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NEWLY FOUND MAYA RECORDS OF ASTRONOMICAL OBSERVATIONS IN THE DRESDEN CODEX

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Abstract: This paper represents our recent efforts in discovering more Maya records in the Dresden Codex that can be identified with astronomical phenomena. We inspected pages D40–D42 and D60 of the Dresden Codex and found 21 new dates. These dates are given mostly in the Long Count, but also in Calendar Round Dates (i.e., by the dates in *Tzolkin* and *Haab*). We used the correlation (the difference between the Long Count and the Julian Date) determined in 1991 by the Böhm brothers (BB), and also the traditional correlation by Goodman, Martínez and Thompson (GMT) to convert Maya dates to the Julian calendar. Then we tried to identify both sets of calendar dates with real astronomical phenomena visible from the Maya territory. We succeeded in identifying them (conjunctions of all visible planets and greatest elongations of Mercury and Venus from the Sun) for all dates in the BB correlation, but we were not so successful for the GMT.

Thus, this paper brings another important argument for using the BB correlation instead of the GMT to convert Maya dates from the Classical Period into our calendar. This is in agreement with several papers published during the past decades, in which it was demonstrated that the GMT correlation (preferred by many historians), is not able to identify astronomical events that occurred in the Classical Period of Maya civilization.

Keywords: Maya astronomy; Dresden Codex; ephemerides; planetary conjunctions.

1 INTRODUCTION

Maya culture was a part of the cultural sphere of Mesoamerica (Coe, 1999; Demarest, 2004; Sharer and Traxler, 2006). Its very beginning, the Archaic Period, is put before 2000 BC, with the first Maya cities developing around 750 BC. Among them, El Mirador was probably the most important (Pérez, 2013). In the Classical Period of its heyday, from about 250 through to 900 AD, Maya territory already covered the area of parts of today's Mexico, Guatemala, Belize, Salvador and Honduras. The old Maya originally cultivated maize, later started developing ceremonial centers, temple cities, and finally real cities. Simple barrows were built first, later followed by stone pyramids with temples, stelae and altars erected on top. The Maya also created hieroglyphic scripture and a Calendar, in which a 365-day astronomical year (*Haab*) and a 260-day sacral cycle (*Tzolkin*) played dominant roles.

Cultural and economic progress expanded throughout the whole Mayan territory (Foster 2002). Stone stelae and temple walls were covered with numerous carved hieroglyphic texts with calendar dates. One of the most elegant temple cities is Palenque in today's Mexican state of Chiapas. All this progress was possible thanks to the efficient agriculture. It enabled to intensively practice civil engineering, advanced commerce, arts, letters, and also astronomy. Attention was devoted to the observation of astronomical phenomena: the Maya observed motions of the Sun, Moon, visible planets and their conjunctions, solar eclipses, and left corresponding written records (see Milbrath, 2010; Rice, 2004).

However, around 800–900 AD came a disaster, and the classical period of Maya civilization ended. This was very probably due to catastrophic draughts and the invasion of militant groups from central Mexico, and Mayan cities were gradually abandoned. Thus, at the beginning of the sixteenth century the Spanish invaders found the Maya living in simple villages.

More details of the rich history of Maya astronomical observations can be found in the papers by Böhm et al. (2013), Klokočník et al. (2008), and Vondrák et al. (2022; 2023; 2024).

2 THE MAYA CALENDAR

The Maya developed a very complicated calen-

dar system, described in full, e.g., by Foster (2002). The Maya Calendar consisted of several cycles, the most important being the *Tzolkin* and *Haab*. The *Tzolkin* contains twenty named days (*Imix*, *Ik*, *Akbal*, *Kan*, *Chikchan*, *Kimi*, *Manik*, *Lamat*, *Muluk*, *Ok*, *Chuwen*, *Eb*, *Ben*, *Ix*, *Men*, *Kib*, *Kaban*, *Etznab*, *Kawak*, *Ajaw*) and day numbers that go from 1 to 13. The days in this cycle start with 1 *Imix*, 2 *Ik*, 3 *Akbal* etc. up to 13 *Ben*, then the day numbers start again at 1 while the named-day sequence continues onwards. Thus, the combination of number/named day is unique in the whole 260-day cycle.

The 365-day Haab consists of eighteen months (*Pop*, *Uo*, *Zip*, *Zotz*, *Tzec*, *Xul*, *Yaxkin*, *Mol*, *Chen*, *Yax*, *Zac*, *Ceh*, *Mac*, *Kankin*, *Muan*, *Pax*, *Kayab*, *Cumku*) of twenty days each plus five nameless days at the end of the year known as *Uayeb*. Each day of the cycle was identified by a day number in the month followed by the name of the month. The first day of the year was 0 *Pop*, followed by 1 *Pop*, 2 *Pop* as far as 19 *Pop*, then 0 *Uo*, 1 *Uo* and so on.

A Calendar Round Date (CRD) is a date that consists of both *Tzolkin* and *Haab* dates. The same CRD repeats in period 18980 days long (the least common multiple of 260 and 365), called a Calendar Round. For example, the current period of Long Count started on 4 *Ahau* 8 *Cumku*.

The Long Count (LC) was used to track longer periods of time. It expresses the number of days elapsed since the mythological origin of Maya chronology. The whole cycle of the LC consists of 1872000 days. After its end, a new cycle began. The LC is similar to the Julian Date (JD), used in astronomy. In the texts preserved in the Dresden Codex (henceforth DC; see the next Section) the dates expressed in the LC are sometimes accompanied by dates in the 260-day *Tzolkin*. It can serve as an important check of the validity of the record in the LC. To express the date in the LC, the Maya used a modified vigesimal (base-20) positional numeral system of five intervals of time and their multiples. These intervals are as follows:

- *K'in* = day,
- *Uinal* = 20 *K'ins*,
- *Tun* = 18 *Uinals* = 360 *K'ins*,
- *K'atun* = 20 *Tuns* = 7200 *K'ins*,
- *B'ak'tun* = 20 *K'atuns* = 144000 *K'ins*

The LC date is written as five numerals. If denoted as n_1 through n_5 (corresponding to the number of *B'ak'tuns* to *K'ins*), the date is written as $n_1.n_2.n_3.n_4.n_5$. All these numbers go from 0 to 19, with the exceptions of n_1 (0 to 12) and n_4 (0 to 17). The number of LC days is then equal to

$$\mathrm{LC} = 144000n_1 + 7200n_2 + 360n_3 + 20n_4 + n_5. \quad (1)$$

In today's astronomy, we use Julian Dates (JD), the number of days counted from an arbitrarily chosen origin (1 January 4713 BC). The difference between the origin of the JD and the LC τ = JD – LC, is traditionally called the 'correlation'. The correlation can be determined if we know the dates of at least one event both in the LC and the JD. In the past, more than fifty different values for the correlation were determined, as listed, for example, by Böhm et al. (2013). They are based on both historical and astronomical events. However, they are mutually highly inconsistent; with individual values of τ ranging from 394483 to 774083 days.

