National University of Singapore

Department of Mathematics
GEK1506 Heavenly Mathematics:
Highlights of Cultural Astronomy

Project

Mayan Calendar

Prepared for:
Assoc Professor Helmer Aslaksen

Group 18:
Kwong Chang Chi
Le Duc Phuong
Lau Mang-Kin, James
Toh Kok Ben
Ku Ka Yan
Hasan Al Murad

Date of Submission: 17th October 2003 (12.19.10.12.5, 3 Chicchan 13 Yax)

Table of Contents

	Page
Abstract	3
Introduction	4
Mayan Math	6
Mayan Calendar System	9
Calendar Round	13
Katun Cycles	14
Solar Year versus Vague Year	15
Correlation Problems in Mayan Calendar	16
Inter-conversion between the Mayan Calendar and the Gregorian Calendar	18
Cultural, Religious and Astronomy Aspects of their Calendar	29
What is so special about 2012 A.D?	42
Conclusion	44
Appendix I Model Description	45
Appendix II Photo of Model	46
Appendix III Glyphs	47
References	49

Abstract

In this project, the calendars devised by the Mayans were studied. In total, 3 main calendars were discussed, that is the Haab, Tzolkin and Long Count. The various combinations of the three calendars that gave rise to different cycles were examined. The conversion between the calendars and to modern calendar was also discussed.

In addition, the cultural aspects of the Mayans under the influences of the calendars were explained. The astronomical achievement of the ancient Mayans together with its connection to the calendars was noted. Finally, this project also considered the calendars from philosophical and religious point of view.

Introduction

Mayan Civilization is one of the most mysterious ancient civilizations of all time. Until now, no one is certain on who the Mayan were, how they lived, and the reason behind the sudden collapse of their civilization.

"I wake up almost every morning thinking how little we know about the Maya," says George Stuart, an archaeologist with National Geographic. "What's preserved is less than 1% of what was there in a tropical climate."[1]

Mayans are believed to have developed their country and their civilization in a giant thumb (Fig. 1) north of the Gulf of Mexico, which is in between North and South America, called the Peninsula of Yucatan.

With respect to modern day geography, the region that was occupied by the ancient Maya comprised of the states of Yucatan; Campeche; Tabasco; the eastern half of Chiapas; the territory of Quintana Roo; the Republic of Mexico; the Department of Peten in Guatemala; and the adjacent highlands to the south, (that is to say most of Guatemala except the Pacific coast-plain); the contiguous western section of the Republic of Honduras; and all of British Honduras. It covers 125,000 square miles, roughly an area equal to 476 times of Singapore[2].

Fig.1 Map of Maya Area http://www.michielb.nl/maya/geographical.html

[1] . *Michael D. Lemonick "Mysteries of the Mayans"*
[2] *Adapted from The Ancient Maya, Sylvanus G. Morley, Stanford University Press, pg. 3*

The whole area of the Maya region lies south of the tropic of cancer and north of the equator. The region is mostly covered by rainforest and with a tropical climate except for the Guatemalan Highlands that has lower temperatures.

However, the lack of knowledge about Mayan civilization may have underestimated the size of the region covered by the Maya. More and more Maya sites are discovered nowadays.

The Maya Civilization is divided into 3 epochs.

(i) **Pre-Maya**, 3000 B.C. to A.D. 317;

(ii) **Maya Old Empire**, A.D. 317 to 987;

(iii) **Maya New Empire**, 987 to 1697.

Each of them is divided into 3 subdivisions. The usage of Hieroglyphic writing was only employed in Pre-Maya III. Therefore, information about Pre-Maya I and II are scarce as there was no form of records. Obviously, as the Mayan calendar system will be discussed in this project, the focus will be on the Pre-Maya III period and onwards.

The Greatest Period of the whole Maya Civilization is in Maya Old Empire and in particular, the “Golden Age” around 400 – 800 A.D. Many pyramids and other monuments were built during this era. Unfortunately, after this period, the southern Maya abandoned their cities. Many archaeologists discovered that they seized to build monuments after 822 A.D, a possible sign of the great civilization’s decline. The Mayan Civilization came to an end in 1200 A.D. when Northern Maya integrated with Toltec, another society located somewhere in Central America. Despite the integration, some peripheral cities continued to thrive.

The sudden collapse of this civilization remained a mystery. Why did they stop producing monuments abruptly during the Golden Age? Why did southern

Maya abandon their cities? Why didn't Northern Maya continue to thrive their own civilization, which is believed to be far better than others? The answer to these questions are difficult to find as well as the history of the Ancient Maya due to the fact that in the 16th century, the Spanish destroyed many cultural relics and books in their conquest. The Spanish forced the Aztecs to believe Christianity by burning nearly all their books of the ancient Maya.

Fortunately, archaeologists and historians were still able to discover some advanced technologies of Maya such as the calendar system and mathematics.

Mayan Math

From the 3rd to 9th century, Maya produced lots of amazing pyramids and temples, highly accurate calendars, mathematics, and as well as hieroglyphic writing. In fact, they are in the same rank with the other ancient civilizations, i.e. Mesopotamia, Chinese etc.

In order to study the Mayan calendar, we will need to have a look on Mayan number system and mathematics.

Only 3 symbols are used in the ancient Maya number system:

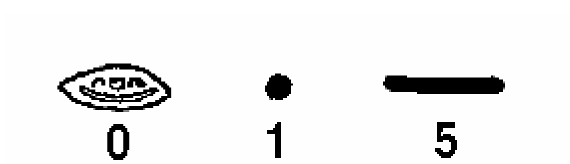


Fig. 2

As it can be seen from the figure above, the shell represent zero, a dot as 1 and a bar as 5. At that time, many civilizations actually did not know the concept of zero and it is astonishing that Mayan could even use a symbol to represent a zero. (In the Roman numeral system, it is obvious that the system did not employ the use of a zero.

The Decimal system is used nowadays; the Mayan however, used a **Vigesimal** system in their number system.

Pictures below shows how Maya write from 0~19. A few examples on how to write numbers greater than 20 is also provided:

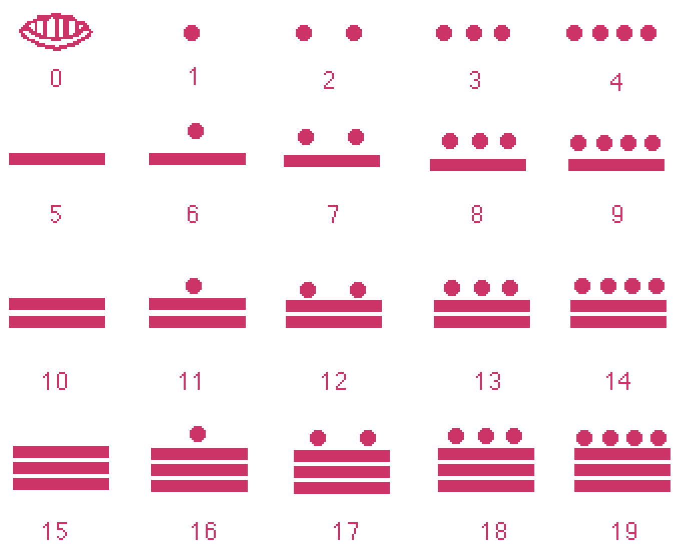


Fig. 3

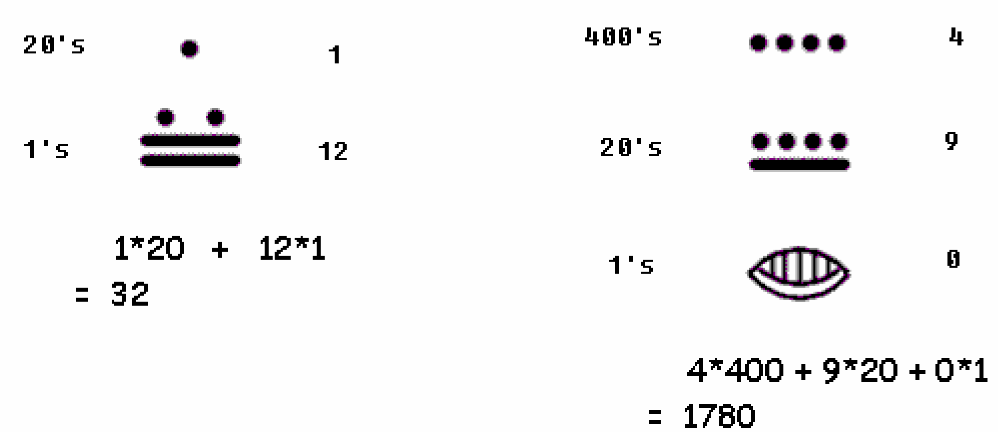


Fig. 4

In the decimal system, the positions to the left of the decimal point increment in tens from right to left – units, tens, hundreds, thousands and so on. However, as we noticed from the pictures above, Maya's positional system is quite different. The position value is incremented by twenties from bottom to top except in counting time.[3]

Picture below shows an example how the addition of two numbers works:

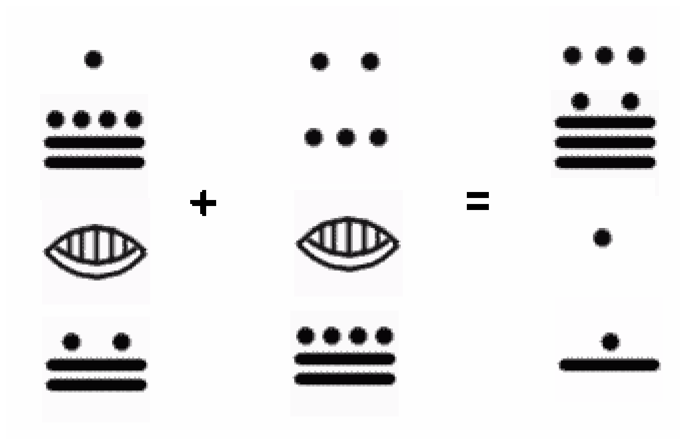


Fig. 5

This kind of number system enables people to visualize and understand addition and other operations in mathematics in an easier manner. As you can see, 1 dot plus 2 dots equals to 3 dots. Every 4 bars lead to a dot for the higher position. It's easier for Mayan to know the concept of some mathematics operation than us. However, as our knowledge on Mayan mathematics is limited, we are uncertain if they invented a system for multiplication and division.

