

The Gregorian y Mayan Calendars.

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1 The Time

The time units of day and year exist in all the cultures and are used as fundamental units of time in all calendars that have been used and are still in use. On the contrary, the lunar month is not explicitly incorporated in all the calendars, except in some of them. It is enough having only one unit of time instead of several units, therefore the measurement of the time in **Julian Days** uses only the days. Because of the relation between days, the lunar month and the year does not correspond to whole numbers, the calendars can differ much from others, because each one looked for different solutions for the same problem.

1.1 The Day (*q'ij*)

Earth rotates around its axis at the rate of 23 hours, 56 minutes and 4 seconds (23.934 *hours*) for every rotation and we, standing on it, also rotate at the very same rate. We can perceive this movement by seeing the sun moving from East to West within a period of nearly 12 hours while completing a revolution around us in 24 hours. The day is the smallest unit of time used for elaborating calendars.

The day is divided in a very complicated way but we have learned this division since we were children and so we're very used to it. The day is divided in 24 hours, each hour is subdivided in 60 minutes and every minute in the 60 seconds. Seconds can be divided as well, but here we use the powers of 10 for the subsequent subdivisions.

The following table shows the equivalences between

the day and its subdivisions according to the second, which is the unit for measuring time in many system units including the international.

Unit	Usual	International
Day	24 hours	86,400 seconds
Hour	60 minutes	3,600 seconds
Minute	60 seconds	60 seconds
Second	1	1
Tenth	$\frac{1}{10}$ seconds	0.1 seconds
Hundredth	$\frac{1}{100}$ seconds	0.01 seconds

The day lasts 23.934 hours \approx 24 hours, this small difference is explained in the Appendix. In the title between parenthesis appears the translation in kiché.

1.2 The Year (*junab'*)

At the same time that Earth is turning around its axis it is also moving around the sun at the rate of 365.2422 turns per year. This movement is more difficult to perceive than the previous one, nevertheless, it is noticeable through making two observations throughout the year. The first observation needs us to know the constellations located in the sky, the second one requires that we observe the point in the horizon in which the sun rises (or descends) all mornings (or afternoons).

1. The most known constellations are the twelve of the zodiac, because astrology has spread them widely. These twelve constellations are those which the sun finds in its route in the sky according to what we perceive while standing on

Earth. This phenomenon can be noticed by observing the hour in which these constellations are born in the horizon just as well as the sun does throughout the days in a year. Every day they appear a little bit earlier and appear again at the same hour after a year has passed, that is to say in 365.2422 days. How much earlier do they rise every day?

$$\begin{aligned}
 t &= \frac{1}{365.2422} = 2.73790926 \times 10^{-3} \text{ d} \\
 &= (2.73790926 \times 10^{-3} \text{ d}) \times (24 \frac{\text{h}}{\text{d}}) \times (60 \frac{\text{mn}}{\text{h}}) \text{ year would be:} \\
 &= 3.94258933 \text{ mn}
 \end{aligned}$$

that is to say 3 minutes 56,55 seconds. The line drawn up by the sun through these constellations is called the Ecliptic.

- When we observe the sun rising from the horizon we can notice that the ascending point displaces towards north from June to December and towards the south from December to June. The midpoint of this displacement is the East and corresponds with the vernal point on March 21 (spring Equinox) and September 23 (autumn Equinox) at the time of the sunup. The greatest shift towards south is 23.45° ($23^\circ 27'$) from the center (East) and happens on June 21 (summer Solstice) and the greatest shift towards north is, also 23.45° from the center (East), happens on December 22 (winter Solstice). In this way a year has passed after the sun has completed a cycle. The Persian calendar starts the year in the spring equinox yet not the Gregorian.

1.3 The lunar month (*ik'ik'al*)

The moon rotates around the Earth completing a turn in 27.32166 days (sidereal period) and we, standing on Earth, can notice it in the moon phases which are repeated every 29,530588 days (synodic period). The lunar month corresponds to the synodic period. The discrepancy between both periods is explained in the appendix.