Historians mostly accept as standard the Goodman–Martínez–Thompson (GMT) value of 584283 days (Thompson, 1935). It is based mainly on historical events, dating to the post-Classical Period of Maya civilization. On the other hand, the Böhm brothers (Böhm and Böhm, 1991; 1993; 1998) published their correlation (BB) of τ = 622261 days, based purely on numerous astronomical phenomena from the Classical Period of Maya civilization. These were recorded in the Dresden Codex, and also carved in stone stelae, altars and walls of Maya temples. Attempts were also made to resolve the correlation issue by using radiocarbon studies (see, e.g., Satterthwaite and Ralph, 1960), but the results usually supported multiple correlations, due to their large uncertainties. A more recent study (Kennett et al., 2013), based on only one wooden lintel from Tikal, strongly supported the GMT correlation. However, its uncertainty of 40 years does not rule out the BB correlation that differs from the GMT one by 104 years.

The difference between the BB and GMT correlations of 37978 days, is almost exactly equal to two Calendar Rounds (104 *Haabs*, or 146 *Tzolkins*). This is probably not a mere random coincidence, as it was stated earlier by Böhm et al. (2013). They proposed the explanation that the GMT correlation is based on the assumption that the Maya calendar was continually used from the beginning of Maya history up to the sixteenth century, see also Vondrák et al. (2023). As Thompson (1935: 56) himself admitted:

> Naturally, if there was a break, all Sixteenth Century evidence must be discarded, and a correlation must be reached through astronomy checked by ceramics and architecture. In this publication the assumption is made that there was no break.

This assumption is however not correct—the system of dating was interrupted during the eleventh century. The interruption can be documented by the fact that mutual synchronization between the 260-day *Tzolkin* and the 365-day *Haab* was different in the Classical and Post-Classical periods. In the Classical Period, only four *Tzolkin* days (*Ik*, *Manik*, *Eb* and *Kaban*) fell cyclically on the first day of *Haab*. This is demonstrated on pages D54–D57 in the Dresden Codex. In contrast to this, in the Post-Classical period these days changed to *Kan*, *Muluk*, *Ix* and *Kawak*, as shown in the Madrid Codex on pages M34–M37 and M3–M6. This was also witnessed by Diego de Landa (Relatión de las Casas de Yucatán, 1569).

In recent years, more Maya records of astronomical phenomena in the DC and on some stelae have been studied. Klokočník et al. (2008) used solar eclipses, planetary conjunctions, greatest elongations of planets from the Sun and heliacal risings and settings of planets to find out which correlation yielded the best fit with reality. Only the BB correlation was found to be compatible with all these astronomical data. Other correlations, including the GMT, would fit only a small subset of them. In order to avoid ambiguities of short-periodic events, Böhm et al. (2013) added some long-periodic ones. Vondrák et al. (2022) demonstrated that the old Maya also observed Mercury and made records of its best visibility around its greatest elongations. In all, 19 records of Mercury's greatest elongations from the Sun and 9 records of its conjunctions with the Sun were found in the DC. Vondrák et al. (2023) studied six records of planetary conjunctions of visible planets, and later (Vondrák et al., 2024) added six additional ones. All of these studies confirmed the validity of the BB correlation. Below we analyze more astronomical phenomena whose records we found recently in the DC.

3 ASTRONOMICAL EVENTS FOUND RECENTLY IN THE DRESDEN CODEX

We use the dates found in the Dresden Codex, one of the four hieroglyphic codices that survived the Spanish Inquisition. It is a book consisting of 39 folded sheets (78 pages). It originates from the Yucatán Peninsula. It is probably a copy made around 1200 CE from three different original sources, as described by Thompson (1972) and by Bricker and Bricker (2011). It contains calendar dates of both historical and astronomical events.

In this paper we concentrate on the dates recorded on pages D40–D42 and D60. These pages are displayed as Figures 1–4, and the dates discovered there are denoted by the code letters A through N.

Page D40, shown in Figure 1, contains dates A and B. Date A is not a complete LC date—it only contains four digits. We completed it with the first one (8) because it leads to a meaningful result within the Classical Period of Maya civilization, and also refers to important astronomical phenomena. Date B is a Calendar Round Date (CRD) that repeats three times (on pages D40, D41, and also on D43, that is not shown here). However, conversion of the CRD to the LC is not unique, date B formally refers to any LC date expressed as 1160684 + 18980*n*, where *n* is any integer. So, the same CRD repeats in intervals slightly shorter than 52 years. The constant 1160684 of the formula above is the Long Count date of the first occurrence of the LC before the beginning of the Classical Period of Maya history. It corresponds to 10 June 169 if the BB correlation is used. A detailed description of the conversion between the CRD and the LC is given in the Appendix. Out of the 16 possible interpretations that fall within the Classical Period of Maya civilization, eight can be identified with some conjunctions. Our first choice for the B date is LC 9.15.9.9.4 (1407424 days), but other interpretations are also possible, as we shall see below.

Figure 2 shows page D41 that contains again date B plus dates C and E, and also intervals that should be subtracted from these (they contain a negative sign) to compute dates D and F. In case of dates D and F the corresponding *Tzolkin* dates are also shown.

Page D42 in Figure 3 completes the list with dates G, I, K, L and N and three intervals whose subtraction from G, I and L lead to dates H, J and M. The dates K and L are partially overlapping, and are distinguished by different colors (black and brown). Date N is not complete, so we had to add the first digit (8), similarly to date A of Figure 1, with the same reasoning. *Tzolkin* dates, corresponding to the Long Count H, J, M, are also displayed.

Some of the preceding information (dates E, I, L and corresponding intervals to be subtracted from them) is repeated on page D60 that is shown in Figure 4. Inscriptions L, L-M in Figures 3 and 4 look very similar (see the difference in parentheses) but not identical; we assume that they refer to the same dates. The date L in Figure 4 was evidently copied from the original to DC with a scribal error—the third and fourth digits (3.13) were switched, and also the interval L-M is slightly different. We accept the values of Figure 3 as correct, because they correspond to the *Tzolkin* date 13 *Akbal* for the date M.

All the dates that we found above are summarized in Table 1, in which we calculated the

