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DATING OF MAYAN CALENDAR USING LONG-PERIODIC ASTRONOMICAL PHENOMENA IN DRESDEN CODEX

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SUMMARY: The relationship between Mayan and our calendar is expressed by a coefficient known as 'correlation' which is a number of days that we have to add to the Mayan Long Count date to get Julian Date used in astronomy. There is a surprisingly large uncertainty in the value of the correlation, yielding a shift between both calendars (and thus between the history of Maya and of our world) of typically several hundred years. There are more than 50 diverse values of the correlation, some of them derived from historical, other by astronomical data. We test here (among others) the well established Goodman-Martínez-Thompson correlation (GMT) based on historical data, and the Böhms' one (B&B) based on astronomical data decoded from the Dresden Codex (DC); this correlation differs by about +104 years from the GMT. In our previous works we used several astronomical phenomena as recorded in the DC for a check. We clearly demonstrated that (i) the GMT was not capable to predict these phenomena that really happened in nature and (ii) that the GMT predicts them on the days when they did not occur. The phenomena used till now in the test are, however, short-periodic and the test then may suffer from ambiguity. Therefore, we add long-periodic astronomical phenomena, decoded successfully from the DC, to the testing. These are (i) a synchrony of Venusian helical risings with the solar eclipses, (ii) a synchrony of Venus and Mars conjunctions with eclipses, (iii) conjunctions of Jupiter and Saturn repeated in a rare way, and (iv) a synchrony of synodic and sideric periods of Mercury with the tropical year. Based on our analysis, we find that the B&B correlation yields the best agreement with the astronomical phenomena observed by the Maya. Therefore, we recommend to reject the GMT and support the B&B correlation.

Key words. ephemerides – eclipses – time – history and philosophy of astronomy

1. INTRODUCTION

The Mayan and Christian calendars are both very accurate, but the relationship between them is surprisingly uncertain. In specialized literature a time shift (in days) between the origins of the two calendars is known as '*correlation*'. Originally based on historical data, the correlation has recently been estimated also with the help of astronomical phenomena, mainly those decoded from the Dresden Codex (DC, Codex Dresdensis); see Böhm and Böhm (1991,1996) among others. Till now, 52 different values of the correlation τ are known in the literature (Table 1). Time differences between the individual correlations correspond to a few hundred years, which is too much and not acceptable from the historical viewpoint. Compatible differences, for example between GMT (Goodman-Martínez-Thompson), as in Thompson (1935, 1950), and that of the Böhm brothers, denoted here as B&B, (Böhm and Böhm 1991, 1996, 1999), which corresponds to about 104 years, are 'too small' to be distinguished by the radiocarbon method of dating (^{14}C). We need another type of test.

Analogously to Julian Date (JD) used in astronomy, the Maya used in their calendar (beside other cycles) the so called Long-Count (LC) that also consists in counting the number of days elapsed from a selected origin in the distant past. Thus, to convert LC to our JD dating, a simple relation:

$$\mathrm{JD} = \mathrm{LC} + \tau \qquad (1)$$

holds. The DC has been analyzed by many authors, e.g., Förstemann (1880), Guthe (1921), Teeple (1926), Vollemaere (1994), Wells and Fuls (2000) or Fuls (2008). The GMT correlation (Thompson 1950), its value being $\tau = 584\,283$ days, is not based on astronomical data, although some of them – contained in the DC – have already been known to Thompson. The correlation B&B (1991, 1996, 1999), $\tau = 622\,261$ days, makes use of both direct astronomical observations and computed ephemerides, derived from the DC. The B&B results, as well as other correlations, were tested by Klokočník et al. (2008). It was clearly demonstrated that the GMT correlation is not capable of predicting solar eclipses that were evidently recorded in DC (missing prediction). Even worse, the GMT predicts eclipses on the days when there were no eclipses visible on the whole Earth (false predictions).

This paper continues our effort to objectively test both GMT and B&B correlations (and other correlations, see Table 1) to demonstrate which one is capable to better explain the astronomical phenomena contained in the DC. We shall not repeat here the information of Klokočník et al. (2008), but only shortly outline the tests of correlations by means of solar eclipses (see Section 2).

We are well aware that the question of calculating the correlation is not unambiguous. The result depends on what data we astronomers will get from historians. Not all historians do agree upon which astronomical phenomena are actually contained in DC. Another problem is that often discussed data on stelae are supposed to contain some astronomical information, but it may not be true. But, the most problematic item (that does not concern the historians' view) is that until now we have worked only with *short-periodic astronomical phenomena* – solar eclipses, heliacal risings/settings of the planets or their conjunctions. These have periods of the order of several months to a few years.

To resolve ambiguities in determining τ, a *non-periodic or a long-periodic phenomenon* is needed as the outburst of supernova in 1054, or comets, etc. But nothing like that has been found for sure in Maya sources yet. We were looking for information of such type, and we discovered it directly in the DC – in an unexpected form – thus we will use it for our new tests. That is the core of our contribution.

The long-periodic phenomena are phenomena occurring during the Maya history only occasionally, once or a few times. It concerns mainly the *synchrony* of the Venus or Mars cycles on one side and the solar eclipses on the other, both phenomena themselves being short-periodic (Sections 3.1 and 3.2), conjunctions of Jupiter and Saturn (Section 3.3) repeated in a specific way or a synchrony of synodic and sideric revolutions of Mercury with the tropical year (Section 3.4).