2 The Calendars

2.1 The Julian Calendar

During the government of the emperor Julius Cæsar in the year 708 from the foundation of Rome, corresponding to the year 46 BC (Gregorian), a reform to the original Roman calendar was made, in which the year lasted 365 days, consisting in the introduction of the leap year. It was settled that the leap year would last 366 days and 3 regular years would follow. Hence, the average time period of the Julian year would be:

$$\frac{(3 \times 365)_{rg} + 366_{lp}}{4} = 365.25 \text{ d}$$

This reform was set in the year 709 from the foundation of Rome and it stayed so until the implementation of the Gregorian calendar. With the arrival of the Spaniards to Guatemala, this calendar officially replaced the Mayan Calendar. This calendar was elaborated by Sosigenes of Alexandria with the idea suggested by Ptolemy II 200 years ago.

The discrepancy between the Julian Calendar and the tropical year is:

$$365.25_{jul} - 365.2422_{tro} = \frac{1}{128.205128}$$

which means that a day is left behind every 128.2 years

2.2 The Gregorian Calendar

The calendar which we normally have hung on the wall of our house is the one elaborated according to the rules established by Luigi Lilio (Aloysius Lilius) in 1,582 under reign of the Pope Gregory XIII. The rules that govern the calendar are:

- Every year that is not the end of a century can be a leap year if they are divisible by four, with a duration of 366 days, or regular if they are not divisible between four, with a time duration of 365 days.
- The ends of century divisible between 400 are leap years whereas those which are not divisible between 400 are regular.

These two rules produce an average time duration of a year during a period of 400 years as:

$$\frac{300 \times 365 + 96 \times 366 + 3 \times 365 + 366}{400} = 365.2425$$

Due to bad approach of the Julian calendar, this correction was necessary because the date of the equinox was systematically moving, a day every 128,2 years as above indicated. The date of the equinox was 10 days late in 1,582.

$$\left[\left(\frac{1582 - 325}{128.2} \right) = 9.80 \sim 10 \right]$$

In 1582 the gregorian correction was made in Italy, Spain, Poland and Portugal jumping from October 4 to October 15, 1582. The correction arrived to America as the information was transmitted from Spain. Other European countries and other parts of the world were gradually summing up like France in December 1582, Great Britain in 1752, China in 1911, Russia in 1918 and Turkey in 1927.

The leap from October 4 to the 15 was set out so that the equinox could return to March 21 as previously fixed by Conciliate of Nicea in the year 325, when it was also determined that easter would be the Sunday after the subsequent full moon to March 20; that is to say after the equinox (already fixed on March 21). After this correction one hopes that there is a correction of a day after $3.333\frac{1}{3}$ years with the fixed tropical year.

$$365.2425_{gre} - 365.2422_{tro} = \frac{1}{3333\frac{1}{3}}$$

and so it leaves that the equinox of March 21 can be moved at the most to the 20 or 22 of March.

2.2.1 The Month

The year is divided in 12 months of a variable duration between 28 and 31 days according to the following table, in a regular year.

Month	Name	Duration
1	January	31
2	February	28
3	March	31
4	April	30
5	May	31
6	June	30
7	July	31
8	August	31
9	September	30
10	October	31
11	November	30
12	December	31

The month of February lasts 29 days in the leap years. In every month there is approximately one Full Moon due to the proximity to the synodic period and the average month period $29.53 \approx 30.44$ although the difference also causes that there are two full moons in some months.

2.2.2 The Week

The week is a 7 days cycle independent from the period of months. The days of the week are:

Day	Name	Gods	Spanish name
1	Monday	Moon	Lunes
2	Tuesday	Mars	Martes
3	Wednesday	Mercury	Miércoles
4	Thursday	Jupiter	Jueves
5	Friday	Venus	Viernes
6	Saturday	Saturn	Sábado
7	Sunday	Sun	Domingo

The days of the week in Spanish language are related to the movable stars and the Gods related to them in agreement with the Roman tradition with an important modification introduced by Constantine, who changed Dies Solis for Dies Dominican in Latin, which later became Sunday (Domingo in Spanish), meaning “the day of the Lord”.