Although the Mayan may find the Vigesimal system easy to use as they are accustomed to it, we on the other hand will have difficulty as we are used to the decimal system. It is amazing that the Mayan invented a numeral system that is more symbolic and easier to visualize compared to other great empires such as the Roman Empire.

[3] *Ibid pg. 280*

Archaeologists believe that Mayan mathematics was more suitable for calculations, according to the monuments and pyramids that they had built.

• • •

Mayan Calendar System

The Mayans used three types of calendars:

1. **Haab**
2. **Tzolkin**
3. **Long Count**

The Haab

The Haab was the civil calendar of the ancient Maya. The year was divided into 18 uinals, each having 20 days and a name, followed by a 5-day period of uayeb. This makes the Haab a 365-day cycle calendar. This type of calendar is tightly connected to the Sun. However, the Mayans did not incorporate the concept of leap year into this calendar. Hence, sometimes this calendar is referred to as the Vague[4] Year calendar.

One thing special about this Haab, in spite of some similarity with the Gregorian calendar, is that the Mayans do not number the years for Haab. It is more like a cycle that has a period of 365 days.

The 18 uinals[5] are named:

1	Pop	2	Uo	3	Zip
4	Zotz	5	Tzec	6	Xul
7	Yaxkin	8	Mol	9	Chen
10	Yax	11	Zac	12	Ceh
13	Mac	14	Kankin	15	Muan
16	Pax	17	Kayab	18	Cumku

[4] *As there were no leap years for correction, the haab drifts with respect to the solar year.*
[5] *Refer to appendix for the glyphs of the 18 uinals and the uayeb.*

For the twenty days in one uinal, they are numbered from 0 to 19. This is something very unique of this Haab calendar. Rarely has a civilization that counts a day starting from 0.

For example, the first day of such a cycle will be 0 Pop, also known as "the seating of Pop". The next day will be 2 Pop and continues to 19 Pop. After 19 Pop, the next day will be 0 Uo.

The 5 uayeb days are special in the sense that they are not grouped into period of 20 and was considered "unlucky" days. It was also known among the superstitious Mayans as the "days without names" or "days without souls".

The Tzolkin

Also known as the sacred calendar or the ritual almanac, the Tzolkin is a religious calendar used by the Mayans. Basically, this calendar was used to predict the fortunes of a certain day, and also the days for the ritual ceremonies.

There are a cycle of 13 days and another cycle of 20 names. The 20 tzolkin names (some writers call this as a veintena) are as follow:

1.	Imix	2.	Ik	3.	Akbal	4.	Kan
5.	Chicchan	6.	Cimi	7.	Manik	8.	Lamat
9.	Muluc	10.	Oc	11.	Chuen	12.	Eb
13.	Ben	14.	Ix	15.	Men	16.	Cib
17.	Caban	18.	Etznab	19.	Cauac	20.	Ahau

The days are named by pairing the numbers 1 to 13 (some writers call this as a trecena) with the 20 of this tzolkin names. For example, one of the tzolkin day is 1 Imix. The next day will be 2 Ik and following day will be 3 Akbal. When we reached 13 Ben, the next day will be 1 Ix, followed by 2 Etzab. Since 13 and

20 is relatively prime with each other, it would actually take 260 days for a cycle of tzolkin to complete[6]. The system exhibits certain degree of similarity as the Sexagenary cycle of Chinese calendar.

For the sacred calendar, the days are numbered starting from 1 and not from 0. As with the haab, the tzolkin does not count the years.

Long count

The long count calendar basically is a way to count the days since a certain day. The long count is stated with 5 numbers, each representing a unit of period. The units are[7]:

kin		1 day
uinal	20 kins	20 days
tun	18 unials	360 days
katun	20 tun	7200 days
baktun	20 katun	144000 days

Sometimes, the Mayan used larger units for longer time periods, though they did not incorporate this into their long count calendar.

pictun	20 baktun	2880000 days
calabtun	20 pictun	57600000 days
kinchiltun	20 calabtun	1152000000 days
alautun	20 kinchiltun	23040000000 days

An alautun is about 63081377 year, which is astronomical!

[6] *Refer to the model in the appendix.*
[7] *Refer to the appendix for the glyphs for kin, uinal, tun, katun and baktun.*

Kin, tun and katun are numbered from 0 to 19; uinal is numbered from 0 to 17. However, baktun are numbered from 1 to 13.

Normally, a date is expressed using 5 numbers, for example, 7.16.3.2.6. This means that (7 × 144000 + 16 × 7200 + 3 × 360 + 2 × 20 + 6) days have passed in the Mayan long count since the start of the date.

At first, one might think the long count is rather atypical of the 3 Mayan calendars, as it seems that the Mayans favoured cycle. Actually, the long count also reflects the beliefs of the Mayan in cyclic time. The Mayan believed that at the end of great cycles of 13 baktuns, the world would be destroyed and only to be recreated again for another cycle. Therefore, the start date for this calendar is the date of creation as believed by the ancient Mayans.

Starting position of the calendars and some interesting facts about the calendars

The Mayans had their long count calendar start from the date 13.0.0.0.0. The current cycle of the long count will end when the date reaches 13.0.0.0.0 again. However, the experts in the field have not reach a consensus on the start date of the long count in Gregorian calendar[8]. There are different view over the actually start date.

Despite the dispute over the date of 13.0.0.0.0, authorities have agreed upon the corresponding date in haab and tzolkin. The start date for Mayan Calendar would be 13.0.0.0.0 4 Ahau 8 Cumku.

---

[8] *Refer to Correlation Problems in Mayan Calendar.*

Calendar Round

Combination of haab and tzolkin will give us another cycle called the calendar round.

This calendar round is actually a cycle where both haab and tzolkin run simultaneously. Since the total days in a haab cycle = 365 = 5 * 73 and total days in a tzolkin cycle = 260 = 5*52, the total days in one round of calendar round is = 5*73*52 that is 18980 days. Therefore, one cycle will end after a period of 52 years of haab or 73 cycle of tzolkin.

For example:

10 Ben 11 Kayab
11 Ix 12 Kayab
12 Men 13 Kayab
13 Cib 14 Kayab
1 Caban 15 Kayab and so on…

Only after 18980 days will the date return to 10 Ben 11 Kayab.

Taking the first day of the haab calendar which is 0 pop, there are different system to which days in tzolkin that this date can be associated. Here, we will take the system employed in the codices, which is 0 pop and can ONLY pair up with Ik, Manik, Eb and Caban.

The answer to why there are 4 "partners" to 0 pop lies in the extra 5 Uayeb days. First of all, let us see what will happen if the haab consist of 360 days without the 5 Uayeb days. For each 20 days, the tzolkin date will finish its cycle, and return to the original date of say Ik. The numbers in front would not be the same, but the tzolkin name is the same. After 18 rounds of such cycle, the tzolkin name also returns to Ik. Therefore, if the haab calendar is 360 days long, then the tzolkin date paired up with 0 pop will always be Ik.

However, there is another 5 extra days. This make the haab drift with respect to the tzolkin. By the next 0 pop, the tzolkin name would not be Ik, but another day 5 days away. This gives us Manik. It is then that the length of tzolkin cycle of 20 days that each day in haab can have 4 tzolkin names to pair up. This is because 20 / 5 =4, and those 4 days are separated from each other by 5 days. This is important for the Mayans in their prediction of the fortune of a certain year.

Katun Cycles

One period of time that is important to the Mayan was the katun, which are 20 tuns. One tun is approximately 1 year and that is 360 days. Therefore, one katun would be approximately 20 years. In fact, the Mayans built a certain monument every 20 years.