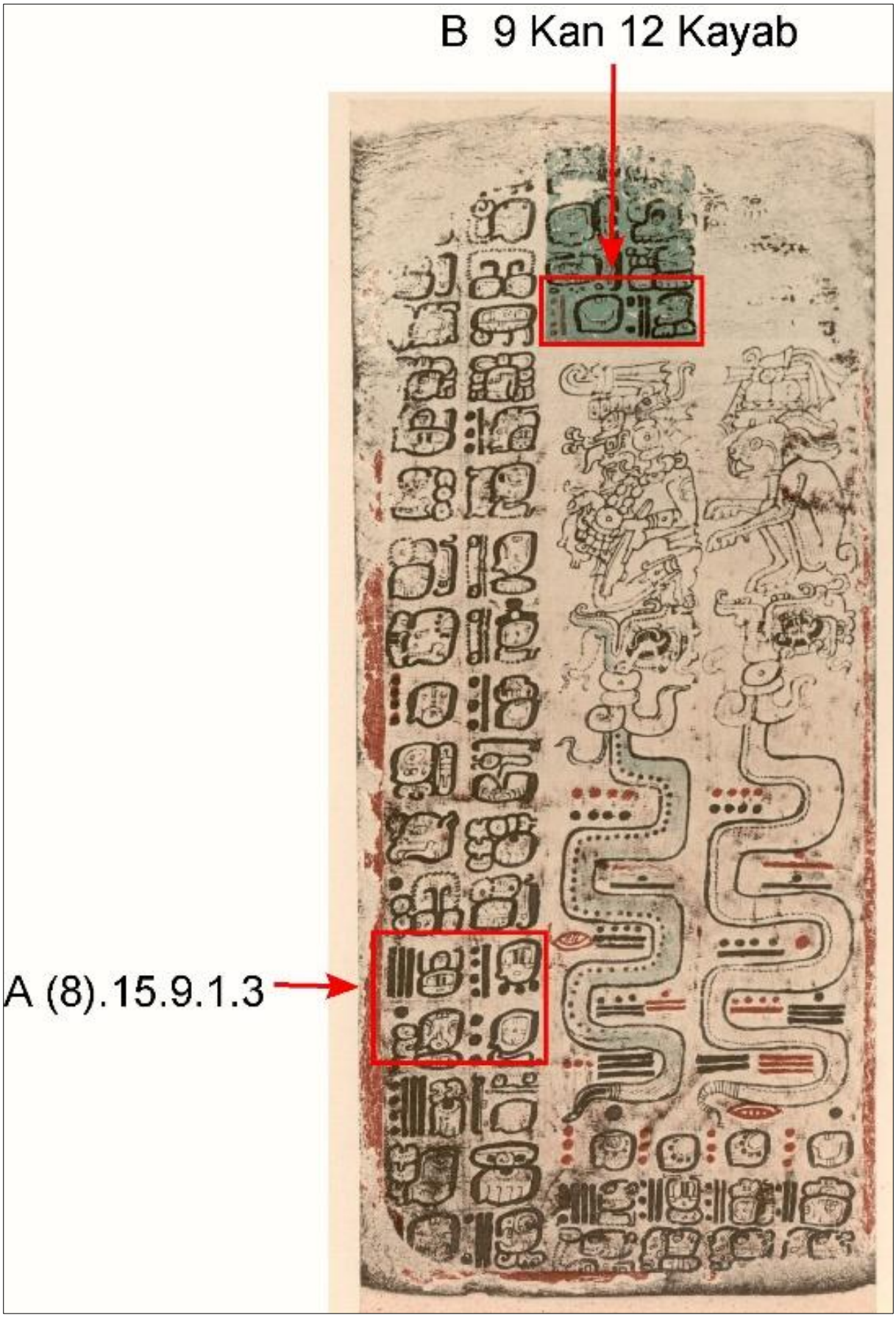

Figure 1: Page D40 in the Dresden Codex.

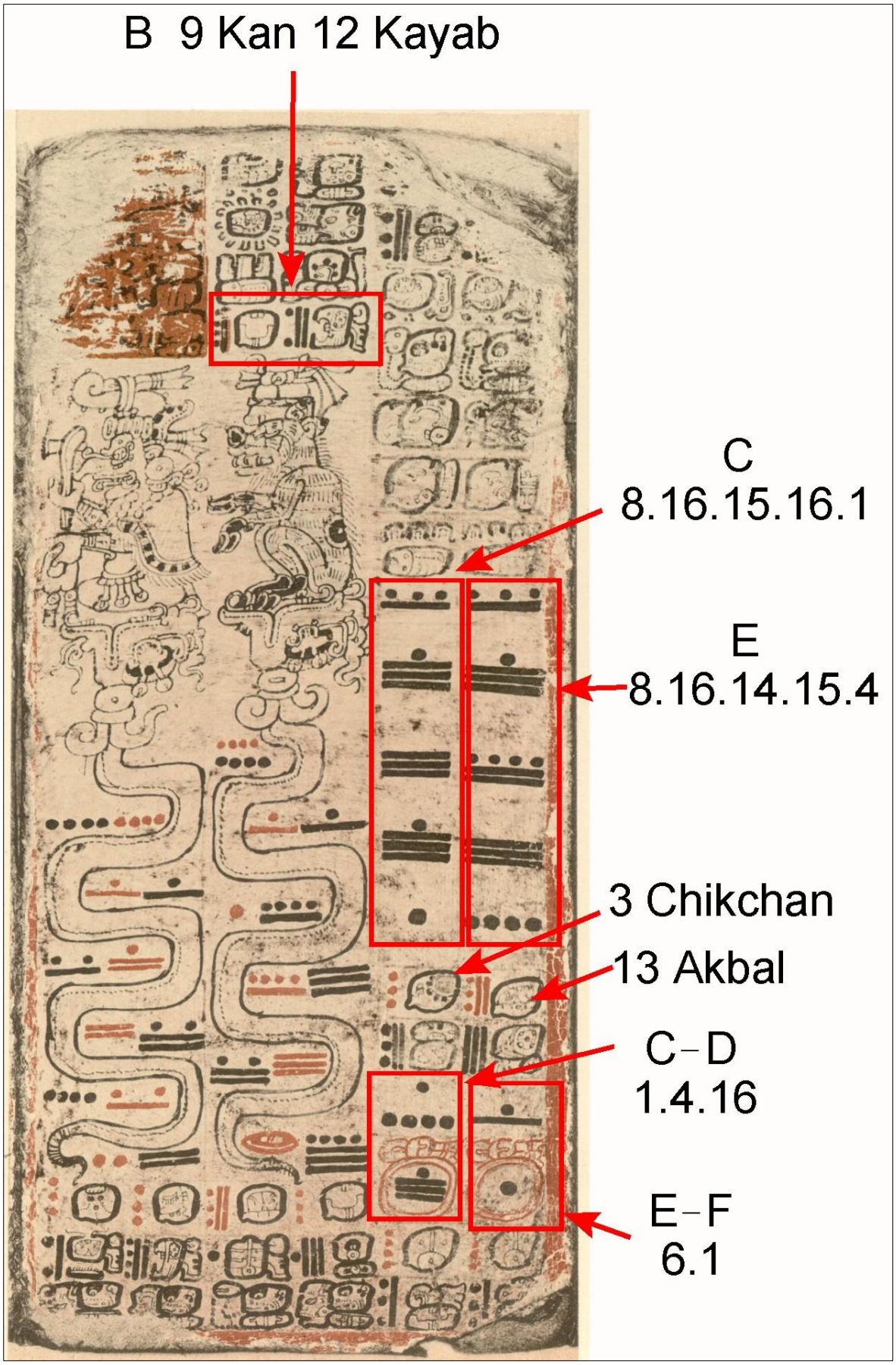

Figure 2: Page D41 in the Dresden Codex.

