calendar (LCC) that was used to pinpoint historical events from a selected beginning time. The smallest unit of time is the day (Kin); 20 Kin form a Winal, 18 Winal form a Tun (360 Kin), 20 Tun form a Katun (7200 Kin), and 20 Katun form a Baktun (144000 Kin). The LCC represents a date  $D$  as a set of coefficients  $(C_i, \dots, C_3, C_2, C_1, C_0)$  such that:  $D = C_0 + C_1 \times 20 + \sum_{i=2}^n C_i \times 18 \times 20^{i-1}$  with  $C_0 = \text{mod}(D, 20)$ ,  $C_1 = \text{int}(\text{mod}(D, 360)/20)$  and  $C_i = \text{int}(\text{mod}(D, 18 \times 20^i)/(18 \times 20^{i-1}))$  for  $i > 1$ . The day count usually restarts when  $C_4$  reaches 13, such as the date is given as a set of 4 coefficients:  $D \equiv \text{mod}(D, 13 \times 144000) = C_4.C_3.C_2.C_1.C_0$ . The Maya used two other independent calendars, one based on a religious year (Tzolk'in) and the other based on a civil year (Haab'). One Tzolk'in of 260 days comprised 13 months (numerated from 1 to 13) containing 20 named days (i.e., Imix, Ik, Akbal, Kan, Chicchan, Cimi, Manik, Lamat, Muluc, Oc, Chuen, Eb, Ben, Ix, Men, Cib, Caban, Etznab, Cauac, and Ahau). One Haab' of 365 days comprised 18 named months (i.e., Pop, Uo, Zip, Zotz, Tzec, Xul, Yaxkin, Mol, Chen, Yax, Zac, Ceh, Mac, Kankin, Muan, Pax, Kayab, and Cumku) with 20 days each (Winal) plus 1 extra month (Uayeb) with 5 nameless days. The Tzolk'in and the Haab' coincide every 73 Tzolk'in or 52 Haab' or a Calendar Round (CR). Their least common multiple (LCM) is  $73 \times 260 = 52 \times 365 = 18980$  days. In the CR, a date is represented by  $\alpha X \beta Y$  with the religious month  $1 \leq \alpha \leq 13$ , X one of the 20 religious days, the civil day  $0 \leq \beta \leq 19$ , and Y one of the 18 civil months,  $0 \leq \beta \leq 4$  for the Uayeb. According to the Goodman-Martinez-Thompson (GMT) correlation to the Gregorian calendar, which is based on historical facts, the Mayan Calendar began on 11 August 3114 BC or 0(13).0.0.0.0, 4 Ahau 8 Cumku and ended on 21 December 2012. This corresponds to a period of approximately 5125 years, or 13 Baktun.

The origin of the Long Count Periods (LCPs) is unknown. A common assumption is the desire of the calendar keeper to maintain the Tun in close agreement with the tropical/solar year of approximately 365.24 days.<sup>1</sup> There is no consensus concerning the origin of

the Tzolk'in, which has been associated with various astronomical cycles. Three Tzolk'in correspond to Mars synodic period, 16 Tzolk'in equal 11 of Saturns synodic periods (+2 days), and 23 Tzolk'in are equivalent to 15 of Jupiters synodic periods (-5 days).<sup>2</sup> It has been tentatively connected to the eclipse half-year (173.31 days) because 2 Tzolk'in are very close to 3 eclipse half-years.<sup>3</sup> Finally, it has been noted that the Tzolk'in approximates the length of time Venus is visible as a morning or evening star.<sup>4</sup> However, these interpretations fail to link the Tzolk'in to the LCPs. This manuscript explains a possible origin of the LCPs, the religious year Tzolk'in, and the 13 Baktun cycle. This new interpretation is based on astronomical planet cycles and gives rise to different day cycles that have been identified in the Maya Codices.

Planet	$P$ [day]	Prime factorization
Mercury	116	$2^2 \times 29$
Venus	584	$2^3 \times 73$
Earth	365	$5 \times 73$
Mars	780	$2^2 \times 3 \times 5 \times 13$
Jupiter	399	$3 \times 7 \times 19$
Saturn	378	$2 \times 3^3 \times 7$
Lunar	177	$3 \times 59$
senesters	178	$2 \times 89$
Pentalunex	148	$2^2 \times 37$

TABLE I. Planet cycles<sup>5,7</sup> and their prime factorizations.

