Calculations of the Tropical Year and Precessional Cycles: Two bone fragments from Tikal Burial 116

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Introduction

The purpose of this paper is to explore and discuss some of the significant calendrical information given by two bone fragments from the tomb of Tikal's Hasaw Chan K'awil in burial 116, Temple 2. The intervals indicated on these fragments reveal important connections to periods that facilitate the calculation of the true tropical year and the 26,000 year cycle of precession, both of which appear to be strongly suggested by the structure of the Long Count.

The subject of Mesoamerican calendrical calculation has been a preoccupation in the field of Maya studies since its inception, and this has been the area in which the greatest initial progress in hieroglyphic translation has taken place. From a recovered a copy of Diego de Landa's *Relación de las Cosas de*

Yucatán from the mid Sixteenth century, Charles Brasseur de Bourbourg revealed the Maya names of the days of the tzolk'in cycle of 260 days, and how it is intercalated with the 365 day Haab' solar year, forming the 52 year calendar round, as found throughout Mesoamerica (Coe 1992:100-102). By the late 1800's, Ernst Förstemann had accurately read and understood the Long Count system in the Dresden Codex, with its repeating cycles of 360 day years which proceeded from the ancient origin date of 4 Ahau 8 Cumku (ibid: 107-108).

In 1905, Joseph Goodman first proposed a nearly accurate correlation between the Long Count and Gregorian/Julian calendars, establishing the antiquity of the origin date (ibid: 111-114). Following this, much of the work in Maya studies in the majority of the twentieth century has been concerned with further calendrical and astronomical information as elucidated in translated texts on both monumental inscriptions and the information found in the few remaining codices.

Eric Thompson, whose extensive work on Maya calendrics dominated the larger part of the twentieth century, later finalized the correlation of the Long Count calendar (Thompson 1935; 1970: 303-310). Though Thompson has been criticized by Coe (1992) for his focus on Maya time cycles at the expense of other textual and phonetic information, his work, and that of his predecessors, must be acknowledged. From their initial efforts, a vast amount of information regarding the complexity and scientific, observational accuracy of the calendrical systems of ancient Mesoamerica has been revealed. We are thus challenged to attempt to understand a way of reckoning time which exists outside the Western tradition, often preceding and exceeding the calculations of the West.

Though much about the Long Count system has been elucidated, there are still some significant questions which remain regarding the function and purpose of the system itself, and the manner in which calculations were made. There is a general consensus that the Maya were able to track and calculate the true tropical year, and the drifting of the Haab’ (Aveni 2001:165). While a great deal has been written on this subject, the question still remains as to the means by which the Maya were able to predict the tropical year, and the accuracy of this count which would allow them to predict its location in the distant past or future. The existence of the 365 day solar year has been clearly demonstrated, yet it becomes immediately apparent that this cycle accounts for no leap year, and drifts approximately one day every four years.

Given the sophistication of the calculation of various lunar cycles, and the absolute accuracy of unambiguously counting each day within a system which spans thousands of years, it is likely that the Maya, and the developers of the Mesoamerican calendar systems, employed a highly accurate method to track the drift of the Haab’ against the true tropical year. According to the early work of J. E. Teeple (1930), some of the repeating intervals of time from the inscriptions at Copan reveal a Metonic cycle of approximately 19 tropical years, also 235 lunations, given on Stela A as two successive dates separated by 9.5.0. or 6,940 days. This would give a tropical year of 365.2631 days, as opposed to the true tropical year at 365.2422 (Aveni 2001: 164). It is interesting to note that this cycle is exactly 260 days, or one tzolk’in, from the ending of a K’atun. We will discuss the possible significance of this in a later section. While this system would successfully operate for short intervals of 19 years within a calendar round of 52

Haab', it rapidly degrades at higher intervals of time. After only three cycles of 19 years, the count again drifts by one day.