The exact timings of all astronomical phenomena needed in the present study were computed by using the well-known semi-analytical solution of the motion of planets VSOP87 (Variations Séculaires des Orbites Planétaires), worked out by Bretagnon and Francou (1988). Positions of the Moon are computed from the lunar theory by Brown (1919) as amended by Eckert et al. (1966) and further modified by Vondrák (1979a,b). The corresponding computer code was later used by Mucke and Meeus (1983) in their *Canon of Solar Eclipses* that we also used.

Although all these phenomena can be computed with a very high accuracy (several minutes for the epochs of Maya civilization) when expressed in uniformly running Terrestrial Time (TT) used as an argument in the ephemerides of solar system bodies, the conversion to the local mean solar time brings about further inaccuracies due to the variations of the rotation of the Earth. The difference TT–UT (Universal Time, based on the rotation of the Earth) is known with a very high accuracy from modern observations for today (better than millisecond), but for the epochs in distant past its value reaches several hours with uncertainties of several tens of minutes. Here, we approximate it (in seconds) by a simple formula $\mathrm{TT} - \mathrm{UT} = 31T^2$ recommended by Stephenson and Morrison (1995), where T runs in centuries since 1820.

Another question is the accuracy of observations made by the ancient Maya with naked eye: the phenomena with a very rapid progress (e.g., solar eclipses) could be observed with accuracy of a few minutes, but the ones that proceed very slowly (e.g., maximum elongations, heliacal risings/settings, or some conjunctions of the planets) could not be observed with precision better than a few days.

Table 1. A set of 52 values of τ [days], in ascending order, authors' names and dates of publication.

No.	τ	Author	year
1	394483	Bowditch	1910
2	438906	Willson	1924
3	449817	Bunge	1940
4	482699	Smiley 1	1960
5	482914	Smiley 2	1960
6	487410	Owen	1975
7	489138	Makemson	1946
8	489383	Spinden 1	1930
9	489384	Spinden 2	1924
10	489484	Ludendorff	1930
11	492622	Teeple	1926
12	497878	Dinsmoor	1965
13	500210	Smiley 3	1960
14	507994	Hochleitner	1974
15	508362	Hochleitner	1974
16	525698	Hochleitner	1974
17	550279	Kelley 2	
18	553279	Kelley 1	1976
19	563334	Martin	
20	577264	Hochleitner	1972
21	578585	Hochleitner	1970
22	583919	Suchtelen	1957
23	584280	Goodman	1905
24	584281	Martinez	1918
25	584283	Thompson	1950
26	584284	Beyer	1937
27	584285	Thompson	1935
28	584286	Lounsbury	1978
29	584314	Calderon	1982
30	585789	Cook	1973
31	588466	Mukerji	1936
32	588626	Pogo	1937
33	594250	Schove 1	1976
34	609417	Hochleitner	1974
35	615824	Schove 2	1977
36	622261	B&B (Böhms)	1991
37	626660	Kaucher	1980
38	626927	Kreichgauer	1927
39	660205	Hochleitner	1974
40	660208	Wells & Fuls	2000
41	663310	Kelley 2	1983
42	674265	Hochleitner	1974
43	674927	Hochleitner	1974
44	677723	Schulz	1955
45	679108	Escalona	1940
46	679183	Vaillant 1	1935
47	698163	Dittrich	1936
48	739601	Verbelen	1991
49	774078	Weitzel	1947
50	774079	Vollemaere 1	1982
51	774080	Vollemaere 2	1984
52	774083	Vaillant 2	1935

Additional tests made below will bring new independent arguments to support the B&B correlation. It is important to note that all phenomena discussed here were used neither in deriving the correlation (Böhm and Böhm, 1991, 1996, 1999), nor in subsequent tests (Klokočník et al. 2008). This is completely new, never and nowhere published. Note finally that the analyzes presented here are all done for Palenque (latitude 17°29′ N, longitude 92°03′ W). The differences for other Mayan localities are negligible for our purpose.

It is important to note that in the DC the glyphs for the solar eclipses or Venus are shown together with the data (intervals for the relevant phenomena on the same relevant pages of the DC). It provides a confidence that the glyphs and the data belong together. We show the known glyphs in Figs. 1 and 2. But nothing similar was discovered and confirmed yet for the other planets and the Moon, so one has still to rely only upon possible astronomical meaning of the time intervals read from the DC. When referring to pages in the DC below, D is numbering according to Knorozov (1963), F according to Förstemann (1880).

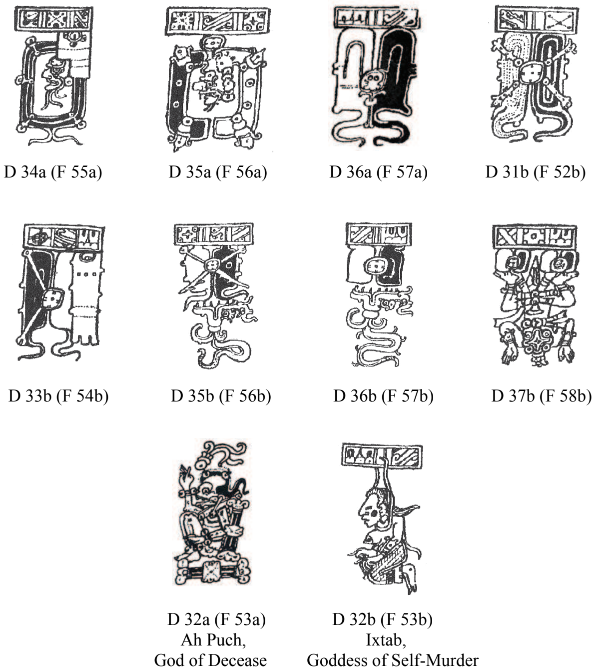

Fig. 1. *Glyphs for the solar eclipses, according to Dresden Codex, tables of the eclipses.*