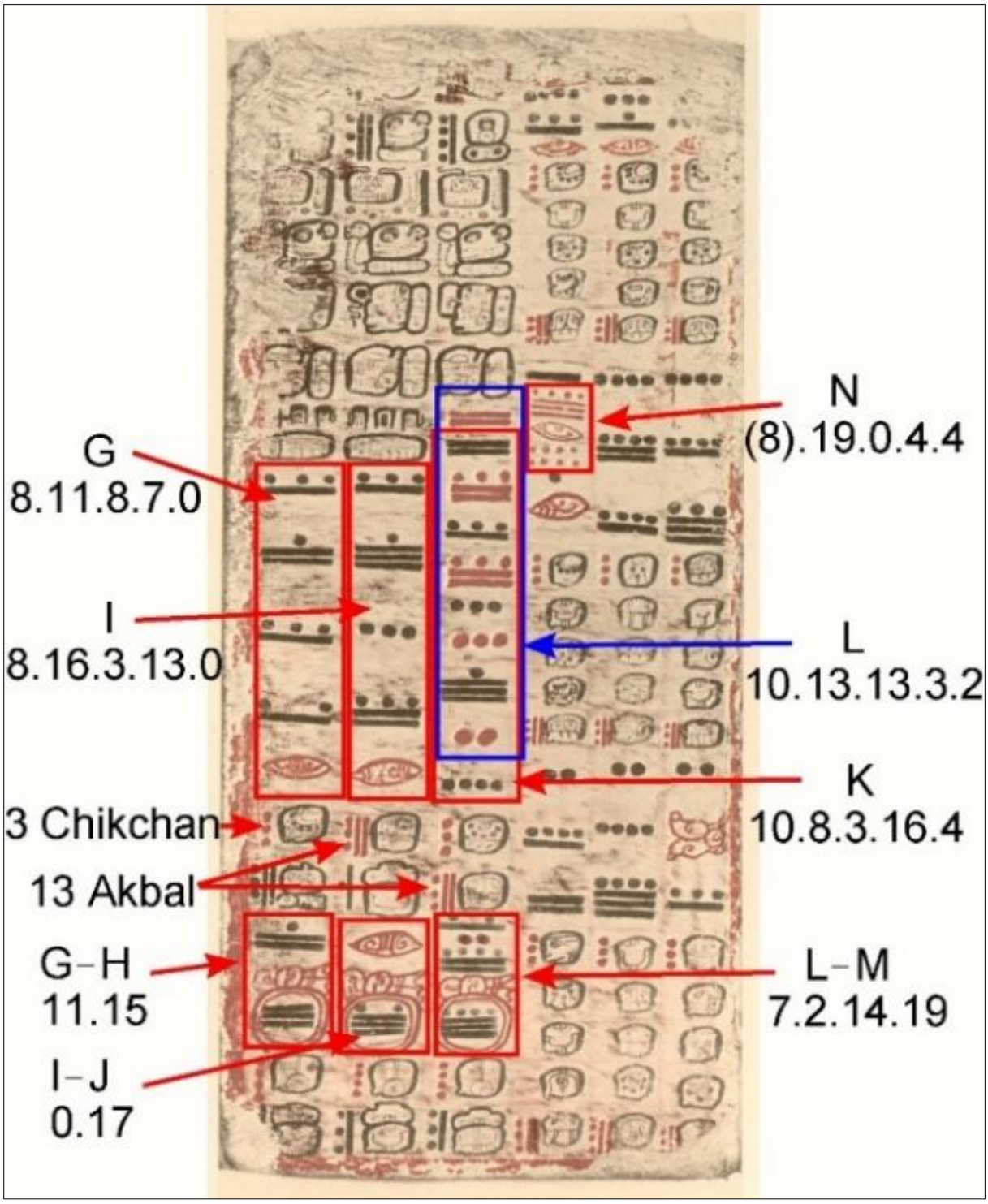

Figure 3: Page D42 in the Dresden Codex.

LC using Equation (1). Then we used both the BB and GMT correlations to convert the LC to the JD, and calculate dates in the Julian Calendar. Not all of these reflect real observations, since the dates K, L and M very likely represent predictions.

A first look at the displayed dates reveals some very interesting mutual differences. They are approximately equal to multiples of the synodic periods of Mercury (≈116 days), Jupiter (≈398 days) and Saturn (≈378 days), the sidereal periods of Mercury (≈88 days) and Jupiter (≈4381 days), or the tropical year (365.2422 days).

Synodic periods are not exactly constant with time, so we are using their approximate average values rounded to integer numbers of days. This information allows us to know which

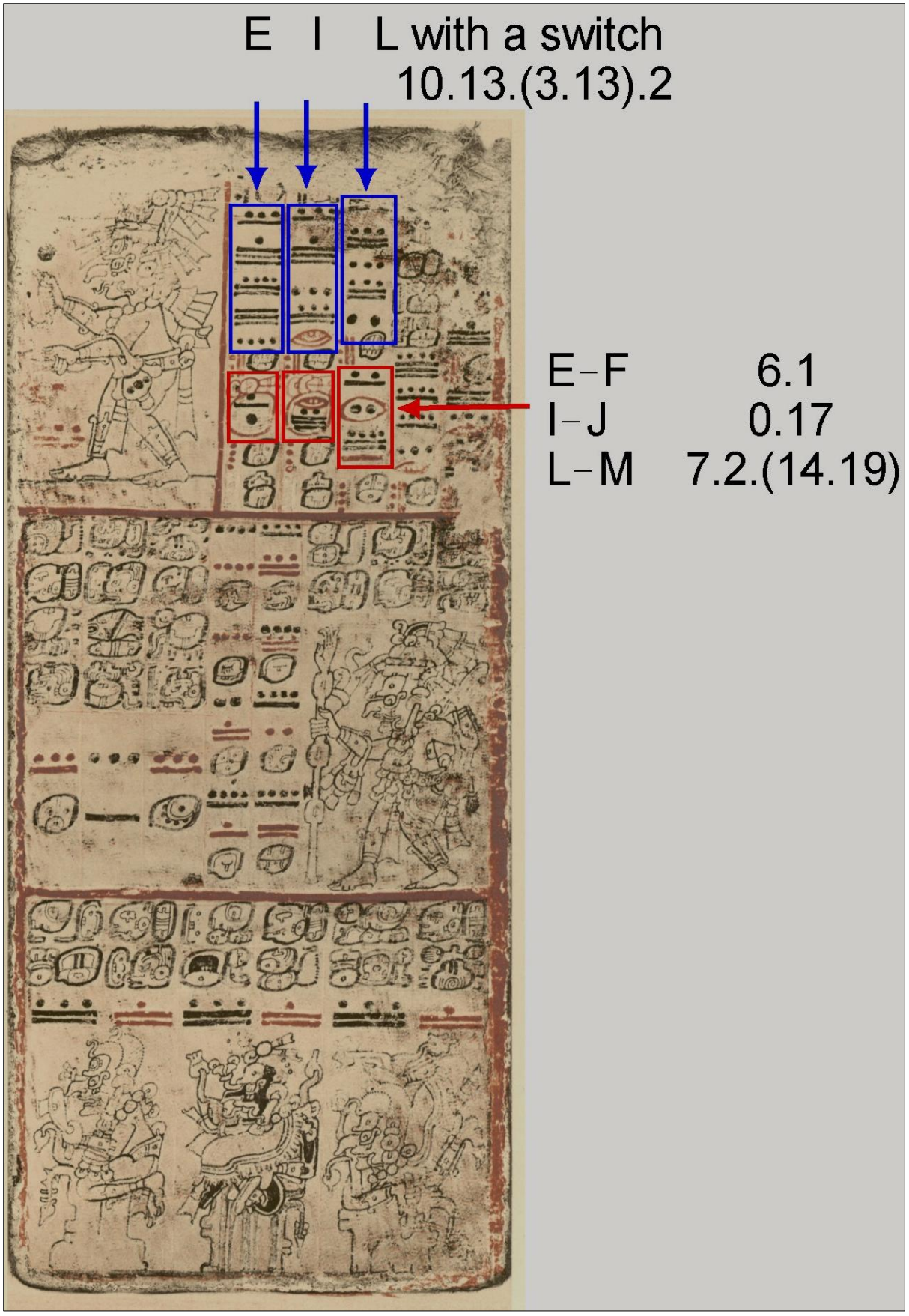

Figure 4: Page D60 in the Dresden Codex.

Table 1: Dates found in the Dresden Codex on pages D40–D42 and D60.