2.3 The Mayan Calendar

The Mayan Calendar has three independent cycles:

1. Long count (*Choltun*)
2. The Haab and
3. The Tzolkin or (*Waqxaqi 'B 'atz '*)

The names of the days, months and cycles of the mayan calendar will be written according to the commonly international used names corresponding to the ones to Yucateco language and in parenthesis the names in Kiché, the most spread Mayan language in Guatemala.

2.3.1 Long count (Choltun)

The long count is classified by 5 denominated positions: baktun, katun, tun, uinal and kin:

$$0^{baktun} . 0^{katun} . 0^{tun} . 0^{uinal} . 0^{kin}$$

whose duration appears in the following table:

baktun	20 katuns	144,000 days
katun	20 tuns	7,200 days
tun	18 uinals	360 days
uinal	20 kins	20 days
kin	1 day	1 day

Kin (Q ' ij) is equivalent to a day. The uinal (Winäq) is equivalent to a month, but with 20 days only. Tun (Tun) is compound of 18 uinales of 20 days, each one with a period of 360 days, five days less than a regular year. Katun is a period of 20 tunes equivalent to 2

$$0 \times 18 \times 20 = 7200$$

7200 days or

$$\frac{20 \times 360}{365.2422} = 19.71$$

19.71 years. Baktun (B ' actun) is a period of 20 katunes

$$20 \times 18 \times 20 \times 20 = 1.44 \times 10^5$$

144000 days or

$$\frac{20 \times 360 \times 20}{365.2422} = 394.25$$

394.25 years. There are also pictun, calabtun, kinchiltun and alautun periods whose durations are

$$20^3, 20^4, 20^5 \text{ and } 20^6$$

tunes respectively.

The long count initiates the day 0.0.0.0.0 that corresponds to August 11 of the year 3.113 BC according to the Gregorian calendar and 584.283 Julian days using Goodman-Martinez, Thompson correlation. The results can have some variations when using other existing correlations.

0.0.0.0.0	8 cumhu 4 ahau
Monday	August/11/-3113
Julian	September/6/-3114
584283	jd

2.3.2 The Haab

The Haab is a period of 365 days divided in 19 months of which 18 have 20 days and 1 month of 5 days. The months are identified with the following names:

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

the last one of these months, Uayeb, last only five days. Each one of the 20-days-months is combined with a number ranging from 0 to 19 and the Uayeb from 0 to 4 in order to generate

$$20 \times 18 + 5 = 365$$

365 different combinations. The Haab initiates the day **0.0.0.0.0** on **8 cumku**.

2.3.3 The Tzolkin or Waqxaqi 'B 'atz '

The Tzolkin is a period of 260 days of two coupled cycles:

- One of 13 days numbered from 1 to 13 and
- other of 20 named days. The 20 different names are in the next table

The combination of the numbers and named produced 260 different combinations. long count

The Tzolkin, the Haab and the Long count are independent but they are coupled.

No.	Kiché	Yucateco
1	imox	imix
2	iq ’	ik
3	aq ’ab ’al	akbal
4	k’at	kan
5	kan	Chicchan
6	kame	cimi
7	kej	manik
8	q ’anil	lamat
9	toj	muluc
10	tz ’i	oc
11	b ’atz ’	chuen
12	e	eb
13	aj	ben
14	i ’x	ix
15	tz ’ikin	men
16	ajmaq	cib
17	no ’j	caban
18	tijax	eznab
19	kawoq	cauc
20	ajpu ’	ahau

The coupling between Tzolkin and the long count is:

The day **4 ahau** correspond to 0.0.0.0.0

The complete date The complete date is written placing the first number corresponding to the long account, next the number of 1 to 13 corresponding tzolkin day, later the name of the tzolkin group, afterwards the number from 0 to the 19 of haab day and finally the name of the haab month.