Fig. 2. *Glyphs for Venus, according to Dresden Codex, pp. D 24–D 29 (F 24, 46–50), left and middle, and the glyph for Venus on the altar R in Copán, right.*

2. TESTS WITH SOLAR ECLIPSES

There is a list of predicted solar eclipses recorded on pp. D 30 – D 37 (F 51 – F 58) of the DC; the initial Mayan date of the solar eclipse 9.16.4.10.8 12 Lamat (LC=1 412 848) is followed by 69 cycles (each comprising 177, 178 or 148 days), reflecting the dates of the next expected eclipses. Quite naturally, only some of them were observable in Yucatan, most refer to the ones occurring at other places on the Earth. The table begins and ends by the same Mayan date, 12 Lamat, and covers altogether 11 960 days (i.e., 405 synodic months, 439.5 draconic months and 46 tzolkin cycles of 260 days). The uncertainty of the prediction ($\pm$1 day) is expressed by three consecutive dates in each case. The list of all these 70 eclipses is reproduced in Table 4. We tested them against all eclipses that really occurred somewhere on the Earth and found that there is a group of correlations with 59 or more successful predictions: Teeple (66), Vollemaere 1 (66), Weitzel (66), Kelley 1 (65), Wells and Fuls (60), Escalone (60), B&B (59), Vollemaere 2 (59). Out of these, Weitzel, Vollemaere 1 and Vollemaere 2 correlations are practically identical (they agree within two days). On the other hand, GMT predicted only 4 of them. It is not zero just by a chance due to the fact that we work with the short-periodic phenomenon (typical periodicity of the eclipses is 177 days, the range is 148–178 days). When similar tests were made against the eclipses visible only in Yucatan, the best scored ones were: B&B (8), Pogo and Hochleitner (7), Willson and Teeple (6). Thus the B&B correlation seems to yield the best agreement.

3. TESTS WITH LONG-PERIODIC ASTRONOMICAL PHENOMENA

For a unique determination of τ we need a non-periodic phenomenon, but there is nothing like that in the DC or another Maya source. But there is a *synchrony* of the dates of heliacal risings/settings of Venus with the Sun's eclipses, or between conjunctions of two planets and the solar eclipses – coincidence between two short-periodic phenomena which is itself of long- periodic character. By synchrony we mean here the situation when there exists in the DC a time interval between two recorded dates that contains integer numbers of periods of different astronomical phenomena. Such synchronies are rare and can simulate long-periodic phenomena. Fortunately, we were able to decode such data from the DC so that we will utilize them now.

3.1 Synchrony in the DC of Venusian heliacal risings with solar eclipses

Let us use the date 9.16.4.10.8 12 Lamat, corresponding to LC = 1 412 848. It points to the first solar eclipse in the series of eclipses in the DC, which is accepted by nearly all investigators; see pages D 30 – 37 (F 51 – 58), e.g. Klokočník et al. (2008). Now we look for the second useful date. Page D 24 (F 24) of DC contains the date 9.9.9.16.0 1 Ahau 18 Kayab, which corresponds to LC = 1 364 360. On that day Venus was first seen, according to the Maya, as the Morning Star after its inferior conjunction with the Sun. This was also the first date for determination of further heliacal risings of Venus (added to this date are various multiples of the cycle of 2 920 days). This interval is the basic periodicity of overlapping Venusian synodic and sidereal orbits with the tropical year after which Venus rises or sets every 8 years in approximately the same place in the sky.

Thus we have two LC dates, 1 412 848 and 1 364 360, marking two different astronomical phenomena visible in the Mayan sky. It is evident that the time interval between these two phenomena, Δ = 48 488 days, must be the same as the time interval actually existing "in the nature". If we take both these Mayan dates and attempt to apply the individual correlations, then the correct correlation must yield the same time interval Δ as was actually observed between the heliacal rising of Venus and the solar eclipse.

We tested all the correlations from Table 1. For 39 correlations, we have got no solar eclipse for LC = 1 412 848, while 12 correlations did correspond to solar eclipses but none was visible in the Mayan region. Apart from B&B, only Teeple's correlation (τ = 492 622) gave a date when there was a solar eclipse visible to the Maya (November 22, 504) but at the maximum of this eclipse, only 12% of the solar disc was obscured. However, for the second date (LC = 1 364 360), the heliacal rising of Venus did not occur; the date corresponding to Teeple's correlation fell on February 21, 372 when Venus was at inferior conjunction and so not visible at all.

We took into account all eclipses that were observable in the Mayan region in the period from June 428 to August 1011; just 207 solar eclipses occurred. For each date of an eclipse, we subtracted the value Δ and checked if the date found coincided with a heliacal rising of Venus (there were 365 of them between May 295 and December 878). Only the pronounced solar eclipse (85%) of October 29, 859 and only the heliacal rising of Venus 48 488 days before it (January 27, 727) fulfil the condition of the synchrony. These dates coincide with LC dating only if the B&B correlation is used, from all τ's in Table 1.

So, the analysis of the synchrony of the solar eclipses with heliacal rises of Venus speaks clearly: none but one of today known 52 correlations (according to Table 1), including the GMT, can be used to convert the Maya dates to our calendar. The only exception is the B&B correlation. With it, the result looks like this:

9.9.9.16.0 1 Ahau 18 Kayab = 1 364 360 + 622 261 = 1 986 621 JD = January 27, 727.

Heliacal rising of Venus occurred, eight days after inferior conjunction with the Sun.

9.16.4.10.8 12 Lamat = 1 412 848 + 622 261 = 2 035 109 JD = October 29, 859.

The solar eclipse occurred in the Maya area, maximum magnitude was 85%.