Code	Date in the DC					Page		*Tzolkin*	LC	Jul. cal. BB.			Jul. cal.GMT		
A	(8)	15	9	1	3	D40			1263263	14	Apr	450	22	Apr	346
B	9	15	9	9	4	D40			1407424	22	Dec	844	30	Dec	740
C	8	16	15	16	1	D41			1272921	22	Sep	476	30	Sep	372
D	8	16	14	11	5	D41		3 *Chikchan*	1272465	24	Jun	475	02	Jul	371
E	8	16	14	15	4	D41	D60		1272544	11	Sep	475	19	Sep	371
F	8	16	14	9	3	D41	D60	13 *Akbal*	1272423	13	May	475	21	May	371
G	8	11	8	7	0	D42			1234220	08	Oct	370	16	Oct	266
H	8	11	7	13	5	D42		3 *Chikchan*	1233985	15	Feb	370	23	Feb	266
I	8	16	3	13	0	D42	D60		1268540	24	Sep	464	02	Oct	360
J	8	16	3	12	3	D42	D60	13 *Akbal*	1268523	07	Sep	464	15	Sep	360
K	10	8	3	16	4	D42			1499004	18	Sep	1095	24	Sep	991
L	10	13	13	3	2	D42	D60		1538342	13	May	1203	07	Jun	1099
M	10	6	10	6	3	D42	D60	13 *Akbal*	1486923	19	Aug	1062	27	Aug	958
N	(8)	19	0	4	4	D42	D60		1288884	06	Jun	520	14	Jun	416

phenomena we should consider:

- The interval between C and I of 4381 days equals one sidereal, 11 synodic periods of Jupiter, and 12 tropical years,
- The interval between E and G of 38324 days equals 96 synodic periods of Jupiter,
- The interval between I and G of 34320 days equals 86 synodic periods of Jupiter,
- The interval between N and I of 20344 days equals 51 synodic periods of Jupiter,
- The interval between C and E of 377 days equals to one synodic period of Saturn,
- The interval between E and H of 38559 days equals 102 synodic periods of Saturn,
- The interval between L and H of 304357 days equals 805 synodic periods of Saturn,
- The interval between L and M of 51419 days equals 136 synodic periods of Saturn,
- The interval between J and G of 34303 days equals 296 synodic, 390 sidereal periods of Mercury, and 94 tropical years,
- The interval between C and J of 4398 days equals 38 synodic, 50 sidereal periods of Mercury, and 12 tropical years,
- The interval between K and C of 226083 days equals 1951 synodic, 2570 sidereal periods of Mercury, and 619 tropical years,
- The interval between K and H of 265019 days equals 2287 synodic periods of Mercury,
- The interval between D and H of 38480 days equals 332 synodic periods of Mercury,
- The interval between N and F of 16461 days equals 142 synodic, 187 sidereal periods of Mercury, and 45 tropical years,
- The interval between N and E of 16340 days equals 141 synodic periods of Mercury,
- The interval between M and N of 198039 days equals 1707 synodic and 2250 sidereal periods of Mercury.

From this we can conclude with a high probability that these dates concern mutual phenomena of all visible planets. We calculated the dates of astronomical phenomena that occurred close to all of the Maya dates listed in Table 1. To this end, we used the semi-analytical theory of motion of all planets VSOP87 (Bretagnon and Francou, 1988) to compute their heliocentric positions. Then we applied standard astronomical procedures to transform them first into geocentric and then into topocentric coordinate systems. The resulting astronomical phenomena are displayed in Table 2, in which only those occurring less than two weeks from the Maya dates are shown. In the case of date B, unlike in Table 1, we show here eight possible conversions to the LC that can be identified with some conjunctions. Date B7 in Table 2 corresponds to B of Table 1. The resulting phenomena are divided into two groups: conjunctions and greatest elongations, and are given for both BB and GMT correlations. The different contents of both parts, referring to BB and GMT correlations, is evident; the GMT part is almost empty.

As seen from Table 2, there occurred quite a large number of conjunctions near the dates that we found in the DC, sometimes even more than one near the same date. We distinguish between conjunctions (when the ecliptical longitudes of both planets are equal), and quasi-conjunctions (when their longitudes are different, but their angular distance attains minimum). In the BB case, they mostly occur within several days from the date in the DC. However, it is not the case with the GMT, where the closest conjunctions occur rather far from them, typically several weeks, and therefore are not shown in

Table 2: Astronomical phenomena that occurred close to the dates of Maya records.

The BB Correlation						
Code	Jul. cal. BB	Conjunctions		Greatest Elongations		
A	14 April 450			Mercury	16	April
				Venus	12	April
B1	28 May 221	Mercury–Jupiter	22 May			
		Venus–Mars	24 May			
B2	14 May 273	Venus–Mars	08 May			
B3	02 May 325	Venus–Saturn	09 May			
B4	18 April 377	Venus–Saturn	23 April			
B5	10 March 533	Venus–Mars	02 March			
B6	26 February 585	Mars–Jupiter	22 February			
B7	22 December 844	Venus–Saturn	18 December	Mercury	18	December
		Mercury–Mars	20 December			
B8	10 December 896	Venus–Saturn	17 December			
C	22 September 476	Mercury–Venus	20 September	Mercury	29	September
D	24 June 475	Mars–Saturn	23 June	Mercury	28	June
E	11 September 475			Mercury	06	September
F	13 May 475			Mercury	10	May
G	08 October 370	Mars–Jupiter	19 October	Mercury	13	October
				Venus	24	September
H	15 February 370			Mercury	23	February
I	24 September 464	Mars–Jupiter	16 September			
J	07 September 464			Mercury	10	September
K	16 September 1095			Mercury	18	September
L	30 May 1203	Mercury–Venus	02 June			
M	19 August 1062	Venus–Mars	11 July	Mercury	08	August
		Venus–Mars	22 September			
N	06 June 520	Mercury–Mars	26 May	Mercury	29	May
		Venus–Jupiter	02 June			
The GMT Correlation						
Code	Jul. cal. GMT	Conjunctions		Greatest Elongations		
A	22 April 346					
B1	05 June 117					
B2	22 May 169					
B3	10 May 221					
B4	26 April 273					
B5	18 March 429					
B6	06 March 481					
B7	30 December 740					
B8	18 December 792					
C	30 September 372					
D	02 July 371					
E	19 September 371					
F	21 May 371					
G	16 October 266					
H	24 February 266	Mercury–Jupiter	20 February			
I	02 October 360			Venus	02	October
J	15 September 360	Mercury–Saturn	10 September			
K	24 September 991					
L	07 June 1099					
M	27 August 958			Mercury	30	August
N	14 June 416	Venus-Saturn	18 June			

the table. The only exceptions are dates H, J and N, where these differences are shorter than one week.

Greatest elongations of Mercury and Venus also occur frequently, as seen in Table 2. They often accompany conjunctions, as can be seen from the table. Again, the fit between their dates and the dates in DC is far better for BB correlation than for GMT, where only two (dates I and M) can be found.