Now, due to the construction of the long count, every katun period will end on only 1 certain day of the tzolkin, Ahau. This is because each katun is 7200 days. The length of a tzolkin cycle is 260 days, so if you start from 11 Ahau and you want to return to the same day 11 Ahau, 260 years would have passed.

$$7200 = 260 \times 27 + 180$$

When 7020 days have passed, the date would be 11 Ahau again. After another 180 days, the tzolkin date would have been Ahau, but it would not be 11 Ahau anymore. We have

$$180 = 13 \times 13 + 11$$

We have 2 days short of 13 days of the number part. Therefore, after 1 katun the tzolkin date would be 9 Ahau. So, the succession would be 11Ahau, 9 Ahau, 7 Ahau, 5 Ahau, 3 Ahau, 1 Ahau, 12 Ahau, 10 Ahau, 8 Ahau, 6 Ahau, 4 Ahau, 2 Ahau, 13 Ahau and it goes back to 11 Ahau. Thus, it would take 260 cycles of tuns in order for that particular katun period to start at 11 Ahau.

After this period of 260 cycles of tuns, which is approximately 257 of the solar year, history was expected to repeat itself[9]. This forms the basic of the Mayan belief in cyclic time.

Solar Year versus Vague Year

In the earliest stela that records the date, the haab cycle was not found by the historians to be part of the calendar system. The historians are of the opinion that the tzolkin and the long count system actually started first.

It is perhaps that they started off the 360-day cycle of tun as a year. However, this is found to be inconsistent with the length of one year. The Mayans then added 5 days to the 360-day cycle to make it the haab cycle. However, this is still not accurate enough. However, the Mayans did not use the leap year concept as the Gregorian calendar does. Instead, they just keep track of the errors in the calendar.

The Mayans actually chose a certain date to record this calculated errors. They chose the date 4 Ahau 8 Cumku that repeated every 52 haab years[10]. During each of this repetition, they would calculate the accumulated error and record it on a stela.

[9] *Refer to Superstitions part in Cultural, religious and astronomical aspects of their calendar.*
[10] *The calendar round repeats itself every 52 cycle of Haab.*

An example is on January A.D. 733 that is one of the anniversaries of the creation date. However, a monument was erected in A.D. 731 and the error is calculated 1 year before the actually anniversary. Comparing with the Gregorian calendar, we would have to insert 932 days as leap days for 3845 years that has elapsed since the creation date of Mayan long count. However, since the Mayans did not concern about the count of years, but only the seasons, we can subtract 730 days from the leap days that gives 202 days. The Mayan correctional date is 7 Mol, 201 days before 8 Cumku.

This is quite an achievement for the Mayans as the value needed for the correction is 201.2. In the long run, the Mayans would correct one or two days less from the actual correction. One needs to keep in mind that the Mayans did not divide the day into hours. Therefore, it takes careful and patient observations that continued for generations to come up with this precision.

Correlation Problems in Mayan Calendar

Complication in correlation is an important problem encountered by historians in understanding a civilization. Though we might know that the ruler of Palenque, Pacal, died on 9.12.11.5.18 6 Edznab 11 Yax, it is incomplete if the date cannot be converted to the Gregorian calendar.

Using Julian day number, we can define a number N as the correlation number whereby the Julian day N is the first day of the Mayan long count calendar. Hence, a date L (converted to numbers of days) in the Mayan long count calendar is (L+N) in Julian day.

The Mayanist[11] used astronomical data recorded in the cordices and the stela to help them determine the correlation number. Besides that, there are certain villages of contemporary Mayans that used the tzolkin. The Mayanist might be able to gather useful data from them.

The first day of long count is recorded as 13.0.0.0.0 in the long count calendar. The calendar round date corresponding to this long count day is 4 Ahau 8 Cumku. However, there is a general disagreement on the correlation number for long count calendar. Each of the correlation number will give rise to a different start date. Two of the more popular correlations are:

- N = 584285, 13 August 3114 B.C (Gregorian)
- N = 584283, 11 August 3114 B.C (Gregorian)

There is problem in determining the correlation number because at the time of Spanish Conquest, the long count calendar was no longer in use. One belief in 584283 correlation is based on calendar round that is still in used by certain villages in Mesoamerica. Belief in the 584285 correlation however was based on astronomical events calculated in the codices and stelas. In this correlation, there must be an assumption that 2 days of difference somehow appeared over the time.

The correlation number remained disputed, and there is no general agreement on value yet.

[11] *People who study Maya*

Inter-conversion between the Mayan calendars and the Gregorian calendar

As we have already mentioned, the three kinds of calendars in the Mayan culture are the haab, the tzolkin and the long count.

While the long count itself defines a way the Mayas used to reckon dates, the first two kinds of calendars together form another way: the calendar round. In this part we will consider how to inter-convert these two ways and the most popular kind of calendars in the world – the Gregorian calendar. Let us just focus on the conversion from a long count or a calendar round date into a Gregorian day number[12] and vice-versa, because to inter-convert the first two we only have to convert one into a day number and then convert it into the other[13].

It is quite important to recall that the long count has been believed to start at the Gregorian date August 11, 3114 BC, which has a Gregorian day number of -1,137,142.

I. ***Inter-conversion between a long count date and a day number:***

1. The long count units:

A day in the long count is specified by 5 numbers, which define the number of days since the start of the great cycle. To make it easier we will denote them by 5 following parameters:

---

[12] *In this project, the term "Gregorian day number" is indicated as the number of days passed since January 1, 1 A.D. at a specific date. For example, January, 5 1 A.D. has the day number 5 while December 31, 1 B.C. has the Gregorian day number 0, and December 30, 1B.C. has the Gregorian day number -1, and so on.*

[13] *Converting between Gregorian day number and Gregorian date is a pretty simple and common task. There have been humorous sources on this problem. The book "Calendrical Calculations" by Nachum Dershowitz and Edward M. Reingold (Cambridge University Press, 1997) is a good example (Note: in this book in stead of the term "Gregorian day number", the writers used the term "R.D." or "Rata Die").*

B = number of baktuns (1 baktun = 20 katuns = 144,000 days)
K = number of odd katuns (1 katun = 20 tuns = 7200 days)
T = number of odd tuns (1 tun = 18 uinals = 360 days)
U = number of odd uinals (uinal = 20 kins = 20 days)
D = number of odd kins (kin = 1 day)

Hence, one long count date will be written as B.K.T.U.D.

2. Conversion from a day number to a long count date:

Let us take L as the number of days that have passed by since the start of the great cycle. Because this cycle started at the -1,137,142 Gregorian day number, a day number G relates to L by the equation:

$$L = G - (-1,137,142) = G + 1137142 \qquad (1)$$

This L-th day in the great cycle is recorded as B.K.T.U.D., which means:

$$L = (((B*20 + K)*20 + T)*18 + U)*20 + D \qquad (2)$$

Therefore the division L/20 will give us the number of complete uinals (the quotient q1) and D, the number of odd days (the remainder).

$$\begin{cases} D = L \pmod{20} \\ q1 = ((B*20 + K)*20) + T)*18 + U = [L/20] \end{cases}$$ [14] [15]

[14] *In this project we define the equation r = N (mod q) (**not** r ≡ N (mod q)) as:*

- *(N – r) is divisible by q*
- *0 ≤ r < q*

For instance, 8 (mod 3) = -1 (mod 3) = 2 but we do not write 8 (mod 3) = -1, since -1 does not lies in the range from 0 to less than 3.

[15] *We define [a] as the biggest integer number that does not exceed a.*

This quotient q1 divided by 18 will give us the number of complete tuns (the new quotient q2) and U, the number of odd uinals (the new remainder):

$$\begin{cases} U = q1 \pmod{18} \\ q2 = (B*20 + K)*20 + T = [q1/18] \end{cases}$$

Similarly:

$$\begin{cases} T = q2 \pmod{18} \\ q3 = B*20 + K = [q2/20] \end{cases}$$

$$\begin{cases} K = q3 \pmod{20} \\ q4 = B = [q3/20] \end{cases}$$

<u>For example</u>: If G = -941,258, L will be:

L = (-941258) – (-1137142) = 195884

L = 195884 = 9794*20 + 4 → q1 = 9794, D = 4
q1 = 9794 = 544*18 + 2 → q2 = 544, U = 2
q2 = 544 = 27*20 + 4 → q3 = 27, T = 4
q3 = 27 = 1*20 + 7 → q4 = B = 1 and K = 7

Therefore the long count date of the Gregorian day number -941,258 is 1.7.4.2.4

3. Conversion from a long count date to a day number:

Following formula *(1)* and *(2)* we can easily convert a long count date, for instance 0.1.7.4.2.4, into a Gregorian day number:

(1) → G = L - 1137142
(2) → G = (((B*20 + K)*20 + T)*18 + U)*20 + D - 1137142

$= (((1*20 + 7)*20 + 4)*18 + 2)*20 + 4 - 1137142$

$= -941258$

This result totally matches the previous example.