The publication date of this pamphlet is Tuesday April 30th, 2.002 in the Gregorian calendar and

$$12.19.9.3.12 \text{ } 5 \text{ } uo \text{ } 3 \text{ } eb$$

the long count is equivalent to 2.002 in the sense that

$$2,002 = 2 \times 10^3 + 0 \times 10^2 + 0 \times 10^1 + 2 \times 10^0$$

is the number of years from the hypothetical beginning of the calendar with a base of 10. Whereas the

$$12.19.9.3.12 =$$

$$12 \times 20^4 + 19 \times 20^3 + 9 \times 20^2 + 3 \times 18^1 + 12 \times 20^0 = 2,075,666$$

corresponds to the number of days passed from the hypothetical beginning of the Mayan calendar in base twenty, with a modification in the second position where it replaces 18 for 20 used in the Mayan temporary notation.

2.3.4 The round of the Mayan Calendar

Haab and Tzolkin has a proportion of

$$\frac{365}{260} = \frac{73}{52}$$

which means that there are 73 tzolkin cycles in 52 haabs that are equivalent to

$$52 \left(\frac{365}{365.2422} \right) = 51.9655$$

51.9655 years, this period of time is known as the round of the calendar. It is also equivalent to

$$2.12.13.0 = 18980$$

18980 days. This relation causes that the same combination of names and numbers repeats identically in Haab and Tzolkin at the end of a round.

2.3.5 Duration of the Mayan year

Several authors, beginning with Morley, have mentioned that the duration of the Mayan year is closer to the value of the average tropical year than that of the Gregorian year, so the following table reports:

Year	Duration	Difference
Tropical	365.2422	-
Julian	365.2500	0.0078
Gregorian	365.2425	0.0003
Mayan	365.2420	0.0002

As mentioned in the previous sections the average duration of the Julian and Gregorian years is already

based on the mechanism of the leap years. On the contrary, the Mayan calendar does not have a mechanism of correction for the leap year, so it must relate by an astronomical fact, two originally independent cycles. These cycles would be Haab and the long count. That value is obtained assuming that exists a precession of Haab throughout the stations in such form that completes two turns from the date 0.0.0.0.0 to 7.13.0.0.0 (equivalent to $1_1101,600$ days).

2.4 Julian Day

The astronomers prefer to use the day like fundamental unit of time so that the temporary distance between two events has a simple process of calculation, reason why instead of using a usual calendar they use the so called Julian day. The Julian day is the number of rotations that the sun has made around Earth starting in zero Julian day (at noon), corresponding to January 1st, 4713 BC according to the Julian calendar and to November 24 4713 BC according to the Gregorian calendar. This system was introduced in 1,583 by Joseph Justus Scalinger and thanks to Herschel, the system found an extended use since XIX century.

2.5 Dates transformation

Next there are 3 examples explaining manual calculus of dates transformations from the Gregorian Calendar to the Mayan Calendar and to Julian days in addition to the determination of the day of the week. In order to be able to relate the calendars it is necessary to know at least a day in the three systems.

The date **Monday January 1st, 2.001** will be used as basis. The Julian day corresponding to that date is **2451911** and in the Mayan calendar is **12.19.7.15.8 11 kankin 13 lamat**.

2.5.1 Example 1:

What day in the week correspond to April 30 2,002, what is the mayan calendar date of it, and what is the julian day of this date?

1. It has been $365_{2001} + 31_{january} + 28_{february} + 31_{march} + 29_{april} = 484$ days.

2. The weekly cycle leaves a residue of $484 \bmod 7 = 1$ then *monday* + 1 = **Tuesday**.

3. In Julian days it's $2451911 + 484 = \mathbf{2452395}$

4. The long count

$$\begin{aligned} \frac{484}{360} &= 1.34 \rightarrow \mathbf{1}, \\ 484 \bmod 360 &= 124, \\ \frac{124}{20} &= 6.2 \rightarrow \mathbf{6}, \\ 124 \bmod 20 &= 4 \rightarrow \mathbf{4} \end{aligned}$$

$$\begin{aligned} 12.19.(7+1).(15+6).(8+4) &= \\ 12.19.8.21.12 &= \\ \mathbf{12.19.9.3.12}. \end{aligned}$$