3.1 The Graphical Representation of Some Phenomena

Below we demonstrate graphically only some of the most spectacular examples. We present motions of the planets, within several weeks

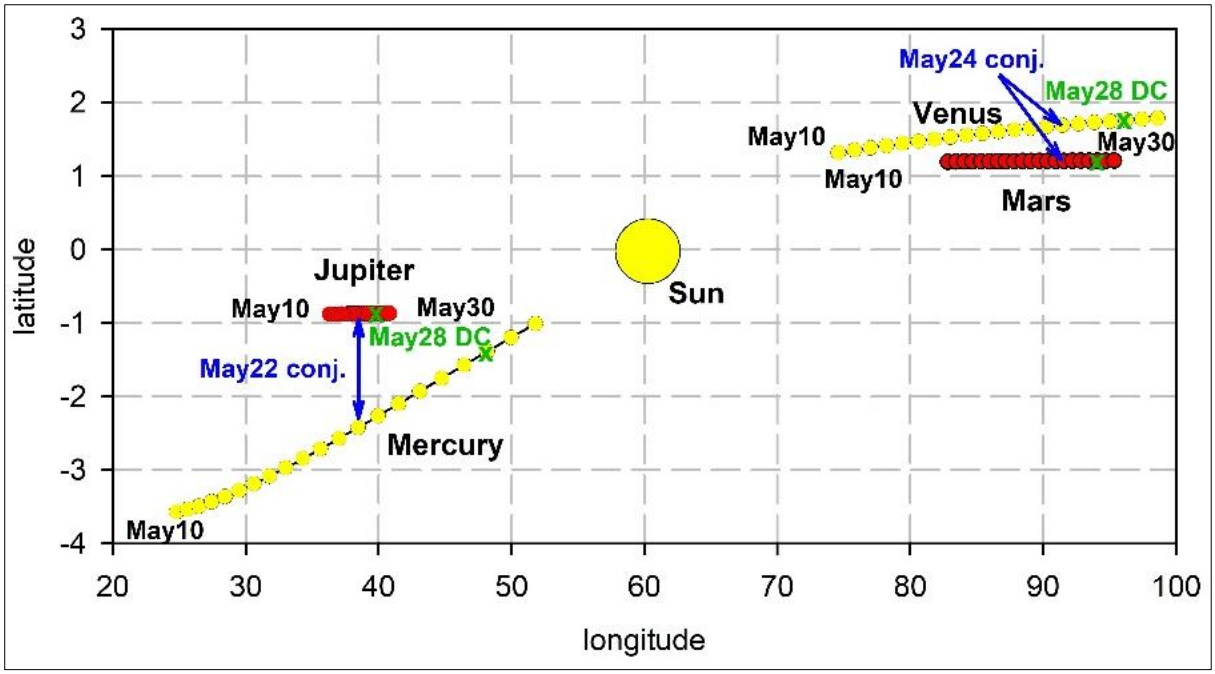

Figure 5: Conjunctions of Mercury–Jupiter and Venus–Mars in May 221.

around the DC date, in two coordinate systems: geocentric ecliptical and topocentric horizontal, calculated for the position of Palenque. The first one displays their motion with respect to stars (i.e., in the ecliptical reference system). In order to show the planetary motions more illustratively, the latitude scale is highly enhanced with respect to longitude. The second one represents the observer's view on the night sky, with the daily positions of each planet calculated for the moment of civil twilight (when the Sun was 6° below horizon). Azimuth *A* is reckoned clockwise from the South, and altitude *h* also accommodates atmospheric refraction.

Two conjunctions appeared around Maya date B1 (28 May 221). On two very close dates conjunctions of Mercury with Jupiter (22 May) and Venus with Mars (24 May) were readily visible from Palenque, with the elongation from the Sun equal to −21° and 30°, respectively. The situation is shown in Figure 5, where the motion of all four planets in ecliptical coordinates is demonstrated. The Sun, which is also depicted, lies approximately in the middle, between the two planets. This means that both conjunctions could not have been seen at the same time of the day and in the same part of the sky. Mercury and Jupiter were visible in the morning before sunrise, above the Eastern horizon, and Venus and Mars in the evening, after sunset, above the Western horizon.

A more instructive diagram of the visibility is shown in Figure 6, which is divided into two separate plots, Mercury and Jupiter in the morning on the right, and Venus and Mars in the evening on the left. Evidently, a better visibility (higher above horizon) was achieved for Venus and Mars than for Mercury and Jupiter.

The corresponding date for the GMT correlation is 6 June 117. As can be seen from Table 2, no astronomical phenomenon occurred close to that date.

A very complex situation occurred around the Maya date B7 (22 December 844). There was a conjunction of Venus and Saturn on 18 December and a quasi-conjunction of Mercury and Mars on 20 December. These were accompanied by the greatest elongation of Mercury on 18 December. Both conjunctions were readily visible after sunset above the Western horizon, with elongations from the Sun of 37° and 21°, respectively. The motion in ecliptical coordinates of all four planets involved in these two conjunctions is shown in Figure 7.

We also demonstrate, in Figure 8, the visibility of all four planets at Palenque, in horizontal coordinates. From the figure we can see that the conjunction of Venus and Saturn occurred much higher in the sky than that of Mercury and Mars. The greatest elongation of Mercury is also evident. In contrast, the close vicinity of the date 30 December 740, which corresponds to GMT correlation (see Table 2), has no astronomical phenomena.

Two conjunctions of Venus and Mars occurred in 1062. The first was on 11 July, and the second on 22 September (just before Venus ceased to be visible). They were accompanied by the greatest elongation of Mercury on 8 Aug-