II. ***Inter-conversion between a round calendar date and a Gregorian day number:***

1. To define a day in the round calendar:

Before going straight into the topic, we would like to remind you that there is a very interesting thing in the Mayan calculation: their usage of the number 0. Besides the names, all of the kinds of their cycles in calendar start with this number, except the trecena in the tzolkin, whose first day is numbered “1”. So in order to make the calculation more convenient, let us follow them by assuming the first days of each tzolkin, haab and calendar cycle are also 0-th.

a) The tzolkin:

The tzolkin cycle is in fact the combination of two smaller cycles: trecena (each trecena lasts for 13 days) and veintena (each lasts for 20 days). Since 260 = 13*20 is the smallest mutual multiple of 13 and 20, a tzolkin cycle has 260 days in total. In a 260-day tzolkin cycle, two numbers can define Z, the position of a specific date, V, the position of its veintena (or 20-day period, and let us just forget about their names), and T, the position of its trecena (or 13-day period). They fall in the ranges:

$$\begin{cases} 1 \le T \le 13 \\ 1 \le V \le 20 \\ 0 \le Z \le 159 \end{cases} \qquad (3)$$

Assume that before the Z-th day in this cycle, there are t trecena and v veintena, of course:

$$\begin{cases} 0 \le t \le 19 \text{ (since there are 20 trecenas in one tzolkin at most)} \\ 0 \le v \le 12 \text{ (since there are 13 trecenas in one tzolkin at most)} \end{cases} \qquad (4)$$

Z is defined by:

$$Z = 13t + T - 1 = 20v + V - 1 \qquad (5)$$

$\Leftrightarrow$ $13t - 20v = V - T = r = r*(13*3 - 20*2)$ (note: $-12 \le r \le 19$ since (3))

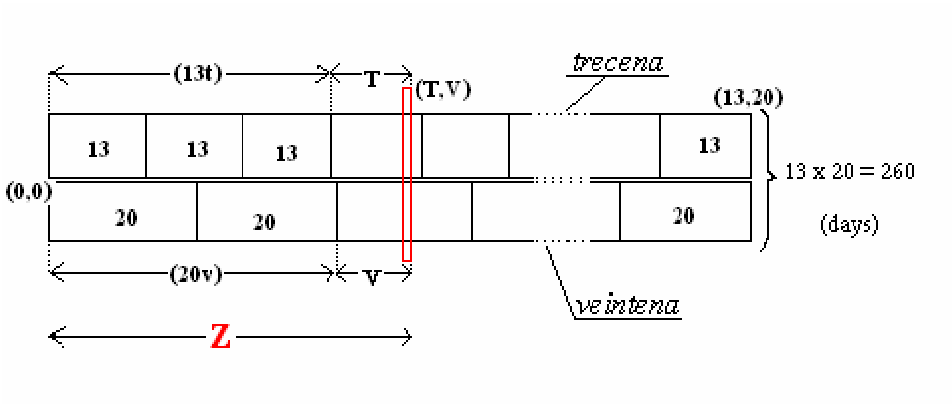


Fig. 6
The Tzolkin cycle contains two small cycles: trecena and veintena

$\Leftrightarrow$ $13(t + 3r) = 20 (v + 2r)$

$\Leftrightarrow$ $(t + 3r)/20 = (v + 2r)/13 = x$

$$\Leftrightarrow \begin{cases} t = 20x - 3r \\ v = 13x - 2r \end{cases}$$

$$\Leftrightarrow \begin{cases} t = (-3r) \pmod{20} & \text{(since } 0 \le t < 20 \text{ and } (t + 3r) \text{ is divisible by 20)} \\ v = (-2r) \pmod{13} & \text{(since } 0 \le v < 13 \text{ and } (v + 2r) \text{ is divisible by 13)} \end{cases}$$

$$\Leftrightarrow \begin{cases} Z = 13*[(-3r) \pmod{20}] + T - 1 \text{ (following } \textit{(5)}\text{)} \\ Z = 20*[(-2r) \pmod{13}) + V - 1 \end{cases}$$

$$\Leftrightarrow \begin{cases} Z = 13*[(3T - 3V) \pmod{20}] + T - 1 \\ \begin{cases} T = 1 + Z \pmod{13} \quad \text{(following } \textit{(5)}\text{)} \\ V = 1 + Z \pmod{20} \end{cases} \end{cases} \qquad (6)$$

Equation *(6)* shows how we can define Z from T and V and vice versa.

b) *The haab:*

Two numbers reckon a haab date: U, its uinal number, and D, the position of the day in that uinal. The first 18 uinals consist of 20 days and the last one only 5. U and D together define H, the position of the date in a 365-day haab cycle (365 = 18x20 + 1x5).

Therefore:

$$\begin{cases} 0 \le U \le 18 \qquad (7) \\ 0 \le D \le 19 \\ 0 \le H \le 364 \end{cases}$$

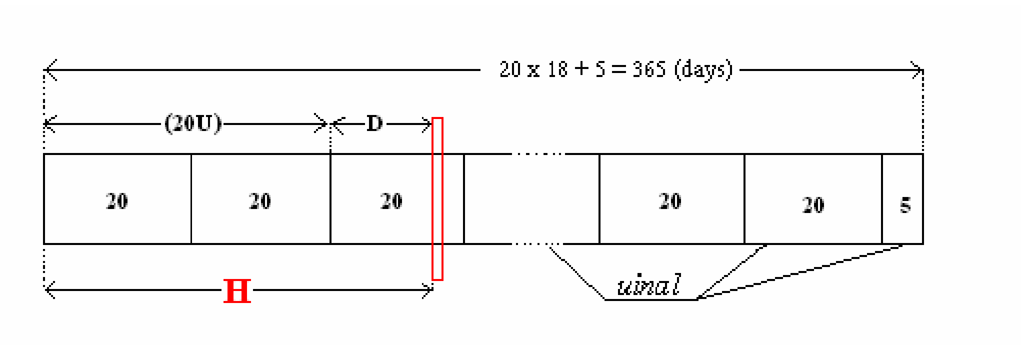


Fig. 7
The haab cycle contains 19 uinals: 18 of them have 20 kins (days) and the other only 5

It is plain to see:

$$H = 20U + D, \text{ or} \qquad (8)$$

$$\begin{cases} D = H \pmod{20} \\ U = [H/20] \end{cases}$$

Equation *(8)* shows how we can calculate H from U and D and vice versa.

c) *The round calendar cycle:*

The round calendar is the combination of the two above cycle: the 260-day tzolkin and the 365-day haab. There are 18980, the smallest mutual multiple of 260 and 356, days in this big cycle, containing 73 tzolkins and 52 haabs.

There are two ways to define R, a date's position in this cycle: (i) giving the position of the current tzokin, z, and Z, the date's position within that tzolkin; or (ii) giving the position of the current haab, h, and H, the date's position within that haab. Immediately we have:

$$\begin{cases} 0 \le R \le 18979 \\ 0 \le h \le 51 \\ 0 \le z \le 72 \end{cases} \qquad (9)$$

and:

$$R = 260z + Z = 365h + H \qquad (10)$$

$$\Leftrightarrow 365h - 260z = Z - H = 5p$$

$$\Leftrightarrow 73h - 52z = p = p*(73*5 - 52*7)$$

$$\Leftrightarrow 73(h - 5p) = 52(z - 7p)$$

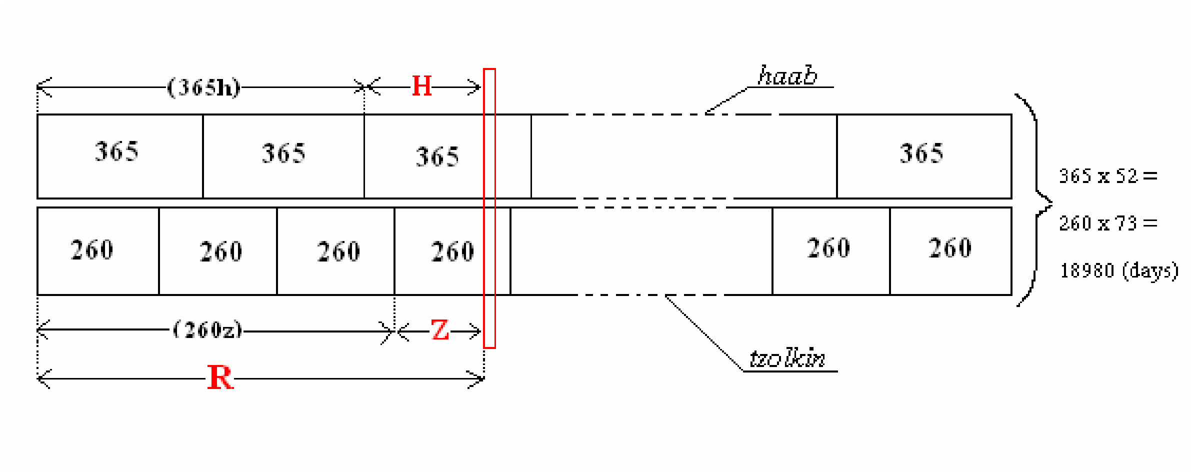


Fig. 8
The round calendar cycle is just the combination of the haab and the tzolkin

$\Leftrightarrow$ $(h - 5p)/52 = (z - 7p)/73 = m$

$\Leftrightarrow$ $\begin{cases} h = 52m + 5p \\ z = 73m + 7p \end{cases}$

$\Leftrightarrow$ $\begin{cases} h = (5p) \bmod (52) & \text{(for } 0 \le h < 52 \text{ and } (h - 5p) \text{ is divisible by } 52) \\ z = (7p) \bmod (73) & \text{(for } 0 \le z < 73 \text{ and } (z - 7p) \text{ is divisible by } 73) \end{cases}$

$\Leftrightarrow$ $R = 365*[(5p) \pmod{52}] + H$ (following *(10)*)

$\Leftrightarrow$ $R = 365*[(Z - H) \pmod{52}] + H$ *(11)*

Equation *(11)* shows how we can define R given Z and H.