3.2 Synchrony of Venus and Mars conjunctions with solar eclipses

Similarly to the Venusian heliacal aspects, there is a synchrony between Venus and Mars conjunctions with the solar eclipses. By this, we mean the situation when the solar eclipse is followed by a conjunction of Venus with Mars after 13 512 days. This occurred in Mayan history only once. It is necessary to say that the average time interval between the conjunctions is 234 days, but in reality the individual intervals can vary between 200 and 300 days, and sometimes they can even exceed 700 days (when two conjunctions do not really occur, and the two planets move in parallel several degrees apart).

We start again with the same 'initial' solar eclipse date 9.16.4.10.8 12 Lamat, LC = 1 412 848, recorded on p. D 31 (F 52) of DC. Other important dates can be found on p. D 37 (F 58): 9.18.2.2.0 4 Ahau (LC = 1 426 360), with the time difference from the preceding one equal to 13 512 days, that is accompanied by 9.12.11.11.0 4 Ahau (LC = 1 386 580), and also by a time interval 12.11 (251 days), in which the number 11 is surrounded by a frame (a glyph of minus sign). The difference between the two dates is equal to 39 780 days, i.e. 170 times the average interval between two conjunctions of Venus with Mars. If we subtract 251 days (again close to the interval between the two conjunctions) from the first above mentioned date, we get 9.18.1.7.9 13 Muluc (whose last part, 13 Muluc, is also recorded there), corresponding to LC = 1 426 109. So, we can assume that all three LC dates (1 386 580, 1 426 109 and 1 426 360) recorded on this page refer to the same phenomenon, conjunction of Venus with Mars.

Next we tested all correlations from Table 1 to find which ones are capable of identifying all four LC dates (one for the eclipse, three for the conjunctions) with real phenomena. The only one that can assure this with sufficient accuracy is the B&B correlation:

phenom.	LC	B&B date	Comp. date
conj.	1 386 580	Nov 28, 787	Nov 25, 787
ecl.	1 412 848	Oct 29, 859	Oct 29, 859
conj.	1 426 109	Feb 18, 896	Feb 16, 896
conj.	1 426 360	Oct 26, 896	Oct 24, 896

Small differences in the dates of conjunctions are fully acceptable, since these phenomena proceed very slowly and the Mayan observations with naked eye could not achieve better accuracy than a few days.

3.3 Repeated conjunctions of Jupiter and Saturn

Conjunctions of Jupiter and Saturn repeat on the average approximately every 19.6 years. At least after 40 years a situation occurs when two conjunctions come shortly one after the other. This is the 'synchronization' that is interesting from our point of view. Consequently, we were looking for two dates in DC differing by a multiple of 40 years (14 560 days). We found interesting complex information, consisting of two Mayan dates and an accompanying table, on page D 74 (F 45) of the DC. This allows to be interpreted as referring to repeated conjunctions of Jupiter and Saturn.

On page D 74, there are two Mayan dates in the system of Long Count (LC) which correspond, after corresponding re-calculation, to the following number of days in decimal expression:

A)	8.17.11.3.0	4 Ahau	1 278 420
	−1.10		−30
B)	(8.17.11.1.10)	13 Oc	1 278 390

The date B is not given directly in LC, but only by the date 13 Oc of 260-day tzolkin cycle; missing digits of LC are given in parentheses. It can be calculated by subtracting 30 days (accompanied by a minus sign hieroglyph) from the date A. This way of calculating the next date by subtracting certain number of days from the initial date is quite usual in DC. New date is sometimes not expressed by all digits of LC, but only by the final date of 260-day cycle (in this case 13 Oc). On the same page of DC below the date B, there is an accompanying table, containing time intervals. The text in DC is partly damaged, but it is possible to reconstruct it and prove that the individual items represent multiples of 364 and 260 days, as explained in Table 2.

Table 2. Mayan table of page D 74 (F 45) of Dresden Codex

Mayan record		Analysis of the table		
of time interval		days	×364d	×260d
?.?.8	13 Etznab	728	2	
3.0.12	13 Ik	1092	3	
4.0.15	13 Cimi	1456	4	
5.1.0	13 Oc	1820	5	7
10.2.0	13 Oc	3640	10	14
15.3.0	13 Oc	5460	15	21
?.?.8.0	13 Oc	14560	40	56
?.0.12.0	13 Oc	21840	60	84
4.0.16.0	13 Oc	29120	80	112

The first column contains the original Mayan inscription; the missing numbers are replaced by question marks. Reconstructed time intervals in days are shown in column two, columns three and four give multiples of 364 (that appears often in the tables of DC) and 260, respectively. Especially important is the 80-year cycle (29 120 days) in the last row of Table 3. It contains 73 synodic periods of Jupiter (398.884 days), 77 synodic periods of Saturn (378.091 days) and 112 tzolkin cycles (260 days). We can assume that it is also the average interval between two conjunctions of both planets. The initial point is the date B, to which we should add the interval of 29 120 days to obtain the next conjunction date C:

B)	(8.17.11.1.10)	13 Oc	1 278 390
	+4.0.16.0	13 Oc	+29 120
C)	(9.1.11.17.10)	13 Oc	1 307 510

Now it is necessary to find such shift between the dating in Julian Days and Long Count for which the dates B and C (in LC) fall into a close vicinity of computed times of conjunctions of Jupiter and Saturn (in JD). We found that this can be achieved only when using the B&B correlation (τ=622 261 days), the others failed. Using this value, we arrive to date B being equivalent to JD = 1 900 651 (i.e., September 13, 491) and date C corresponding to JD = 1 929 771 (June 5, 571).