5. Tzolkin

$$\begin{aligned} 484 \bmod 260 &= 224, \\ 224 \bmod 13 &= 3 \rightarrow \mathbf{3}, \\ 224 \bmod 20 &= 4 \rightarrow \mathbf{4}. \end{aligned}$$

then it will be

$$\left. \begin{array}{l} 13 + 3 = 3 \\ lamat + 4 = eb. \end{array} \right\} \rightarrow \mathbf{3 eb}.$$

6. Haab

$$484 \bmod 365 = 119$$

$$\begin{aligned} 119 - 9_{kankin} - 20_{muan} - 20_{pax} - 20_{kayab} \\ - 20_{kumku} - 5_{uayeb} - 20_{pop} \\ = 5_{uo} \end{aligned}$$

then will be **5 uo**.

2.6 Example 2:

Repeat the calculus for the date March 31, 2.000.

1. There are $1_{march} + 30_{april} + 31_{may} + 30_{june} + 31_{july} + 31_{august} + 30_{september} + 31_{october} + 30_{november} + 31_{december} = 276$ days until the year 2001.
2. The weekly cycle leaves a residue of $276 \bmod 7 = 3$ then *monday* - 3 = **friday**
3. In Julian days it is $2451911 - 276 = 2451635$.

4. The long count

$$\begin{aligned}\frac{276}{360} &= 0.7666 \rightarrow \mathbf{0}, \\ 276 \bmod 360 &= 276, \\ \frac{276}{20} &= 13.8 \rightarrow \mathbf{13}, \\ 276 \bmod 20 &= 16 \rightarrow \mathbf{16}\end{aligned}$$

then

$$\begin{aligned}12.19. (7 - 0) \cdot (15 - 13) \cdot (8 - 16) &= \\ 12.19.7.2. - 8 &= \\ 12.19.7.1. (20 - 8) &= \\ \mathbf{12.19.7.1.12.}\end{aligned}$$

5. Tzolkin

$$\begin{aligned}276 \bmod 260 &= 16, \\ 16 \bmod 20 &= 16, \\ 16 \bmod 13 &= 3\end{aligned}$$

then it will be

$$\left. \begin{aligned}13 - 3 &= 10, \\ \text{lamat} - 16 &= \text{eb.}\end{aligned} \right\} \rightarrow \mathbf{10 \text{ eb.}}$$

6. Haab

$$276 \bmod 365 = 276$$

then

$$\begin{aligned}-276 + 11_{kankin} + 20_{mac} + 20_{ceh} + 20_{zac} + 20_{yax} \\ + 20_{chen} + 20_{mol} + 20_{yaxkin} + 20_{xul} + 20_{tzec} \\ + 20_{tzotz} + 20_{zip} + 20_{uo} + 20_{pop} \\ = -5_{uayeb} = 0_{uayeb}\end{aligned}$$

hence it will be **0 uayeb**.

2.6.1 Example 3:

Repeat the conversion for the date of the founding of Universidad de San Carlos, January 31, 1676.

1. Until the year 2001, there are

$$\begin{aligned}(2001 - 1676) * 365.2425 &= 118703.813 \\ \text{Integer}(118703.813) &= 118703 \\ 118703 + 1_{2001} - 30_{1676} &= 118674\end{aligned}$$