Associated with the above interval of 6,940 days is an additional date of 9.14.19.8.0 12 Ahau 18 Cumku, exactly 200 days before the K'atun ending of 9.15.0.0.0 4 Ahau 13 Yax. Teeple proposes that this is a more accurate calculation of the tropical year starting from the zero year of the Long Count to this K'atun ending, over which the Haab' had drifted by two full cycles plus a remainder of 200 days, for a total of 930 days giving a tropical year of 365.2418 days. The actual drift is a close 931 days using a 365.2422 day tropical year. This would suggest that the authors of the inscription were acknowledging 18 Cumku as the original day and month at the time the K'atun ending was then falling. The Haab' had drifted to the point where the calendar round was a full 200 day after the original date in the zero year (Teeple 1930; Aveni 2001: 164-165; 352). In this case, it is a solar anniversary of a day which fell exactly ten days after the origin date of 4 Ahau 8 Cumku.

The 9.15.0.0.0 calculation appears to be highly accurate, much more than the Metonic cycle, though it still reveals an error of one day over this period of 3,846 years. Teeple has received some criticism for his assertions, given that the dates provided may be historical in nature, and the absence of proof of the calculation process or the intention of representing the drift of the Haab'. However, the calendrical nature of the K'atun ending, and the correspondences between significant astronomical and calendrical events and historical events has clearly been demonstrated (Aveni 2001: 165).

The tomb of Hasaw Chan K'awil contained a cache of many incised bones, some of which are illustrated. Two of these bones contain information which may help us to understand how the Maya and their predecessors were able to perform such an accurate calculation of the tropical year. First, bone #4P-113 contains two dates, beginning with the origin date of 4 Ahau 8 Cumku. The next date is 4 Ben 1 Xul, giving an interval of 2.12.0.13 or 18,733 days. This is exactly 52 Tuns of 360 days with the addition of 13 days. Most significantly, this is 260 days before 52 tropical years, or 52 Haab' plus 13 days. Again, as with the Metonic cycle of 19 years, we see that the addition of a 260 day tzolk'in brings us to another significant event, which will be discussed further.

To illustrate:

52 Tuns **52 tr.yr.**

< | ----------------------------260 days --------------------------- |

-13 days- | | -13 days-

18,733 days from origin date **52 haab**

The interval suggested by this bone uses the Calendar Round system of 52 Haab', associating it with 52 Tuns which is 260 days before, with the addition of 13 days of drift from the true tropical year. This gives a tropical year of 365.25, operating much like a leap year over one Calendar Round of 52 Haab'. This is the exact quarter-day addition, in that 13 is precisely one quarter of 52, and this would serve as a more accurate calculation than the Metonic cycle, but not quite as accurate as the 9.15.0.0.0 calculation. Because the actual interval between 52 Tuns plus 13 days and the true solar year is 259.5944 days, the cycle breaks down after periods of over 128 Haab', and this is the very reason that the leap year is omitted at the turn of every odd numbered century in the Gregorian calendar.

Nonetheless, this system could be used within periods under 128 Haab' for any increment of time. Every 52 Haab' requires the addition of 13 days, and the remaining years can then be divided by four, or an extra day can be added every four years. For instance, the amount of Haab' drift in 77 Haab' will be 13 days for 52 Haab', plus 6 days for the remaining 25 Haab', giving a total of 19 days of drift from 77 Haab' to the true solar year. Again, this breaks down beyond 128 Haab', and requires a more accurate correction for longer durations of time.

Was there an additional correction to this Calendar Round calculation? It seems, from Teeple's evidence, that an even more precise calibration was needed for durations far in excess of 128 years. Using the Calendar Round system, in 5 Calendar Rounds, or 260 Haab', the expected drift using the quarter day system would be 65 days. However, the actual drift is 2.028 days less, at 63 days. Given that the Calendar Round drift was being regularly calculated and recorded at 13 days of Haab' drift to reach the true tropical year, it is highly likely that successive generations would have noticed that the expected drift was off by 2 days every five Calendar Rounds. Would this correction suffice to calculate much longer durations? If so, what is the exact error accumulated?