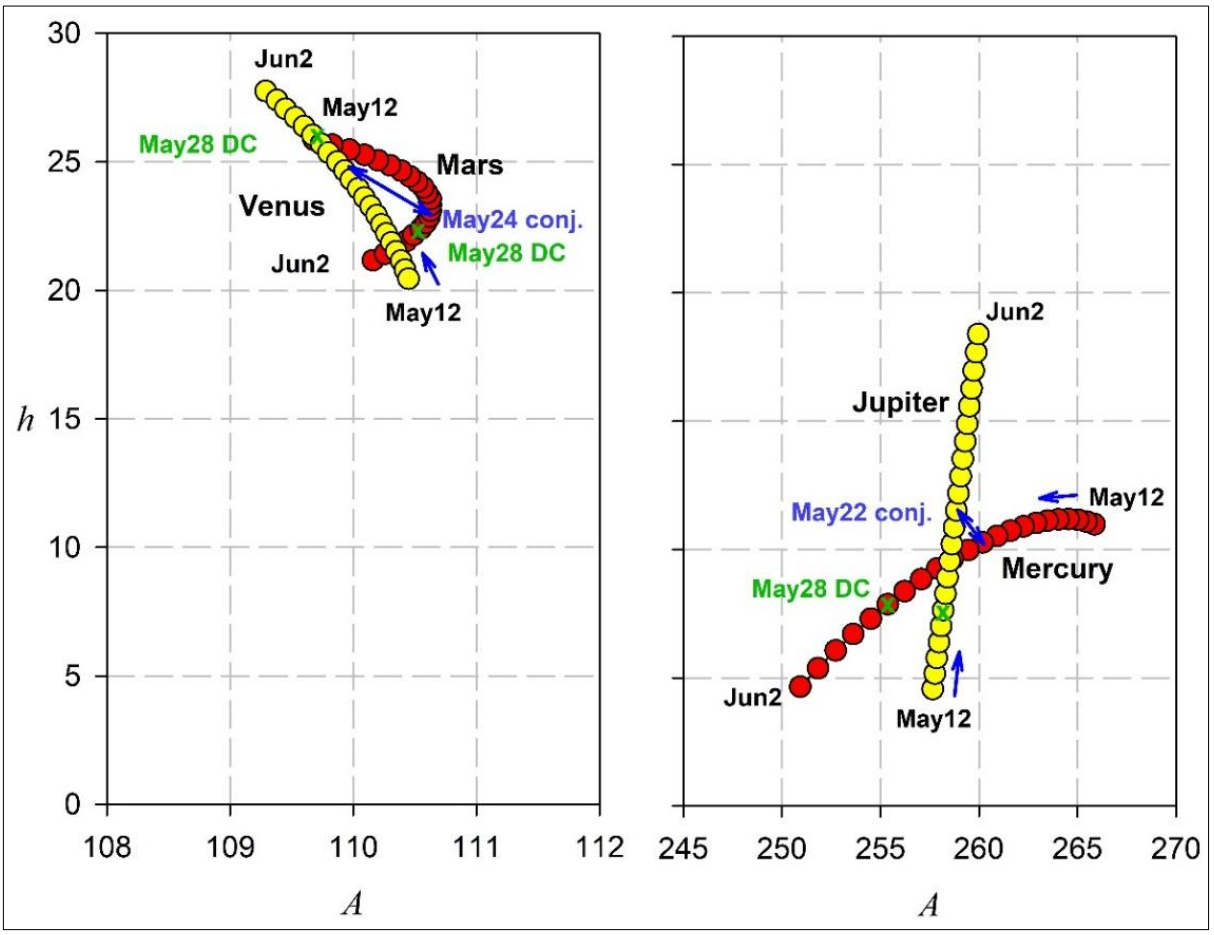

Figure 6: Visibility of conjunctions Mercury–Jupiter and Venus–Mars in May 221 at Palenque.

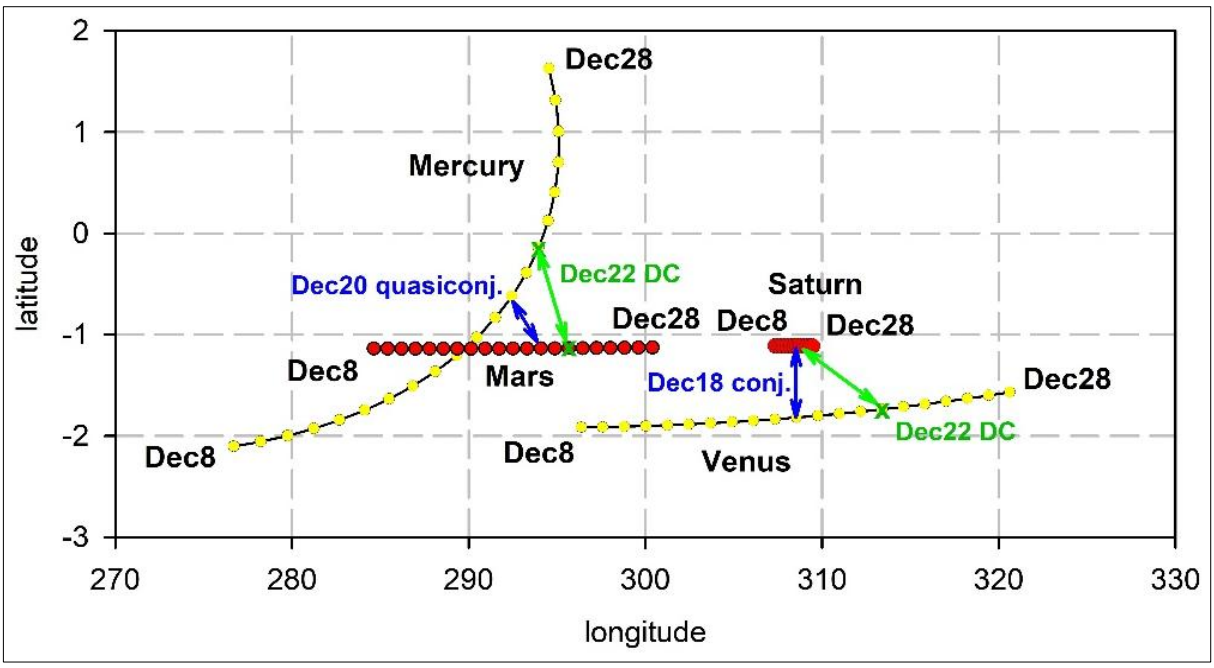

Figure 7: Conjunction of Venus–Saturn and quasi-conjunction of Mercury–Mars in December 844.

ust. The motion of Venus, Mars and Mercury in ecliptical coordinates is depicted in Figure 9. Venus and Mars were observable almost during the whole year, from February to September, Mercury only in July and August. Positions of all three planets at DC date M (19 August) are placed approximately in the middle between the two conjunction dates.