2. Conversion from a Gregorian day number to a round calendar date:

In this section we have to find T, V, U and D (4 factors indicating a date in the round calendar cycle) when given G.

With L, the number of days elapsed since the start of the great cycle and a day number, J, from *(1)* we have:

$L = G + 1137142$

Then Y, the number of 18980-day round calendar cycle completed, is:

$Y = [L/18980]$ *(12)*

The remainder of this division is exactly R, the position of the day in the current calendar round:

$R = L \pmod{18980}$ *(13)*

Now we can define T, the trecena number by *(6)*. However, we must arrange that $T = 4$ when $R = 0$ (since this is the first day of the great cycle) and $1 \leq T \leq 13$. This leads to:

$T = 1 + (R + 3) \pmod{13}$. *(14)*

Similarly, V, the veintena number is:

$V = 1 + (R + 19) \pmod{20}$ *(15)*

The days of the haab, $0 \leq H \leq 364$, is:

$H = (R + 348) \pmod{365}$ *(16)*

We can calculate D and U from H by *(8)*.

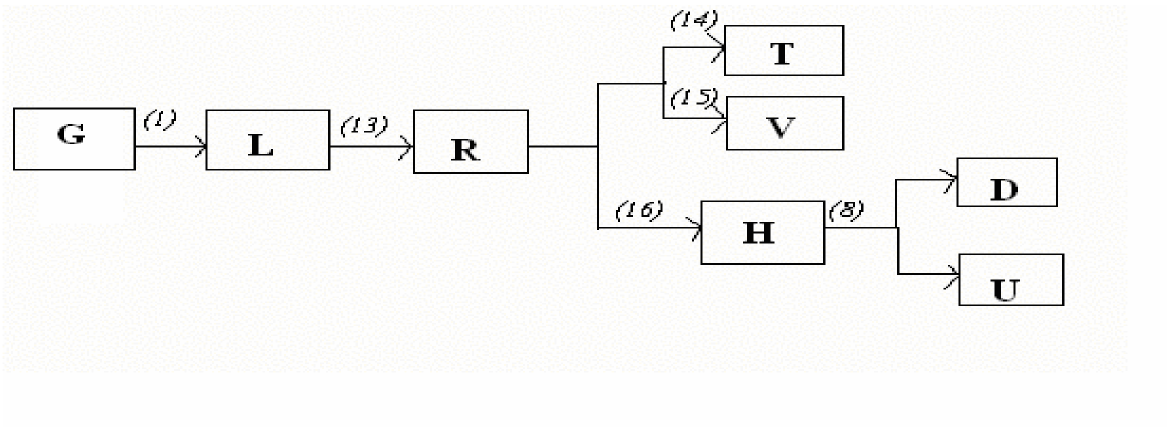


Fig. 9
The picture showing the process and the equation numbers to calculate T, V, D and U from a given G

For example: When G = -1,138,139 → L =0 → R = 0, using the equations above we can find T = 4, V = 20, D = 8 and U = 17. In other words, the Gregorian date whose position is -1,138,139 has a name in the calendar round as 4 Ahau 8 Cumku.

3. Conversion from a round calendar date to a Gregorian day number:

Conversely to the above part, now we are given T, V, D and U.

Are all of the combinations of these 4 numbers possible? There are totally 260*365 = 94900 combinations, but in fact only one-fifth of them are possible, since 94900/5 = 18980 is the smallest common multiple of 260 and 365. Hence, before beginning our job, we must assume that the specific considered set of T, V, D and U is a valid combination.

One more important number we need to know is Y, the number of cycles that have passed.

Our job is to calculate G. As we have mentioned above:

$$G = L - 1137142 = 18980Y + R - 1137142 \qquad (17)$$

As Y is given, we need to define R. Equation *(11)* give us:

R = 365*[(Z – H) (mod 52)] + H

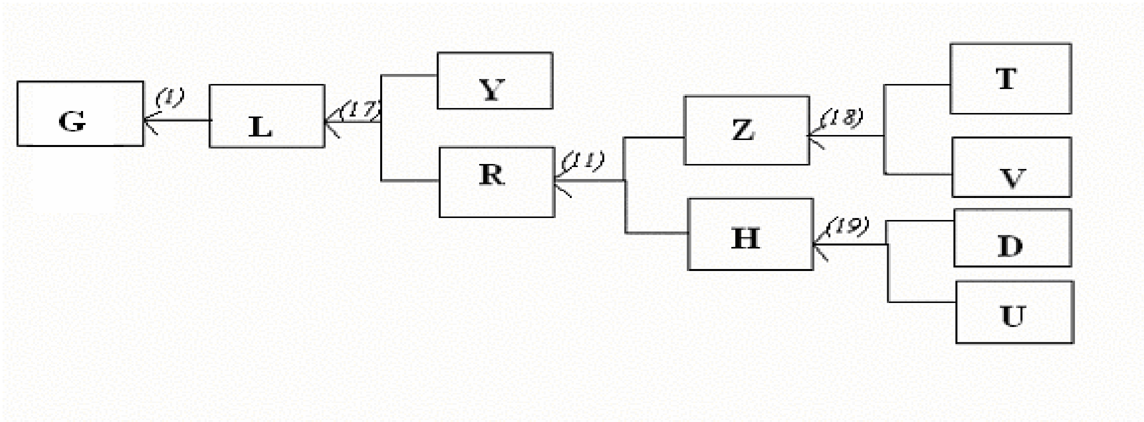


Fig. 10
The picture showing the process and equation numbers to calculate G from given T, V, D, U and Y.

How to get Z and H then? Can we use equation *(6)* and *(8)*? There is a small problem here:

- In order to get *(6)* we have supposed the first day of the first tzolkin was Z = 0 (with T = 1, V = 1). But here, in the calendar round cycle, it actually was Z = 159 (with T = 4, V = 20). The distance is 159, so we have to subtract it by 159 in order to get an accurate Z for the equation *(11)*:

  Z = 13*[(3T – 3V) mod (20)] + T – 160 *(18)*

- Similarly, to get *(8)* we have supposed the first day of the first haab was H = 0 (with D = 0, U = 0) when in fact it was H = 348 (with D = 8, U = 17). The accurate H in *(11)* is the subtraction of this H by the distance of 348 days:

  H = 20U + D – 348 *(19)*

This is the way we used to convert a calendar round date to a Gregorian day number./.

Cultural, religious and astronomical aspects of their calendar

How they record the events

Recording an event is important for every civilization. The Egyptians used the papyrus; the Sumerians used the clay tablets and others. Mayans have their own books to record events. However, most of the books were destroyed during the invasion of the Spaniards. Around four are spared and is being kept at libraries at various locations. Besides the books, there is the stela, which can be considered as a stone monument erected to commemorate certain important events.

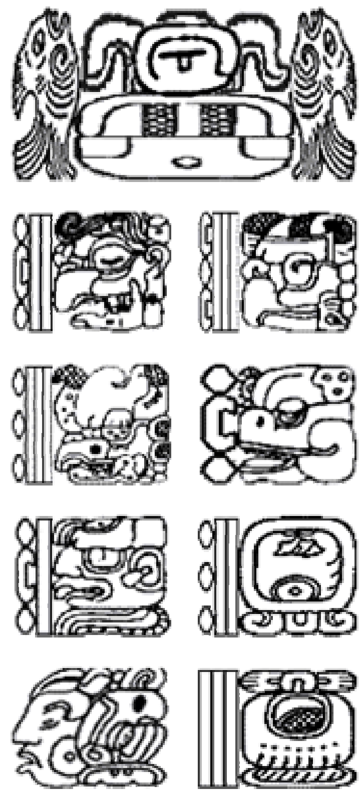


Figure 11
http://www.jaguar-sun.com/calendr.html

The dates are normally recorded according to a certain format. Firstly, there are the initial series. The initial series contained the long count and the calendar round. Usually the long count and calendar round are present, but such is not the case with the other glyphs.

The initial series begin with the “initial series introductory glyph”. After the initial series introductory glyph, it is the glyphs for the long count. For example, if the date is 9.0.19.2.4, the Mayans would merge the glyph for 9 and glyph for baktun together. The rest of the long count calendar is written with the same format.