Using the suggested correction of subtracting 2 days from the expected Calendar Round Haab' drift of 65 days per 260 Haab', we get a solar year calculation of 365.2423 days, even closer to the true value of 365.2422 days. This would only accumulate an error of 1 day after 36 x 260 Haab', or 9,360 Haab', a duration almost twice as long as the 13 B'ak'tun cycle. However, the Maya and their predecessors may not have been calculating this correction to the fullest extent of accuracy in that fractions or decimals may not be observed.

From another bone fragment from the cache of Hasaw Chan K'awil, noted as Miscellaneous Text 26 from Burial 116, we find a series of three Calendar Round dates, with an associated glyph which has been noted by Matthew

Looper (2002) and Nikolai Grube, Alfonso Lacadena and Simon Martin (2003). This glyph is a recognizable image of pih or pik, usually representing a B'ak'tun of 400 Tuns. Above this image is the number 11, somewhat like a distance number, while to the left usually appears the number three, preceeded by the ordinal u-. In several examples, the glyph reading 3-11-pih exists as part of the title of an ahau. However, in the example from the bone fragment from burial 116, we find that there are three successive examples associated with Calendar Round dates. The first is 6 Ahau 8 Mak, u-1-11-pih, or the first 11-pih. This is a period of 8660 days, as noted by Looper, within the Calendar Round. The second 11-pih follows with 8 Ahau 8 Mak, and the third with 10 Ahau 8 Sip. Each successive 11-pih, then represents the exact same interval of 8660 days. The accumulated periods of 3 x 8660 days, or 25,980 days seem to reflect a temporal title much like the 3-K'atun ahau titles, bestowed only to those who live within three periods of 20 years (Looper 2002).

However, Grube, et al., noticed that the interval seems to represent periods of 11 B'ak'tuns in length, resulting in the exact same Calendar Round positions. This would seem to explain the usage of the B'ak'tun glyph, yet the title of 3-11-pih ahau remains somewhat obscure. Gurbe, et al. suggest that it denotes the duration of the present creation, with the title meaning "Lord of the present Creation" (Grube, et al. 2003: II-6). However, these authors overlook that the u- may simply reflect ordinals and not the alternative meaning of possession.

There are several interesting things about this interval, both as 11 B'ak'tuns and as 8660 days. Looking at the period of 11 B'ak'tuns as a measuring device for the calculation of the tropical year may provide some insight.

To illustrate, using the Calendar Round calculation process outlined above to obtain the amount of Haab’ drift from the true tropical year:

11 B’ak’tuns = 4400 Tuns

4400 Tuns = 1,584,000 days = 4339 Haab’ + 265 days

4339 Haab’ = **83** Calendar Rounds + **23** Haab’

For 13 days of drift every C.R.:

83 C.R. x 13 = 1079 days }
+ } = 1084 days expected = 2 Haab’+354 d
$\frac{\mathbf{23}\text{ Haab'}}{4}$ = 5.75 days (5)} = **11** days drift from Haab’

For correction, subtract 2 days for every 5 C.R., or 1 day every 130 Haab’:

$\frac{83\text{ C.R.}}{5}$ = 16.6 x 2 days = **33.2 days**

or, more accurately:

$\frac{4339\text{ Haab'}}{130\text{ Haab'}}$ = **33.4 days** drift from expected (1/4 day drift)

1084 days - **33 days** = 1051 days = 2 Haab’ + 321 days = **44 days**

44 days btwn. Haab’ and tropical year

For a visual illustration:

At 11 B’ak’tuns:

Tropical Year | Haab’ | 11 B’ak’tuns

-11 days- | -265 days-

-33 days- |

Expected C.R. calculation (1/4 year)

The telling thing about this configuration, is the relationship to the number 11, in 11 B’ak’tuns, in that the expected drift, using the Calendar Round calibration, gives us a tropical year 11 days before the Haab’. However, the correction gives us a more accurate 44 days between the tropical year and the Haab’, which seems to reflect the 4400 Tun cycle, informing us that the accurate

Haab' drift is 44 days every 4400 Tuns. Note that this only works in these higher increments of time.