Both Mayan dates B, C fall into the period when Jupiter and Saturn were very close to their opposition with the Sun (only three days apart, respectively), and they stayed close to each other for many months, describing wobbles with direct and reverse motions, and showing unique situation when two conjunctions repeated during the same year. Mayan dates then reflect encounters of Jupiter with Saturn in the moments when they were close to stationary points (change from retrograde to direct motion). The mutual positions of Jupiter and Saturn during the two years 491 and 571 are given in Table 3. First column describes the mutual positions of both planets (1st or 2nd conjunction, their opposition with the Sun and the Mayan dates B and C described above). The second column gives the JD and calendar date, computed with the B&B correlation. The positions (geocentric mean ecliptical longitude λ and latitude β) of both planets in degrees are given in columns 3 and 4 calculated for the dates given in column 2, only for the cases of conjunctions. For the oppositions, their computed JD and calendar dates are given instead, for Jupiter and Saturn, respectively. Last column then shows the angular distances of both planets at the moments of their conjunctions and also for the Mayan dates given in DC. The situation of the table is graphically depicted in Figs. 3 and 4, for better illustration. The angular distance between the two planets changed during the years 491 and 571 only a little and very slowly, so that for a terrestrial observer they both stayed for many weeks in a very close vicinity, describing the apparent wobbles almost in parallel.

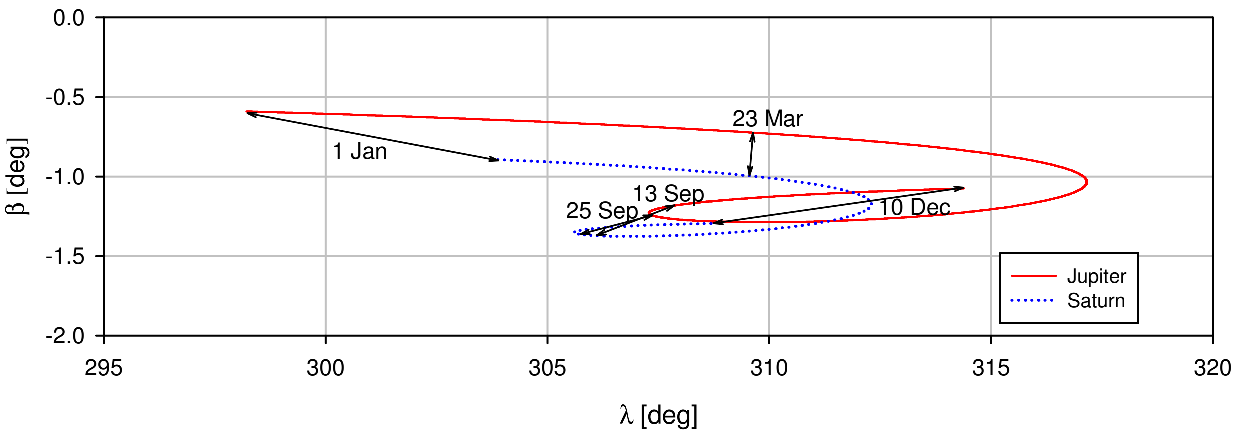

Fig. 3. *Ecliptical longitude λ and latitude β of Jupiter and Saturn, during the year 491 AD, covering their repeated conjunctions.*

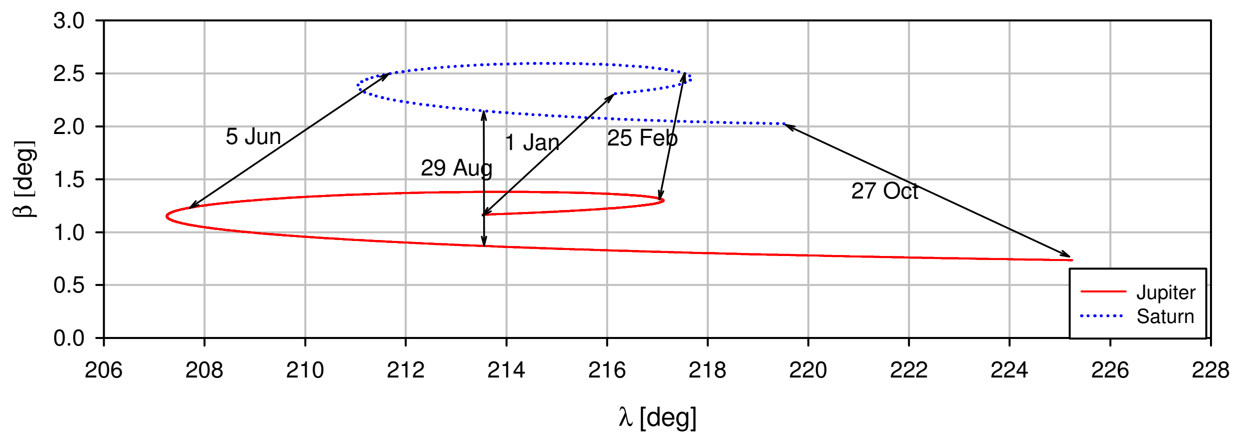

Fig. 4. *Ecliptical longitude λ and latitude β of Jupiter and Saturn, during the year 571 AD, covering their repeated conjunctions.*

Table 3. Mutual positions of Jupiter and Saturn close to their repeated conjunctions.