In a stela, the Mayans normally record one long count date only. For subsequent dates that might appear in the stela, they used a certain number, called distance number to indicate. This number represents the distance of a certain event from the long count date stated earlier. However, they still refer to that certain day's calendar round date. The long count starts from larger unit (baktun) and continue to smaller ones (kin). To differentiate, the distance number is the total inverse of long count date format. For example, a distance number recorded for 4 kins 8 uinals 4 tuns would be 4.8.4.

This distance number is flexible because it can be counted forward or backward. For both cases, there are different glyphs responsible to represent whether a certain number is counted forward or backward.

The series is then continued by the glyph for the tzolkin day. Also in the initial series is the haab day. However, the arrangement of the haab is at the last place of the series.

Situated between the haab and the tzolkin is the supplementary series. First of all, there is the night god glyph. It is supposed to represent the name of one of the night gods, in a cycle of nine.

Next on the series will be the lunar series. This normally appears as a cluster of glyphs, among which some of them are attached with numbers. It is found that the series represented lunar data for the particular day. The data presented include the number of days passed since new moon, the position of lunation in a certain 6 lunation cycle and whether the length of the lunar month is 29 or 30.

It is important to note that the series above are of the more common ones. The glyphs that appear may vary from each other in the sense that some glyphs might be left out or added in for certain ones. However, the initial series always appears in the record.

<u>Philosophy of time among the Mayans</u>

The Mayans were actually obsessed with time. They built a lot of monuments including altars and stela to mark the passage of time. Inscribed on the monuments would be the series of glyphs that record the date, the gods and lunar information. In addition to that, Venus is rather important in Mayan culture. Information on Venus can be found also among the glyphs.

The Mayans considered the days as divine whereby gods are assigned to the days. This is evident in certain villages in Guatemala where some form of the Mayan calendar still survives up to this day. They conceive the dates and time as burdens to be carried by their various gods. As there are a lot of numbers and date in the Mayan calendar, the system actually employed many divine bearers together for a day.

Along one cycle of calendar round, the haab will shift with respect to the tzolkin. In a calendar round, a year bearer is the name of the tzolkin day that coincides with 0 Pop[16]. In one of such system employed by in the codices, there are only four-year bearers possible, which are Ik, Manik, Eb and Caban. These four gods associated with the day then determined the fate of this whole haab year.

---

[16] *The first day in one cycle of haab.*

Superstitions

It is the bearers of the burden which determine whether a certain day is good or ill fortune. For example, as Kan was an aspect of the maize god in Mayan religion, a year that started with Kan as the first day will be a good year with good corp. As there was a lot of different gods viewed as the burden carrier of the day by the Mayans, the actual task of prophecy is more complex. This allows some space for the priests to avoid embarrassment if the prophecy turns out to be wrong.

As their concept of time based on cyclic time[17], the Mayans believe that on the same day of their calendar, history of past event will repeat itself. Perhaps not identically, but the events will be similar.

For example, the 260 cycles of katuns where the tzolkin date Ahau repeat with a decreasing attached number each cycle. Each time a particular katun return, similar events would be expected to happen. For example, katun of 8 Ahau was associated with fighting and political changes.

Such superstition is prevalent in the Mesoamerican culture that it led to the fall of the Tayasal to the Spaniards. A Spanish Franciscan who had knowledge of Mayan calendar visited Tayasal that held out against the Spaniard. During his visit, he pointed out that the katun 8 Ahau, and he urged Tayasal to submit. Tayasal actually submitted to the Spaniards. They put up little resistances as deep in their mind they think that the katun of political change is inevitable.

[17] *There are records of distant past in the Mayan records. They actually believed that the world is constantly being destroyed and recreate. This current period of baktun is supposedly to be the fifth. However, they believe that history will repeat itself.*

Background of their astronomy

One thing that inevitably emerges when talking about the Mayan calendar is the enormous influence of astronomy. As already mentioned, the Mayans of Mesoamerica considered measurement of time a crucial part of their religious and social lives: almost each visible astronomical object had a corresponding deity or 'god' associated with it; the movements of the Sun, the Moon, planets and constellations implied certain consequences on people's normal day-to-day concerns. Furthermore it was important to tell apart one season from another to determine when the right time for agriculture was; otherwise the people would simply starve. Thus it can be inferred that astronomical observations were of great importance to the success of the Mayan civilization: from their agriculture to theology to time keeping, the prevalence of astronomical and cosmological observations was widespread.

And that is what we will be dealing with in this section.

Fig.12
A priest astronomer can be seen observing the heavens
Courtesy of www.physics.unr.edu

Very adept astronomers of their times, the Mayans were primarily interested in the Zenial passages of the Sun. Their territory was located within the tropics – north of the Equator and south of the Tropic of Cancer – and there the Sun reaches the Zenith twice every year, once before and once after the Summer

Solstice for the *ilhuica tlamatilizmatini* or the Mayan priest astronomers. It was in fact quite easy for the priests to ascertain the time of the Zenial Passage, as the Sun would have an altitude of precisely 90 degrees (i.e. an object will not cast a shadow during that time).

Although they appreciated the infinite dimensions of the Universe in general, the *ilhuica tlamatilizmatini* were particularly keen on knowing the precise paths that the Sun and certain other astronomical objects followed through the course of the year across the sky. Among them were the Moon, Venus and certain constellations like Pleiades, Gemini and Scorpios as well as the Milky Way in general.

SUN

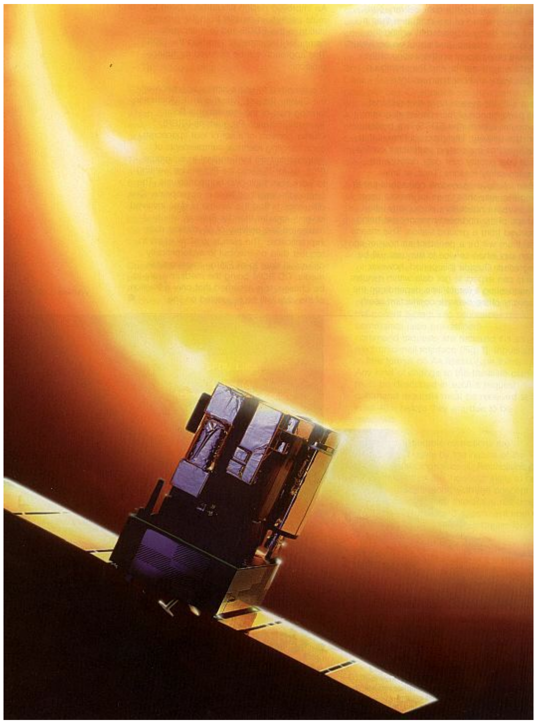


Fig. 13

A modern portrayal of the Sun

Photo Courtesy: NSSDC Master Catalog Spacecraft; NSSDC ID: 1995-065A

Fig. 14

Mayan portrayal of the Sun

Courtesy: http://pages.pomona.edu/~tlm02000/www/maya_astronomy.html

The most important and noticeable object in the sky was the Sun, which was associated with the god *Tonatiuh*, a red eagle with large eyes. The Earth revolves around the Sun in an elliptical orbit with a very low eccentricity, thus essentially making the orbit circular. But the Earth does so with a tilt: the Earth's axis is tilted at an angle of 23.5 degrees to the ecliptic plane. So at different times of the year (in other words, at different phases of its orbit) different places on the Earth receive different amount of sunlight causing different seasons. Although from historical evidence it seems the Mayans were probably not aware of such detailed reasoning behind the causation of seasons, the Mayans were very accurate when it came to measuring the length of such a revolution of the Earth. Their estimate for the solar year was 365 days, which is quite close to the current estimate of 365.2422 days; yet this small difference accumulated over the years and over a century would amount to almost a month. Some evidence, however, suggests that the *ilhuica tlamatilizmatini* were aware of this discrepancy. The *ilhuica tlamatilizmatini* continually updated their calendars, making revisions as required to keep it at par with the solar year, according to scholarly opinion.

MOON

Deities also represented the next most conspicuous object on the sky, the Moon. Depending on whether the Moon was waxing or waning, it was represented by either a beautiful woman or an old woman. Accounts of Mayan reckoning of synodic lunations or intervals between successive full moons cite lunations to be 29.53 days in some cases while even more accurate observations by another Mayan astronomer reveal that 11960 days contained 405 full moons, at an average lunation of 29.53086 days. This value is very close indeed to the modern value of 29.53059 days for a lunation on average. The following pictures just blatantly expose the limitations of the average Mayan's perspectives of the Moon as deities; at least that is what one will be tempted to think but considering that the priest astronomers purposefully misled the people to associate these heavenly objects with deities for their own benefits may help to revise that thought. Given the above, one cannot help but wonder at the Mayan priest astronomers' level of understanding of these heavenly bodies particularly motions of heavenly bodies across the sky and prediction of their orbits.