When we multiply 11 B'ak'tuns three times, some interesting things occur. Again, we can use a Haab' drift of 44 days for each 11 B'ak'tuns, giving 44, 88, and 132 days of drift for each respective 11 B'ak'tun cycle. At 33 B'ak'tuns, or 3-11-pih, let us note the interesting configurations of the position of the Haab' relative to the tropical year. For the sake of this discussion, I will use the 584383 correlation which places the origin date at August 11, 3114 B.C.E.:

At 33 B'ak'tuns = 13,200 Tuns

Distance between tropical year and Haab' = 132 days

8/11
Tropical Year | 33 B'ak'tuns

-132 days- | -65 days-

Haab'
12/21

From this image, we can see that the position of the tropical year remains constantly on August 11, where the count began on 4 Ahau 8 Cumku. This also coincides closely with the second solar zenith passage in Copan, and Izapa, near 15° N latitude. The zenith passages of the sun, as we shall see, are the most accurate way of measuring the exact day of the solar year. Furthermore, at this latitude, the two zenith passages are separated by exactly 260 days, with the winter solstice precisely at the midpoint between the zenith passages, 131 days in either direction (Aveni 2001: 144).

At 33 B'ak'tuns, we see the position of the Haab' falling on the winter solstice, 132 days after the second zenith passage on August 11. Given that the zenith passages of the sun may occur over two days around 15° N latitude, with slight differences in location, the 132 days may include this extra day. Similarly, it may also require two days to determine the exact last day of the zenith. It appears that the creators of the Long Count system, and those who noticed the 33-B'ak'tun pattern were intending to determine when the date 4 Ahau 8 Cumku would reach the point of the winter solstice. This is most fascinating, however, it should be noted that the Haab' by this time would have drifted in and out of the winter solstice over eight times. What is more interesting is the length of time being measured. 13,200 Tuns is exactly one half of a precessional cycle of 26,000 years. This is an apparent midpoint, as we shall see what happens when we multiply 13,200 Tuns by two.

33 B'ak'tuns appears to be the relevance of 3-11-pih, yet when multiplied twice, it gives us 66 B'ak'tuns, or 26,400 Tuns. This is equal to 26,038 Haab' + 130 days, or 26,021 tropical years + 32 days. This is almost exactly the cycle of precession, and in this time period, the equinoxes and solstices will have precessed through the entire zodiac and back to their exact location a full year of 365.54 days. This is a measurement which will bring the position of the zenith passage on August 11 to the exact sidereal position as it was on the day of origin.

At 66 B'ak'tuns = 26,400 Tuns

Distance between tropical year and Haab' = 264 days

8/11
Tropical Year | 66 B'ak'tuns
-29 days-
-264 days- | -101 days- |
Haab' **5/2** | **8/11** Tr.Yr.

Amazingly, also on this day, according to the calculation of 264 days of Haab' drift for 26,400 Tuns, the Haab' location of 4 Ahau 8 Cumku will be found on the day of the first zenith passage on May 1 or 2nd. This was apparently the intention of the creators of the calendar system, coordinating the long cycle of precession – the longest observable astronomical cycle – with the drift of the Haab' from the tropical year. Curiously, the positioning of the Haab' at this date of 66 B'ak'tuns may indeed approximate the positioning of the Haab' during the earliest appearance of the Long Count.

It should be mentioned that this apparently intended pattern begins to show an error of three additional days of drift at 66 B'ak'tuns, over the corrected drift of 264 days, reaching 267 days. A slight error at 33 B'ak'tuns is evident, with the true Haab' drift being 133.978 days rather than 132 days. This error is certainly slight given the vast expanses of time being dealt with accurately.