Mutual position	JD, calendar date	Jupiter's position λ	Jupiter's position β	Saturn's position λ	Saturn's position β	Angular distance
1st conjunction	1 900 477 March 23, 491	309.632	−0.724	309.569	−0.996	0.279
opposition		1 900 610 August 3, 491		1 900 607 July 31, 491		
(8.17.11.1.10) 13 Oc	1 900 651 September 13, 491	307.846	−1.266	306.125	−1.371	1.724
2nd conjunction	1 900 663 September 25, 491	307.352	−1.243	305.746	−1.363	1.611
1st conjunction	1 929 671 February 25, 571	217.046	1.318	217.532	2.500	1.280
opposition		1 929 725 April 20, 571		1 929 728 April 23, 571		
(9.1.11.17.10) 13 Oc	1 929 771 June 5, 571	207.674	1.229	211.652	2.496	4.172
2nd conjunction	1 929 856 August 29, 571	213.532	0.871	213.528	2.147	1.276

3.4 Synchrony of synodic and sideric periods of Mercury with tropical year

Similarly to the preceding section, we were looking in the DC for two dates differing by 2 200 days, the interval after which the synodic and sideric periods of Mercury and tropical year are again it the same phase. We found such occurrence on page D 24 (F 24). Two introductory Mayan dates on page D 24 and the form of the inscription is the following:

A)	9.9.16.0.0	4 Ahau	8 Cumku	1 366 560
	−6.2.0			−2 200
B)	9.9.9.16.0	1 Ahau	18 Kayab	1 364 360

The interval of 2 200 days between the two dates A and B is expressed directly and accompanied by a minus glyph (Fig. 5). This interval is equal to multiples of synodic and sideric period of Mercury and tropical year. After this interval, Mercury rises and sets at the same place in the sky. The interval contains:

19 synodic periods of Mercury (115.877484d),
25 sideric periods of Mercury (87.968581d),
6 tropical years (365.242199d).

When using the B&B correlation, both Mayan dates refer to the positions of Mercury when close to maximum west elongations. In addition, they assure that the planet was close to the aphelion of its eccentric orbit, when maximum elongation was 27°49′. The conditions to observe Mercury were thus extremely favorable; for a terrestrial observer, Mercury was not only near the maximum elongation, but also near its maximum distance from the Sun, so that it was more than 19 degrees above the horizon before sunrise (Fig. 6).

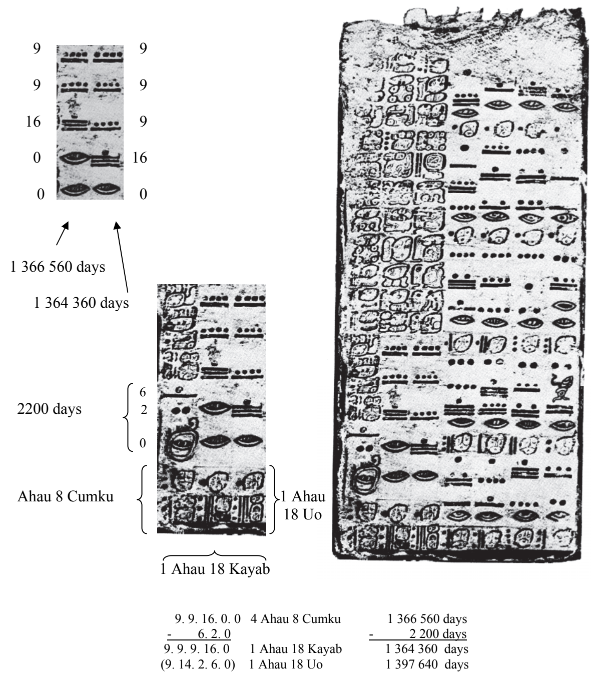

Fig. 5. *Dresden Codex, p. D 24 (F 24), data for Mercury. The newly discovered interval of 2 200 days means a synchrony of synodic and sideric periods of the planet with the tropical year. The minus glyph is represented by a frame around 'glyph zero'(see left column 6.2.0).*

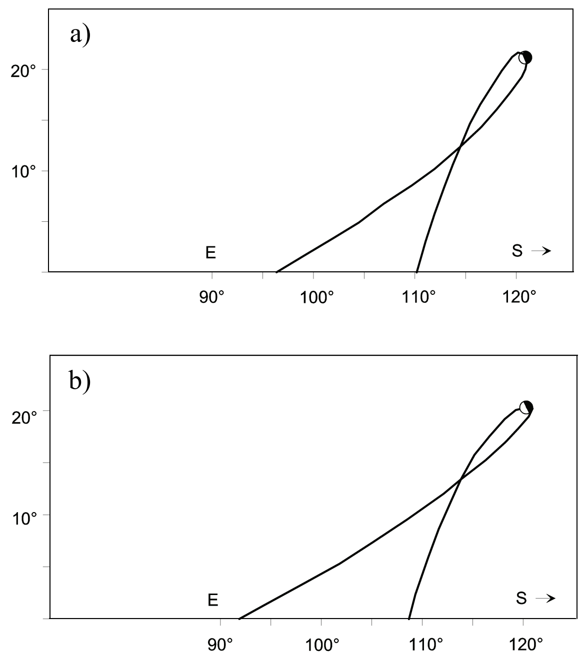

Fig. 6. *The positions of Mercury (Dresden Codex p. D 24 (F 24)) in the morning sky shortly before sunrise between a) December 29, 726 and March 5, 727, b) January 7, 733 and March 15, 733, close to its maximum elongations on January 27, 727 and February 4, 733, respectively (corresponding Maya dates are 9.9.9.16.0.1 Ahau 18 Kayab and 9.9.16.0.0 4 Ahau 8 Cumku, using the B&B correlation).*

a) January 27, 727 Mercury close to maximum west elongation (26 degrees), altitude before sunrise 19 degrees. Maximum west elongation occurred January 21, 727.

b) February 4, 733 Mercury close to maximum west elongation (26 degrees), altitude before sunrise 20 degrees. Maximum west elongation occurred January 31, 733.