The Maya were known for their astronomical skills. This is exemplified on page 24 of the Dresden Codex by the so-called Long Round number, which is noted as 9.9.16.0.0 or 1366560 days, a whole multiple of the Tzolk'in, the Haab', the Calendar Round, the Tun, Venus and Mars synodic periods:  $LR = 1366560 = 5256 \times 260 = 3744 \times 365 = 72 \times 18980 = 3796 \times 360 = 2340 \times 584 = 1752 \times 780$ . Only the moon, Mercury, Venus, Earth (solar year), Mars, Jupiter, and Saturn are visible to the naked eye. Their respective mean synodic periods are given in Table I. Evidence has been found in different Mayan Codices that Mayan astronomers observed the periodic movements in the night sky of Mercury, Venus, and Mars, but it is unclear whether they

tracked the movements of Jupiter and Saturn.<sup>6</sup> The periods relevant for the prediction of solar/lunar eclipses are the pentalunex of 148 days (5 Moon synodic periods of 29.53 days) and the lunar semesters of 177 or 178 days (6 Moon synodic periods), which are the time intervals between subsequent eclipse warning stations present in the Dresden Codex Eclipse Table.<sup>7</sup> The LCM of these numbers is  $N = 20757814426440$  days (including the planet synodic periods and the two lunar semesters) or  $N^\dagger = 768039133778280$  days (also including the pentalunex).  $N$  is such that:

$$\text{int}(N/13/73/144000) = 338 + 360 + 7200 + 144000. \quad (1)$$

$N^\dagger$  gives the same result but divided by 13, 37 and 73. That defines the Tun, Katun, and Baktun as a polynomial expression of  $\text{int}(N/13/73)$  of the form  $18 \times 20^3 \times (C_0 + \sum_{n=1}^3 18 \times 20^n)$  with  $C_0 = 338$ . The  $\text{LCM}(338,360) = 169 \times 360 = 234 \times 260 = 60840$ ; 338 and 365 are relatively prime numbers: the  $\text{LCM}(338,365) = 338 \times 365 = 123370$ ; 234 and 365 are also relatively prime numbers: the  $\text{LCM}(234,365) = 234 \times 365 = 85410$ . The  $\text{LCM}(260,365)$  is  $73 \times 260 = 52 \times 365 = 18980$  days or a Calendar Round. That may define the Tzolk'in. Noting  $N' = 13 \times 73 \times 144000 \times (338 + 360 + 7200 + 144000) = 20757773088000$  days,  $N'$  is dividable by the Long Round number: the  $\text{mod}(N',\text{LR}) = 0$ .  $N$  is such that the  $\text{mod}(N,\text{LR}) = 341640$  Kin or 2.7.9.0.0 in the LCC. This number has been identified on the Xultun Table.<sup>8</sup> It is to be noted that 341640 is a whole multiple of the Tzolk'in, Haab', Tun, and Venus and Mars synodic periods:  $341640 = 1314 \times 260 = 936 \times 365 = 949 \times 360 = 585 \times 584 = 438 \times 780$ . 341640 is also the largest common divisor of LR,  $N'$  and  $N$ .

LCP	$D$ [day]	$L$ [day]	$M$ [day]	$N$ [day]	$L/260$	$L/234$
Winal	20	3380	260	2340	13	14.44444
Tun	360	60840	4680	4680	234	260
Katun	7200	1216800	93600	93600	4680	5200
Baktun	144000	24336000	1872000	1872000	93600	104000

TABLE II. Coincidence of the 234-, 260- and 338-day periods with the LCP.  $L = \text{LCM}(D,338)$ ,  $M = \text{LCM}(D,260)$  and  $N = \text{LCM}(D,234)$ .