2. The weekly cycle leaves a residue of $118674 \bmod 7 = 3$ *Monday* - 3 = **Friday**

3. Julian days $2451911 - 118674 = \mathbf{2333237}$

4. The long count

$$\begin{aligned}\frac{118674}{7200} &= 16.4825 \rightarrow \mathbf{16} \\ 118674 \bmod 7200 &= 3474 \\ \frac{3474}{360} &= 9.65 \rightarrow \mathbf{9} \\ 3474 \bmod 360 &= 234 \\ \frac{234}{20} &= 11.7 \rightarrow \mathbf{11} \\ 234 \bmod 20 &= 14 \rightarrow \mathbf{14}\end{aligned}$$

$$\begin{aligned}12. (19 - 16) \cdot (7 - 9) \cdot (15 - 11) \cdot (8 - 14) &= \\ 12.3. - 2.4. - 6 &= \\ 12.2. (20 - 2) \cdot 3. (20 - 6) &= \\ \mathbf{12.2.18.3.14}\end{aligned}$$

5. Tzolkin

$$\begin{aligned}118674 \bmod 260 &= 114, \\ 114 \bmod 20 &= 14, \\ 114 \bmod 13 &= 10\end{aligned}$$

then it will be

$$\left. \begin{aligned}13 - 10 &= 3 \\ \text{lamat} - 14 &= \text{ix.}\end{aligned} \right\} \rightarrow \mathbf{3 \text{ ix}}$$

6. Haab

$$118674 \bmod 365 = 49$$

then

$$-49 + 11_{kankin} + 20_{mac} = -18_{ceh}$$

so it will be

$$(20 - 18 = 2)$$

2 ceh.

3 Appendix

3.1 Day:

The period of 23 hours, 56 minutes and 4,09 seconds (23.9344697 *hours*) is denominated sidereal day and the period lasting 24 hours as solar day. The difference is due to measurement made by the observer, in the first period, who rests on the sun and in the second is made by the observer standing on Earth which

rotates around its axis and around the sun simultaneously. The relation between both periods is given by

$$\frac{1}{23.9344697} - \frac{1}{365.2564 \times 23.9344697} = \frac{1}{24}$$

where 365.2564 is a sidereal year

3.2 Year:

The period of 365,2564 days is denominated **sidereal year** and the period of 365.2422 days as **tropical year**. The difference between them is that first one is measured by an observer who rests on the sun, and therefore notices the rotation of the greater semiaxis of the Earth orbit. The second one by a fixed observer on Earth that under the effect of precession. The relation between both periods is given by

$$\frac{1}{365.2564} + \frac{1}{25770 \times 365.2564} = \frac{1}{365.2422}$$

where 25,770 years is the rotation period of the greater semiaxis of the Earth orbit. This movement of precession, noticed for the first time by Greek astronomer Hyparchus, causes a displacement of the Earth axis through some constellations in a way that now the axis is closely together to the pole star but was several thousands of years ago far from this one. Precession is the one causing "pitching" of a spin while it turns around its axis and moves on the ground. Earth also has this "pitching" but it is almost imperceptible that we cannot directly notice it throughout our life.

3.3 Lunar Month:

The **sidereal period** of the moon $T_{Sd} = 27.32166$ days is the one determined by an observer located on the sun, where as the **synodic period** of the moon $T_{Sn} = 29.530588$ days is that determined from the Earth, where we are affected by its translation. The relation between both periods is

$$\frac{1}{27.32166} - \frac{1}{365.2564} = \frac{1}{29.530588}$$

where 365.2564 it is the sidereal year.

Since

$$\frac{365.2422}{29.530588} = 12.36826$$

every year has 12 or 13 full moons. In 432 BC the Athenian astronomer Meton found the following relation

$$\frac{235}{19} = 12.36842$$

which defers from the previous quotient only in the fourth decimal. This means that in a cycle of 19 years (metonic cycle) we practically have a full moon succession in the same days. The metonic cycle was already well-known by the Babylonians who were first to realize that in 19 years there were 235

$$(19 \times 12.36826 = 234.997)$$

almost complete cycles of the moon.

3.4 The duration of the Mayan year

As it was already indicated, it's assumed that the year is run throughout the stations completing two turns in the time passed between 0.0.0.0 and 7.13.0.0

Of where it follows that:

$$7 \times 144000 + 13 \times 7200 + 0 \times 360 + 0 \times 20 + 0 = 1101600$$

then

$$\frac{1}{365} - \frac{1}{\frac{1101600}{2}} = \frac{1}{x}$$

giving as a result

$$x = \frac{40208400}{110087} = 365.242036$$

365.24203 days for the year. Clearly, this is a better approach than the Gregorian approach, although many people think that it is only a coincidence.