In the DC there are dates to which time intervals are added that are typical of some repeated astronomical phenomena, or typical intervals between two dates. Some of them were explained in the past. They are as follows:

a) 2 920 days and their multiples, when synodic and sideric periods of Venus are in a synchrony with tropical year and heliacal rising of this planet occurs (Teeple 1926).

b) 11 960 days of repeated solar eclipses (Meinshausen 1913, Guthe 1921).

Here we found the new interval (2 200 days) and tested it via all the correlations in Table 1. The real astronomical meaning has been confirmed only when the B&B correlation was used. The 2 200-day interval means a synchrony of synodic and sideric periods of Mercury with the tropical year, (Fig. 6).

4. DISCUSSION

All tests described above show that the B&B correlation yields the best agreement with the astronomical phenomena recorded by the Maya in the DC. The dates of these events fall into the classical period of the Maya history, when Long Count (LC) was in general use. On the other hand, the GMT correlation, mostly accepted by historians, is based only on comparing historical events with no direct LC dating. We can only speculate why the historical events used by the GMT lead to a correlation different by about +104 years (precisely 37 978 days) from the one based on astronomical events recorded in the DC. This difference is almost precisely equal to double interval of 18 980 days (about 52 years) in which tzolkin and haab cycles are in the same phase. Maybe, it is just a mere random coincidence, but it is also possible that it might be caused by an error in the backward reconstitution of the LC, made by GMT to obtain the dating of historical events in the LC from the sixteen century sources (when the LC had been abandoned for several centuries).

5. CONCLUSIONS

In addition to our previous test of validity of different correlation coefficients (Klokočník et al. 2008), we made another one, quite independent. This time we rather use long-periodic astronomical phenomena whose records we succeeded to find in the Dresden Codex – a synchrony of Venusian heliacal risings with solar eclipses (interval of about 132 years), synchrony of conjunctions of Venus with Mars and solar eclipses (interval of about 37 years), repeated conjunctions of Jupiter with Saturn (interval of about 80 years), and synchrony of synodic and sideric period of Mercury and tropical year (interval of 6 years, after which Mercury rises and sets at the same place in the sky). All these events, as recorded by the Maya, *coincide with reality only if the B&B correlation is used; all others fail.* Thus the B&B correlation is confirmed again, using different astronomical phenomena from those used in deriving it (Böhm and Böhm 1991) and by testing different correlations (Klokočník et al. 2008). So, we must state that, from the astronomical point of view, the most frequently used GMT correlation is wrong and should be abandoned, at least for the classical period of the Maya history. The possible explanation why the GMT and B&B correlations differ by +104 years, suggested in Discussion, certainly deserves further investigation.

Table 4. Full list of the solar eclipses from the Dresden Codex: Col. 1 the ordering number; Col. 2 sum of lengths of cycles in days; Col. 3 tzolkin date; Col. 4 length of cycle in days; Col. 5 LC date. * The initial date No. 1 (9.16.4.10.8 12 Lamat) corresponds to 1 412 848 days in the LC dating. Data in parentheses – script reconstructed from damaged text.

1	2	3	4	5
1	0	12 Lamat	*	1 412 848
2	177	6 Kan 7 Chicchan 8 Cimi	177	1 413 025
3	354	1 Imix 2 Ik 3 Akbal	177	1 413 202
4	502	6 Muluc 7 Oc 8 Chuen	148	1 413 350
5	(679)	1 Cimi 2 Manik 3 Lamat	177	1 413 527
6	856	9 Akbal 10 Kan (11) Chicchan	177	1 413 704
7	1 033	4 (Ahau) 5 Imix 6 Ik	177	1 413 881
8	1 211	(13) Etznab 1 Cauac (2) Ahau	(178)	1 414 059
9	1 388	8 Men 9 Cib 10 Caban	177	1 414 236
10	1 565	3 Eb 4 Ben 5 Ix	177	1 414 413
11	(1 742)	11 Muluc 12 Oc 13 Chuen	177	1 414 590
12	1 919	6 (Cimi) 7 (Manik) 8 Lamat	177	1 414 767
13	(2 096)	1 Akbal 2 Kan 3 Chicchan	177	1 414 944
14	2 244	6 Chuen 7 Eb 8 Ben	148	1 415 092
15	2 422	2 Muluk 3 Oc 4 Chuen	(178)	1 415 270
16	(2 599)	10 Cimi 11 Manik 12 Lamat	177	1 415 447
17	2 776	5 Akbal 6 Kan 7 Chicchan	177	1 415 624

Table 4. continued.

1	2	3	4	5
18	2 953	13 Ahau 1 Imix (2) Ik	177	1 415 801
19	3 130	8 (Caban) 9 (Etznab) 10 (Cauac)	177	1 415 978
20	3 278	(13 Chicchan) (1) Cimi (2) Manik	148	1 416 126
21	3 455	8 Ik 9 Akbal 10 Kan	177	1 416 303
22	3 632	3 Cauac 4 Ahau 5 Imix	177	1 416 480
23	3 809	11 Cib 12 Caban 13 Etznab	177	1 416 657
24	3 986	7 Ix 8 Men 9 Cib	(177)	1 416 834
25	4 163	2 Chuen 3 Eb 4 Ben	177	1 417 011
26	4 340	10 Lamat 11 Muluc 12 Oc	177	1 417 188
27	4 488	2 Cib 3 Caban 4 Etznab	(148)	1 417 336
28	4 665	10 Ben (11) Ix 12 Men	177	1 417 513
29	4 842	5 Oc 6 Chuen 7 Eb	177	1 417 690
30	5 020	1 Lamat 2 Muluc 3 Oc	(178)	1 417 868
31	5 197	9 Chicchan 10 Cimi 11 Manik	177	1 418 045
32	5 374	4 Ik 5 Akbal 6 Kan	177	1 418 222
33	5 551	12 Cauac 13 Ahau 1 Imix	177	1 418 399
34	5 728	7 Cib 8 Caban 9 Etznab	177	1 418 576
35	5 905	2 Ben 3 Ix 4 Men	177	1 418 753

Table 4. continued.