The measurement of the precise tropical year can be accomplished using a vertical zenith sight tube, as can be found in Monte Albán, and other Mesoamerican sites. This consists of a narrow vertical opening through which a beam of light passes on the day of the solar zenith, illuminating a chamber beneath, which otherwise is never lit by the sun on all other days of the year (Aveni 2001: 262-271).

This may indeed be the original purpose of using the solar zenith passage days to calculate increments of time which then leave 260 days additional days to reach the final goal. At the latitude of Copan or Izapa, if we count forward from 4 Ahau 8 Cumku on the origin date and the second zenith passage of the sun, this would place the day of the intended goal on the date of the first zenith passage, 260 days later. The Metonic interval of 19 tropical years plus 260 days to reach an exact K'atun, and the 52 Tuns thirteen days plus 260 days is yet another example. All count forward form 4 Ahau 8 Cumku. Clearly, there is interwoven in this system the utilization of solar zenith passage calibrations which rely on the specific latitude where the two zenith passages are 260 days apart.

We also see the specific calculation of the cycle precession within these cycles, which apparently was intended in the inception of the Long Count. The 66 B'ak'tun cycle implied in the bone fragment of Hasaw Chan K'awil accounts for an exact measurement of one precessional cycle. Curiously, this is also implied in the Long Count system of 13 B'ak'tuns, in that five cycles of 13 B'ak'tuns gives 65 B'ak'tuns, or 26,000 Tuns, exactly one B'ak'tun less than the 66 B'ak'tun cycle, accounting for exactly 360 days of precession, presumably to fit the 360 day Tun.

Curiously, the calculation of exactly one day of precession corresponds to 26,000 days, which is coincidentally, or perhaps intentionally close to the calculation of 3 x 8,660 days, or 25,980 days, the original number proposed by Looper (2002) which falls within the nearest Calendar Round. If this was intended, the increment of one day of precession, some 71 years, indeed may have been a significant event for an individual, thus affording them the title of 3-11-pih ahau as Looper suggests. Alternately, the naming of an ahau as 3-11-pih may confer upon them , as Grube, et al. suggest, that the ahau is lord over creation. In this case, the half-precessional cycle may relate a sense of centering oneself in time, as in space, with alpha and omega points at equal distances.

In this exploration, it appears highly likely that the ancient Mesoamericans devised an ingenious system with which to track and observe the cycles of nature and the cosmos. That they succeeded at this much earlier than Europeans, or even earlier civilizations in the West, may come as some surprise and a definite challenge to the Eurocentric bias against non-Western histories, traditions, and sciences. There is much more to understand regarding the operations of this system, and the meanings of this knowledge to those who recorded it. Yet, what appears in the system of the Long Count is an unparalleled understanding of the workings of the earth as it relates to the heavens, and the human realm as it relates to the entirety of time.

Appendix

There is perhaps more to understand regarding the possible connection of 11 B'ak'tuns to the increments of 8,660 days. The increments 25,980 and 8,660 appear to be based on multiples of 433 days, conferring perhaps another reading on 3-11-pih, or 3 x 11 + 400. The number 433 is curiously composed of one 360 day Tun plus 73 days, or one fifth of a Haab' year, so that:

433 days = 360 days + 73 days

8,660 days = 20(433) days = 20 Tuns + 4 Haab'

25,980 days multiplied by six brings us to exactly 433 Tuns, accurate for measuring six days of precessional drift. When added to exactly 70 tropical years, 433 brings us to precisely 26,000 days, or one day of precessional drift. Following this, 1,400 tropical years plus 8,660 days is equal to 20 days of precessional drift.

83 Calendar Rounds + 8,660 days = 4,400 Tuns or 11 B'ak'tuns

83 C.R. + 8,300 days + 360 days = 11 B'ak'tuns

This gives us the same remainder of 8,660 days from the point of starting a new Calendar Round.

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