Fig. 15

Near side of the Earth's Moon, photographed by the Galileo spacecraft on its way to the Jupiter system on December 7, 1992. The dark areas are impact basins: Oceanus Procellarum (left) Mare Imbrium (centre left), Mare Serenitatis and Mare Tranquillitatis (centre), and Mare Crisium (near the right edge).
Photo Courtesy of NASA/JPL/Caltech (NASA photo # PIA00405)

VENUS

The Mayans were particularly interested in Venus among all other notable ancient civilizations. With a precision of more than 1 in 10000, the value of Venus' synodic period was found to be 584 days. As already mentioned, this value is extremely accurate, coming close to the modern value of 583.92 days for one complete revolution of Venus around the Sun. Venus was actually reckoned at the time when it was aligned with the Earth and the Sun in an approximately straight line while at the same side of the Sun as the Earth. Such an alignment of Venus with the Earth and the Sun is called an Inferior Conjunction and inferior planets (planets closer to the Sun than the Earth) actually are invisible (i.e. when viewed from the surface of the Earth) during Inferior Conjunction, for Venus this period lasts for around eight days after which it becomes visible. These planets are dimmest when they are near Superior Conjunction (the time when they are on the opposite side of the Sun as the Earth). Venus is thus visible for around 260 days after Inferior Conjunction; afterwards, it gets below the horizon and reappears after around another 50 days when it can be seen on the sky in the direction opposite the Sun as "evening star". This period lasts for about 260 days after which Venus goes through eastern elongation and comes back to Inferior Conjunction. And this goes on cyclically.

Fig. 16

Hemispherical view of Venus thanks to the spacecraft Magellan

Photo Courtesy: NSSDC Photo Gallery: Venus

Venus had a great impact on the Mayan culture and religion: human sacrifices were made after Superior Conjunction of Venus and the Dresden Codex contains an almanac showing five sets of 584 days or 2920 days to be approximately equal to 8 years or 5 Venus cycles.

Fig. 17

The way Mayans portrayed their God of Venus

Courtesy of http://pages.pomona.edu/~tlm02000/www/maya_astronomy.html

Fig. 18

The complete Dresden Codex

Courtesy of http://pages.pomona.edu/~tlm02000/www/maya_astronomy.html

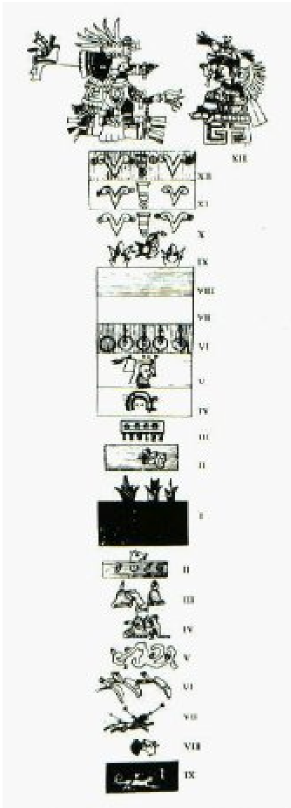


Fig. 19

The Mayan view of the Milky Way, as shown to the left, was based more on mythology than scientific reasoning. Contrasted with present day view of the Milky Way (shown below), the Mayans were very backward when it came to observing something as great and astronomical as the Milky Way; but then again, were they? Because historical evidence suggests that the *ilhuica tlamatilizmatini* were very skilful manipulators, could it be just one of their hoaxes?

Fig. 20

Image of the centre of the Milky Way Galaxy, produced from the observations made by the Infrared Astronomy Satellite (IRAS). The bulge in the band is the centre of the Galaxy. The yellow and green spots and blobs are giant clouds of interstellar gas and dust. The warmest material appears blue and colder material red. IRAS was launched Jan. 25, 1983.
By courtesy of the National Aeronautics and Space Administration

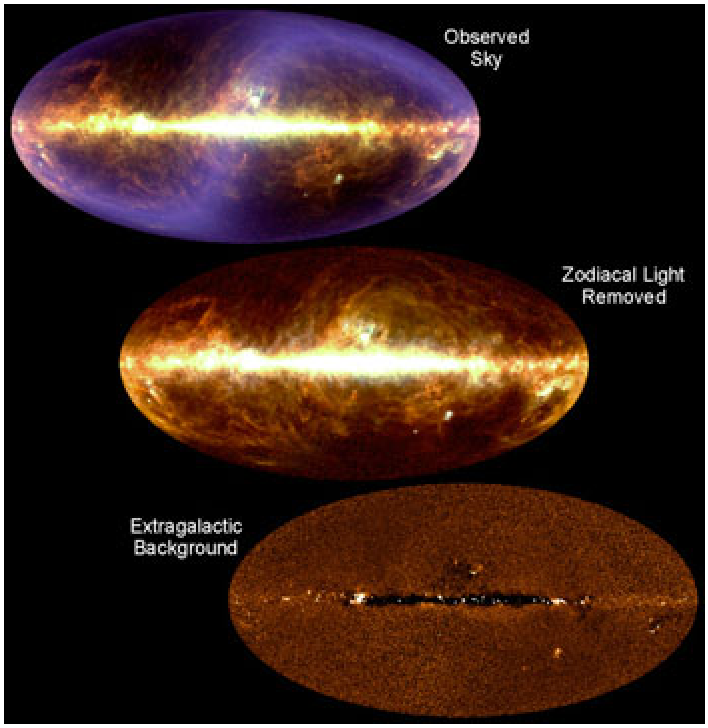


Fig. 21

Three views of the universe by the Cosmic Background Explorer (COBE).

In the infrared view of the full sky (top), the blue areas are caused by dust in our solar system. When that light is removed (middle), light from dust in the Milky Way (the band at the centre) and Magellanic Clouds (lower right) remains. A uniform field of cosmic background radiation is revealed when the galactic light is removed (bottom); the dark line at the centre is an artifact of the filtering process.

Photo Courtesy Of AURA/STScI/NASA/JPL (NASA photo # STScI-PRC98-01)

What is so special about 2012A.D?

This current 5th era of long count cycle of the will end on December 2012. The exact date will depend on what correlation used. If the correlation factor is 584285, then the end date will be on 23rd December 2012. If the correlation of 584283 is used, then the end date will end on 21st December 2012.

There are a lot of popular myths regarding the end date of Maya calendar:

1. The end of world
2. Alien visit
3. Pole shift and a lot more

There are a lot of people who believe totally in these myths and they dedicated a lot of websites to these beliefs. However, these claims are baseless. As one website noted,

"What a marvelous people the Maya are who could recognize cycles so vast! How sad that some people have distorted their ancient wisdom into a faddish cult. Meanwhile, the true Maya people are suffering oppression and extermination."[18]

However, there is also a claim that this long count calendar's start date was determined by projecting the end date so that it matches the December solstice in the year 2012. That is the Mayan with their vast knowledge of astronomy intentionally set the end date of the long count calendar on the December solstice of 2012 that is on 21st December 2012 according to 584283 correlation.

---

[18] *http://www.jaguar-sun.com/contents.html*

During that day, the Milky Way band will cross the ecliptic. To the Mayan, the Milky Way is known as the sacred tree or the world tree. It is seen as the tree of life that gives rise to life. Therefore, the crossing of the Milky Way with the ecliptic could be something important to the Mayan.

The Mayan (or perhaps the Olmecs) observed the conjunction of Milky Way with the ecliptic and found a certain drift with respect with time that is caused by precession of equinoxes. Throughout the ages, the Maya perhaps realized precession without even knowing what it is. They incorporate it in their long count calendar so that the end date would be on a December solstice date with the occasion of conjunction of Milky Way and ecliptic.

The viewpoint above is a possibility, however still much controversial. First of all, due to the different correlation, this view is applicable only for the 584283 correlation only. Therefore, it is still possible that the end date is actually 23rd December, which is uninteresting, unless perhaps the Mayan made mistakes in their calculations.

Besides that, it is possible that even though the Mayan observe the effects of the precession of equinoxes, the Mayan did not give any physical explanation to it[19]. The Maya only utilized the precession to coincide with their beliefs in calendar[20].

Any conclusion is impossible now, as the basis of the argument has not yet being confirmed. The 584283 correlation may not be the correct one. Another obstacle to this is lack of written records. The Spanish Conquest had spelled disaster to the Mayan culture at large and only around 4 pre-Columbian books survived. There are a lot of blanks in interpreting the glyphs and records. Perhaps, later a Mayanist will come out with the correct answer to the start and

[19] There was no mention of earth revolving around the sun in the Maya cosmology.

[20] The start of the long count is viewed as the creation of an era. Hence, it is logical to associate this date with certain astronomical element such as the world tree and solstices.

end date of long count calendar. Of course, there is still the possibility of all this is just a coincident.

Conclusion

The Mayan calendars are a very unique kind of calendar system, whereby 3 different main types of calendars were used. We can see that the calendars influence the life of the ancient Mayans closely, even to the extreme of worshipping time itself.

Astronomical knowledge plays a part in determining how the Mayan calendars work. The Mayans were mainly concerned with heavenly bodies such as Venus, Sun and Moon. The inscriptions on stela and writings on codices reflected their importance.

The Mayan's philosophy on time is that they mainly see it as a divine and cyclic time. Each day is divine and is in "charged" by a few gods. With this, the superstitious Mayans were able to predict fortunes of a certain day.