Table II gives the coincidence of the 338-day period with the LCPs, as well as the Tzolk'in and the 234-day period. As described earlier, the Tun and 338-day period coincide every 60840 days, or 234 Tzolk'in. The 338-day period also coincides with the Winal every 3380 days, corresponding to 13 Tzolk'in, a cycle that does not coincide with the 234-day period. Rather, the 234-day period coincides with the Winal every 2340 days or 9 Tzolk'in =  $9 \times 260 = \text{LCM}(9,13,20)$ . This 2340-day cycle is present in the Dresden Codex on pages D30c-D33c and has been attributed to a Venus-Mercury almanac because  $2340 = 20 \times 117 = 5 \times 585$  is an integer multiple of Mercury and Venus mean synodic periods (+1 day).<sup>9</sup> Another explanation may be of divination origin because  $117 = 9$

$\times 13$ . In Mesoamerican mythology, there are a set of 9 Gods called the Lords of the Night<sup>10-13</sup> and a set of 13 Gods called the Lords of the Day.<sup>13</sup> Each day is linked with 1 of the 13 Lords of the Day and 1 of the 9 Lords of the Night in a repeating 117-day cycle. This cycle coincides with the Winal every 2340 days. On Table II figures a date  $D = \text{LCM}(338,7200) = 1216800$  days or 8.9.0.0.0 in the LCC or 5 February 219 CE according to the GMT correlation. This date may have marked the beginning of the reign of Yax Moch Xoc, the founder of the Tikal dynasty, in 219 CE.<sup>14</sup>

We now examine the cycles that can be constructed from the combination of the Tzolk'in ( $260 = 13 \times 20$ ), the Haab' ( $365 = 5 \times 73$ ) and the LCPs ( $D = 18 \times 20^n$ ). Because 13 is not present in the prime factorizations of the LCPs, we obtain  $\text{LCM}(260,D) = 13 \times D$ . There is, for example, a 13 Katun cycle of 93600 days (360 Tzolk'in) reminiscent of the Katun Wheel and a 13 Baktun cycle of 1872000 days (7200 Tzolk'in). This means that the Baktun cycle coincides with the Tzolk'in cycle every 13 Baktun, corresponding to approximately 5125 years. This is the origin of the 13 Baktun cycle. Because 73 is not present in the prime factorizations of the LCPs, we obtained  $\text{LCM}(365,D) = 73 \times D$ . This gives rise to 73 LCP cycles. There is, for example, a 73 Katun cycle of 525600 days and a 73 Baktun cycle of 10512000 days. There is also  $\text{LCM}(260,365,D) = 13 \times 73 \times D$ . This is the case of the Xultun number  $341640 = \text{LCM}(260,365,360)$  which makes coincide the Tzolk'in, the Haab' and the Tun.

Planet	$P$ [day]	$N = \text{LCM}(P,260)$	$N/260$	$N/P$
Mercury	116	7540	29	65
Venus	584	37960	146	65
Earth	365	18980	73	52
Mars	780	780	3	1
Jupiter	399	103740	399	260
Saturn	378	49140	189	130
Lunar	177	46020	177	260
semesters	178	23140	89	130
Pentalunex	148	9620	37	65

TABLE III. Coincidence of the planet cycles<sup>5,7</sup> and the Tzolk'in.

Various religious cycles can be constructed by taking the LCM of 260 and the planet synodic periods (Table III). The most important one in Mayan religion is the Calendar Round, which is the  $\text{LCM}(260,365) = 73 \times 260 = 52 \times 365 = 18980$  days. There is a coincidence between Venus synodic period and the Tzolk'in: the  $\text{LCM}(260,584) = 65 \times 584 = 146 \times 260 = 104 \times 365 = 37960$  days (2 Calendar Rounds), the length of the Venus Table in the Dresden Codex. There is also a coincidence between Mars synodic period, the Tzolk'in and the Haab': the  $\text{LCM}(780,365) = 73 \times 780 = 219 \times 260 = 156 \times 365 = 56940$  days (3 Calendar Rounds): this is the largest common divisor of the numbers present on the Xultun Table.<sup>8</sup> The cycles of Venus and Mars are of particular importance in the Maya religion. The Kaul cycle

of 819 Kin coincides with the Tzolk'in and Saturn synodic period: the  $\text{LCM}(260,378) = 49140 = 60 \times 819$ . There is another cycle of  $46 \times 260 = 11960$  days, corresponding to 405 Moon synodic periods and used for the prediction of solar/lunar eclipses in the Dresden Codex.<sup>7</sup> Two other cycles are based on the coincidence of the Tzolk'in and the 234- and 338-day periods: the  $\text{LCM}(260,234) = 9 \times 260 = 2340$  days and the  $\text{LCM}(260,338) = 13 \times 260 = 3380$  days.