3.5 The Easter date

determined the following algorithm to calculate the beginning of the Easter.

Let n be the year,

$$x \text{ and } y \text{ the constants} \left\{ \begin{array}{lll} x & y & \text{time} \\ 15 & 6 & \text{Julian} \\ 22 & 2 & 1583-1699 \\ 23 & 3 & 1700-1799 \\ 23 & 4 & 1800-1899 \\ 24 & 5 & 1900-2099 \end{array} \right. ,$$

$$a = n \bmod 19,$$

$$b = n \bmod 4,$$

$$c = n \bmod 7$$

$$d = (19a + x) \bmod 30 \text{ y}$$

$$e = (2b + 4c + 6d + y) \bmod 7.$$

then if Easter is in March it will be the

$$(22 + d + e)$$

and if Easter is in April it will be the

$$(d + e - 9)$$

. If $d = 28$ and $a > 10$ hen, from equation April 25 or 26 must be respectively replaced by 19 and 18.

3.5.1 Example

Let 2002 be the year,

$$x \text{ and } y \text{ the constants} \left\{ \begin{array}{lll} x & y & \text{time} \\ 24 & 5 & 1900-2099 \end{array} \right. ,$$

$$a = 2002 \bmod 19 = 7$$

$$b = 2002 \bmod 4 = 2$$

$$c = 2002 \bmod 7 = 0$$

$$d = (19(7) + 24) \bmod 30 = 7 \text{ y}$$

$$e = (2(2) + 4(0) + 6(7) + 5) \bmod 7 = 2$$

then if Easter is in March it will be the

$$(22 + 7 + 2) = 31$$

and if Easter is in April it will be

$$(7 + 2 - 9) = 0$$

,since April 0 does not exist , easter must evidently be March 31.

3.6 The Constellations and the Sun

The sun in its annual way around stars passes by the 12 constellations of the Zodiac. It begins its

route in January from Sagittarius towards Capricorn, Aquarius, Pisces Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra and Scorpio, to finalize again in December in Sagittarius. Due to the precession of the equinoxes and to different dimensions of the constellations, the dates appearing in the horoscope do not correspond with the real movement. Additionally, with the present division of the sky in constellations, the sun also passes through Ophiuchus between Scorpio and Sagittarius. Another important fact is that the horoscope begins on March 21 in Aries, that would have to correspond to the vernal point in Aries (the equinox) nevertheless ,the vernal point in Aries is in fact in Taurus.

In addition to the constellations of the Zodiac there are other 76 constellations, from which the most well-known ones might be: Orion, Ursa Minor, Ursa Major, Ophiuchus, Carina, Cassiopeia, the Swan, Vela, Lira and the Southern Cross.

Bibliography

References

- [1] Dershowitz and Reingold, Calendrical Calculations, Cambridge University Press, USA (1997) <http://emr.cs.iit.edu/home/reingold/calendar-book/index.shtml>
- [2] The kiché names was proportionated by the Guatemala Mayan Languages Academy.
- [3] Vorontsov y Veliamínov, Problemas y ejercicios prácticos de astronomía, Editorial MIR, Moscú (1979).
- [4] Carrol y Ostlie, Modern Astrophysics, Addison Wesley (EUA) 1,996.
- [5] Enciclopedia Italiana di Scienze, Istituto delle enciclopedia italiane da Giovanna Trecacani- Roma, Edizione 1949, Tomo VIII
- [6] Morley, Sylvanus, An introduction to the study of the mayan hieroglyphs, Dover, New York (1975).
- [7] <http://www.michielb.nl/maya/>
- [8] <http://www.mayan-calendar.com/links.html>

[9] <http://www.pauahtun.org/tools.html>

[10] http://hermetic.magnet.ch/cal_stud/maya/conts.htm