Studies on Mayans in certain parts were inconclusive due to the lack of resources. Mayan is a lost civilization that only began to reveal itself to the world during the 20th century. Much research would have to been conducted, especially in deciphering the glyphs so that a complete account of their astronomy, calendars and philosophy will be possible.

Appendix I

Model Description

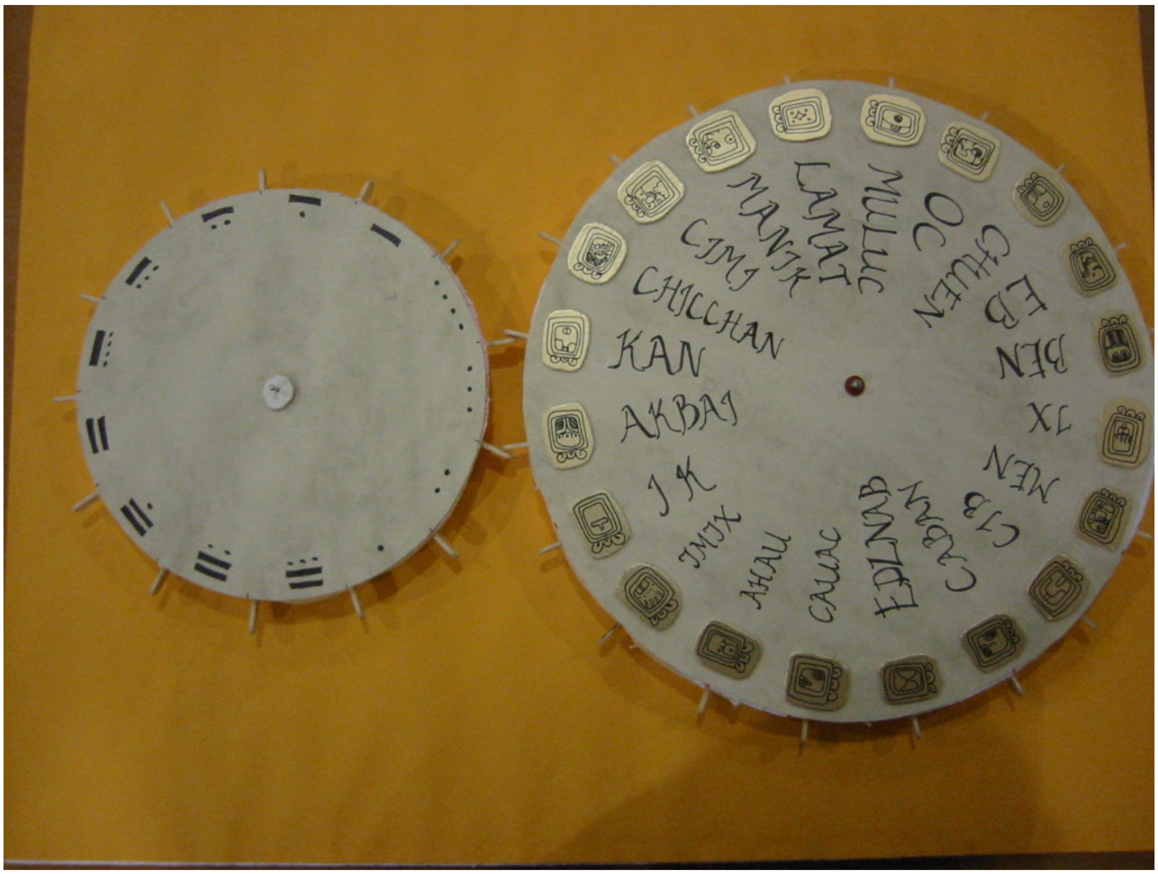
Our model represents the concepts involved in the Tzolkin calendar of the Mayans. One has to note however that the Mayans did not construct such a thing and that this model is useful in aiding the understanding of the Mayan Tzolkin calendar.

The ratio of the two wheels is chosen so that they are in ratio of 13:20 so that it represents the ratio between the trecena and veintena. The starting combination can be chosen arbitrarily and the direction of rotation has to be noted, that is the numbers in trecena must be increasing. Ice cream sticks are inserted at the position of each veintena element. For the trecena, the ice creams sticks are position such as it the trecena element is situated between 2 sticks.

There are however certain weaknesses in our model, as the divisions and ratios cannot be constructed to a very good accuracy and precision. The cycle might to go out of synchrony after some rounds. This is the reason we position the ice cream stick such that the 2 sticks enclose the region of trecena element. Adjustments can be made with the region between the 2 ice cream sticks.

Appendix II

Photo of Model



Appendix III

Glyphs

Note the Glyphs are only available in hard copy

References

Morley, Sylvanus Griswold (1947) *The Ancient Maya 2nd ed.,* Standford University, Calif., Standford Univ. Press.

Reingold, Edward M., Dershowitz, Nachum (2001) *Calendrical Calculations the millennium ed.*, New York: Cambridge University Press.

Henderson, John. S (1997) *The world of the ancient Maya 2nd ed.*, London: John Murray.

Schmidt, Peter, de la Garza, Mercedes, Nalda, Enrique (eds.) (1998) *Maya civilization*, London: Thames and Hudson.

Krupp, Edwin C. (1997) *Skywatchers, shamans & kings: astronomy and the archaeology of power*, New York: Wiley.

Danien, Elin C., Sharer, Robert J. (eds.) (1992) *New Theories On The Ancient Maya*, Philadelphia: University Museum, University of Pennsylvania.

The nature of the Maya chronological count, American Antiquity, Volume 42, Issue 1

Arithmetic in Maya numerals, American Antiquity, Volume 36, Issue 1

"Archaeology of the ancient Mayan civilization of Mesoamerica – Table of Contents"
< http://www.jaguar-sun.com/contents.html >, September 2003

"Calendars through the Ages – The Mayan Calendar"
< http://webexhibits.org/calendars/calendar-mayan.html >, September 2003

"Gbonline Maya Codices"
< http://pages.prodigy.com/GBonline/awmayac.html >, September 2003

"The Maya Calendar"
< http://www.michielb.nl/maya/calendar.html >, September 2003

"Maya Mathematics"
<http://www.michielb.nl/maya/math.html>, September 2003

"Mayan Astronomy"
< http://www.crystalinks.com/mayanastronomy.html >, September 2003

"Mayan Calendar"
< http://www.saxakali.com/historymam7.htm >, September 2003

"Mystery of the Maya – Maya Civilization"
<http://www.civilization.ca/civil/maya/mmc01eng.html, September 2003

"WAYEB – European Mayanists Association"
< http://www.wayeb.org/indexregistration.htm >, September 2003

"World Mysteries – Strange Artifacts – Mayan and Aztec Calendars"
< http://www.world-mysteries.com/sar_3.htm >, September 2003

Aldana, Gerardo. "2001 K'in in the Hieroglyphic Record: Implications of a Pattern of Dates at Copán, Honduras." Mesoweb
<www.mesoweb.com/aldana/implications.html>, September 2003

Aslaksen, Helmer. "Heavenly Mathematics: Cultural Astronomy (GEK1506)"
< http://www.tondering.dk/claus/cal/calendar26.html >, September 2003

Astbury, Michael. "Calendopaedia: The Encyclopaedia of Calendars
<http://www.geocities.com/calendopaedia/ >, September 2003

Encarta. "MSN Learning & Research – Maya Civilization
< http://encarta.msn.com/encnet/refpages/refarticle.aspx?refid=761576077 >,

Jenkins, Major John. "The How and Why of the Mayan end date in 2012 A.D"
< http://www.levity.com/eschaton/Why2012.html >, September 2003

Markman, H. Roberta, Markman, T. Peter. "Masks of the Spirit : Image and Metaphor in Mesoamerica"
< http://ark.cdlib.org/ark:/13030/ft7x0nb536/ >, September 2003

McNelly, Nancy. "Rabbit in the Moon"
< http://www.halfmoon.org/index.html >, September 2003

Meyer, Peter. "The Maya Calendar"
< http://www.hermetic.ch/cal_stud/maya/cont.htm >, September 2003

Mills, L. David. "The Classic Maya Calendar and Day Numbering System"
< http://www.eecis.udel.edu/~mills/maya.html#cal >, September 2003

Reddick, Gregory. "Short Count"
< http://www.xoc.net/maya/help/shortcount.asp >, September 2003

Strom, M. Karen. "Mayan Calendar"
< http://www.hanksville.org/yucatan/mayacal.html >, September 2003

Swanson, C. L. “Welcome to Chicén Itzá”
< http://www.internet-at-work.com/hos_mcgrane/chichen/chichen_index.html >, September 2003

Tøndering, Claus. “Frequently Asked Questions about Calendars Version 2.6”
< http://www.tondering.dk/claus/cal/calendar26.html >, September 2003

Welker, Glenn. “Mayan Civilization”
<http://www.indians.org/welker/maya.htm>, September 2003

Yucatan’s Maya World Studies Center. “The Maya Calendar”
< http://www.mayacalendar.com/mayacalendar.html >, September 2003