The data presented here describe a possible explanation of the origin of the LCC and its connection with the Tzolk'in and Haab' calendars. Based on astronomical observations of the solar system, the LCC gives rise to three different periods of 234 days, 260 days (Tzolk'in) and 338 days. The correlation between the 234-day period and the Tzolk'in, a 2340-day cycle identified in the

Dresden Codex, was certainly used for divination purposes. The correlation between the 338-day period and the Tzolk'in gave rise to a 13-Tzolk'in cycle that has not yet been identified in the Codices. These results suggest that Mayan astronomers knew the synodic periods of all the planets visible to the naked eye, as well as the basic cycles for solar/lunar eclipse prediction, the pentalunex, and the lunar semesters. The 13 Baktun cycle originated from the correlation between the Baktun and the Tzolk'in. The coincidence of the Tzolk'in, the Haab' and the Tun gives rise to a 341640-day cycle which has been identified on the Xultun Table. Various religious cycles may have been used by the Mayans based on the correlation of the planet cycles and the Tzolk'in. Among them, the cycles of Venus and Mars are of primary importance.

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- <sup>1</sup> A. F. Aveni, in *Skywatchers: A Revised and Updated Version of Skywatchers of Ancient Mexico* (University of Texas Press, 2001), p. 136.
- <sup>2</sup> J. S. Justeson, *The ancient Maya Ethnoastronomy: An Overview of Hieroglyphic Sources*, in *World Archaeoastronomy: Selected Papers from the Second Oxford International Conference on Archaeoastronomy*, edited by A. F. Aveni, (Cambridge University Press, 1989), p. 82.
- <sup>3</sup> A. F. Aveni, in *Skywatchers: A Revised and Updated Version of Skywatchers of Ancient Mexico* (University of Texas Press, 2001), p. 144.
- <sup>4</sup> H. M. Bricker and V. R. Bricker, in *Astronomy in the Maya Codices* (American Philosophical Society, Philadelphia, 2011), pp. 69.
- <sup>5</sup> <http://nssdc.gsfc.nasa.gov/planetary/factsheet/>
- <sup>6</sup> H. M. Bricker and V. R. Bricker, in *Astronomy in the Maya Codices* (American Philosophical Society, Philadelphia, 2011), pp. 163, 367, 847.
- <sup>7</sup> H. M. Bricker and V. R. Bricker, *Current Anthropology* **24**, 1-23 (1983).
- <sup>8</sup> W. A. Saturno, D. Stuart, A. F. Aveni and F. Rossi, *Science* **336**, 714 (2012).
- <sup>9</sup> H. M. Bricker and V. R. Bricker, in *Astronomy in the Maya Codices* (American Philosophical Society, Philadelphia, 2011), p. 235.
- <sup>10</sup> A. F. Aveni, in *Skywatchers: A Revised and Updated Version of Skywatchers of Ancient Mexico* (University of Texas Press, 2001), pp. 156-157.
- <sup>11</sup> E. H. Boone, in *Cycles of Time and Meaning in the Mexican Books of Fate* (University of Texas Press, 2007), pp. 44-45.
- <sup>12</sup> F. Lounsbury, in *Dictionary of Scientific Biography*, vol. 15, (Scribners, New York, 1978), suppl. 1, p. 787.
- <sup>13</sup> T. A. Joyce, in *Mexican Archaeology: An Introduction to the Archaeology of the Mexican and Mayan Civilizations of Pre-Spanish America* (Cambridge University Press, New York, 1914), p. 64.
- <sup>14</sup> L. Schele and D. Freidel, in *A forest of Kings* (New York William Morrow and Co., 1990), p. 134.