1	2	3	4	5
36	6 082	10 Oc 11 Chuen 12 Eb	177	1 418 930
37	6 230	2 Etznab 3 Cauac 4 (Ahau)	148	1 419 078
38	6 408	11 Cib 12 Caban 13 Etznab	(178)	1 419 256
39	6 585	6 Ben 7 Ix 8 Men	177	1 419 433
40	6 762	1 Oc 2 Chuen 3 Eb	177	1 419 610
41	6 939	9 Manik 10 Lamat 11 Muluc	177	1 419 787
42	7 116	4 Kan 5 Chicchan (6) Cimi	177	1 419 964
43	7 264	9 Eb 10 Ben 11 Ix	148	1 420 112
44	7 441	4 Muluc 5 Oc 6 Chuen	177	1 420 289
45	7 618	12 Cimi 13 Manik 1 Lamat	177	1 420 466
46	7 795	7 Akbal 8 Kan 9 Chicchan	177	1 420 643
47	7 972	2 Ahau 3 Imix 4 Ik	177	1 420 820
48	8 149	10 Caban (11) Etznab 12 Cauac	177	1 420 997
49	8 326	5 Ix 6 Men 7 Cib	177	1 421 174
50	8 474	10 Ik 11 Akbal 12 Kan	148	1 421 322
51	8 651	5 Cauac 6 Ahau 7 Imix	177	1 421 499
52	8 828	13 Cib 1 Caban 2 Etznab	177	1 421 676
53	9 006	9 Ix 10 Men 11 Cib	(178)	1 421 854

Table 4. continued.

1	2	3	4	5
54	9 183	4 Chuen 5 Eb (6) Ben	177	1 422 031
55	9 360	12 Lamat 13 Muluc 1 Oc	177	1 422 208
56	9 537	7 Chicchan 8 Cimi 9 Manik	177	1 422 385
57	9 714	2 Ik 3 Akbal 4 Kan	177	1 422 562
58	9 891	10 Cauac 11 Ahau 12 Imix	177	1 422 739
59	10 039	2 Manik 3 Lamat 4 Muluc	148	1 422 887
60	10 216	10 Kan 11 Chicchan 12 Cimi	177	1 423 064
61	10 394	6 Ik 7 Akbal 8 Kan	(178)	1 423 242
62	10 571	1 Cauac 2 Ahau 3 Imix	177	1 423 419
63	10 748	9 Cib 10 Caban 11 Etznab	177	1 423 596
64	10 925	(4) Ben 5 Ix 6 Men	177	1 423 773
65	11 102	12 Oc 13 Chuen 1 Eb	177	1 423 950
66	11 250	4 Etznab 5 Cauac 6 Ahau	148	1 424 098
67	11 427	12 Men 13 Cib 1 Caban	177	1 424 275
68	11 604	7 Eb 8 Ben 9 Ix	177	1 424 452
69	11 781	(2) Muluc 3 Oc 4 Chuen	177	1 424 629
70	11 958	10 Cimi 11 Manik 12 Lamat	177	1 424 806 1 424 808

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ДАТИРАЊЕ КАЛЕНДАРА МАЈА КОРИШЋЕЊЕМ ДУГОПЕРИОДИЧНИХ АСТРОНОМСКИХ ПОЈАВА У ДРЕЗДЕНСКОМ КОДЕКСУ

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Оригинални научни рад

Однос између календара Маја и нашег календара дат је коефицијентом познатим под називом "корелација", који представља број дана који треба да се дода на датум у систему Дугог бројања дана код Маја да се добије Јулијански Датум (број дана) који се користи у астрономији. Изненађујуће је колико је велика неодређеност у вредности корелације (а тиме и између историје Маја и историје нашег света) која међу овим календарима достиже најчешће неколико стотина година. Постоји више од 50 различитих вредности корелације, од којих неке проистичу из историјских, а неке из астрономских података. Ми смо овде тестирали (између осталог) највише употребљавану GMT корелацију (добијену из историјских података) и корелацију Бемових (B & B), добијену из астрономских података декодираних из Дрезденског кодекса (DC), која се разликује од GMT за око +104 године. У претходним радовима за проверу смо користили неколико астрономских појава које су забележене у DC. Јасно смо показали да: (i) GMT корелација није била у стању да предвиди ове појаве које су се стварно десиле у природи и (ii) GMT предвиђа те појаве у дане када нису забележене. Појаве које смо користили до сада за тестирање су, међутим, краткопериодичне и резултат теста не мора да буде једнозначан. Стога смо за даље тестирање изабрали дугопериодичне астрономске појаве, које су успешно декодиране из DC. Те појаве су (i) синхроност хелиачких излаза Венере и помрачења Сунца, (ii) синхроност конјункција Венере и Марса са помрачењима, (iii) ретко поновљиве конјункције Јупитера и Сатурна, и (iv) синхроност синодичког и сидеричког периода Меркура са тропском годином. Из наше анализе следи да B & B корелација даје најбоље слагање са астрономским појавама које су забележиле Маје. Зато предлажемо да се одбаци GMT и прихвати B & B корелација.