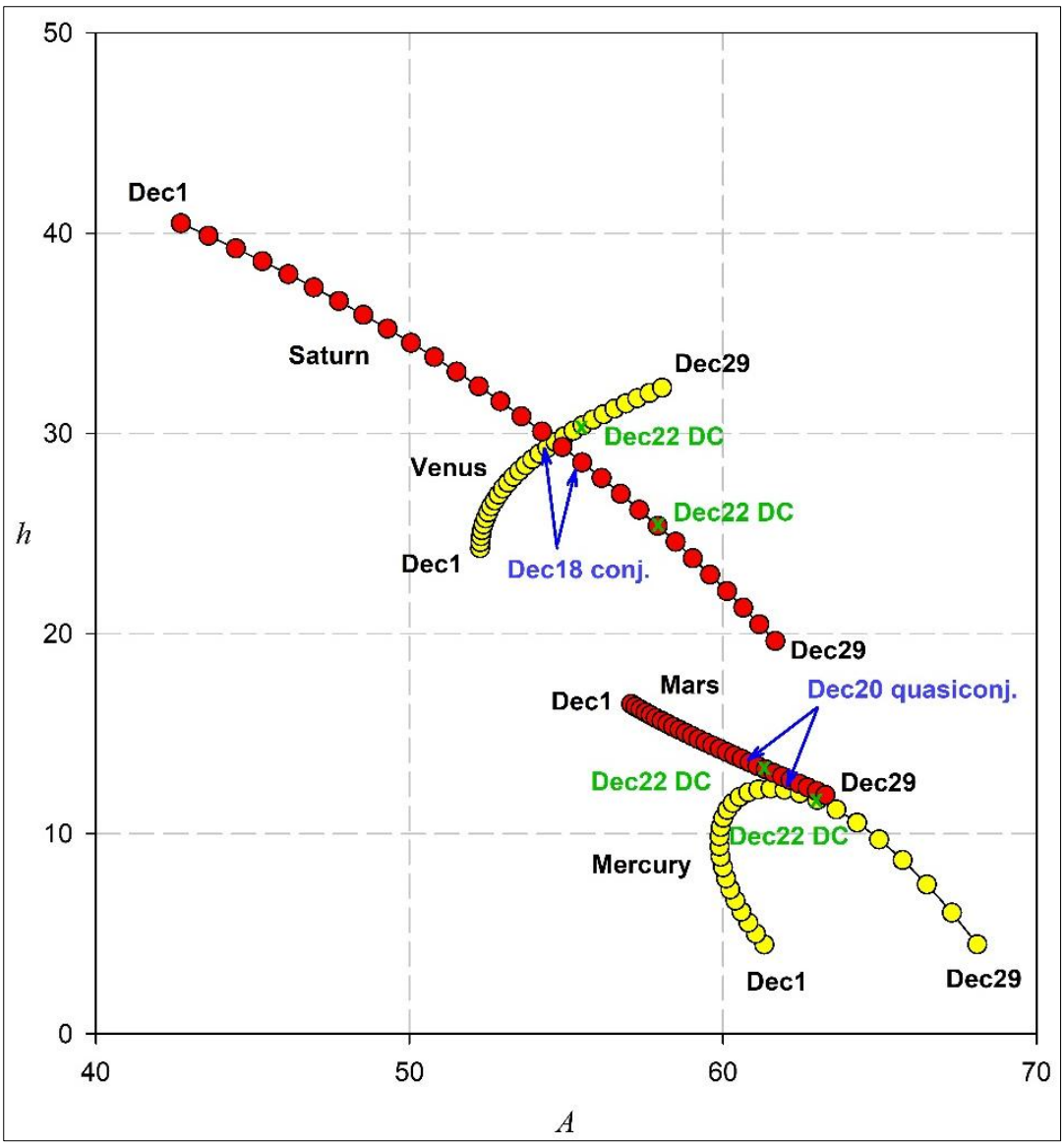

Figure 8: Visibility of conjunctions Venus–Saturn and Mercury–Mars in December 844 at Palenque.

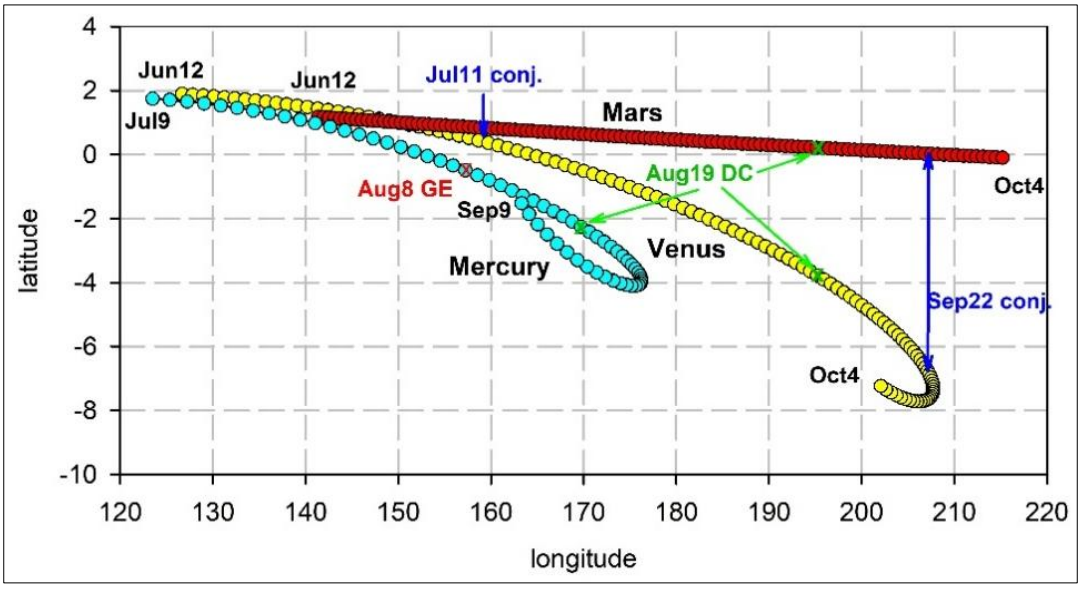

Figure 9: Two conjunctions of Venus–Mars and greatest elongation of Mercury in 1062.

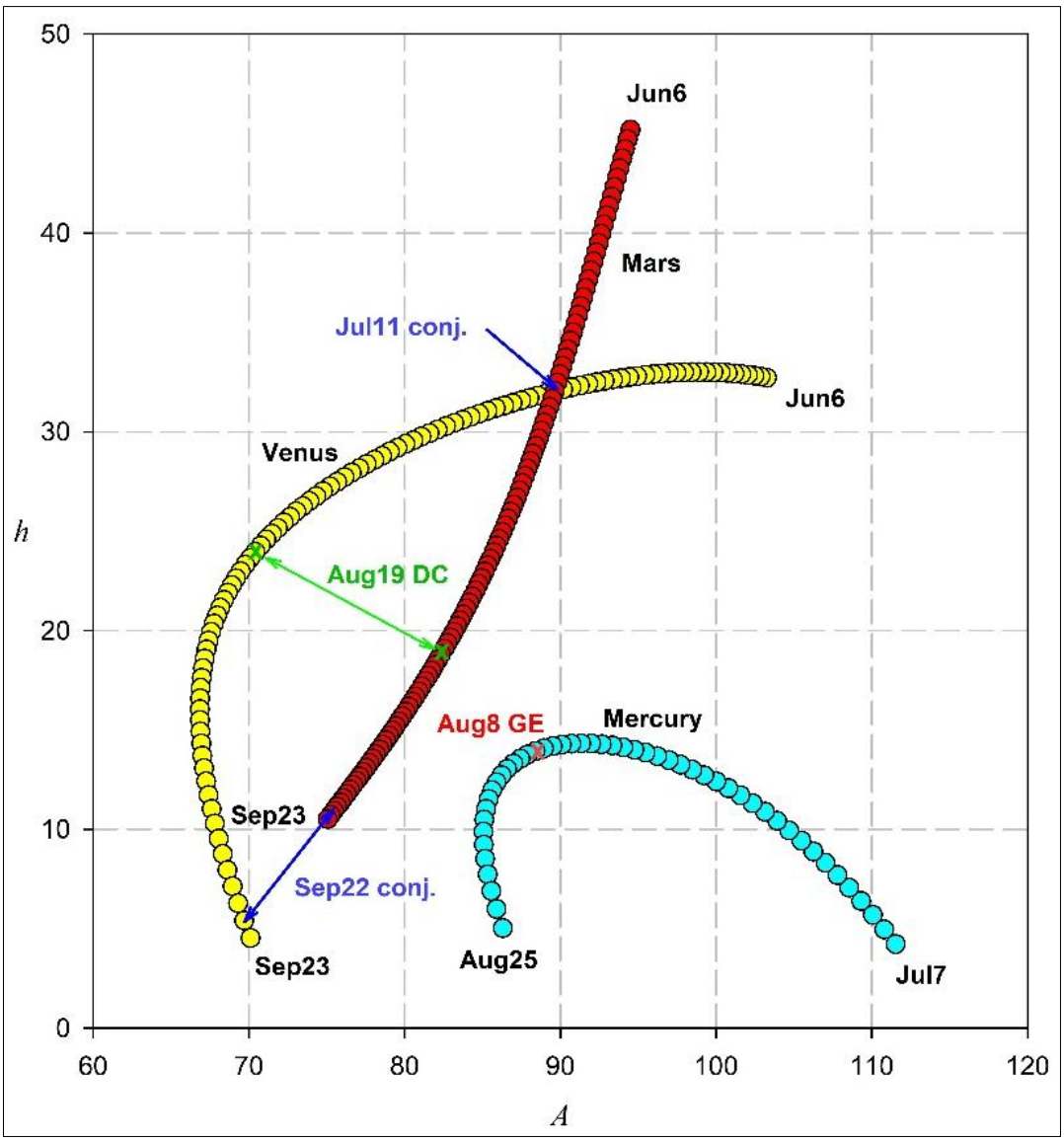

Figure 10: Visibility of Venus, Mars and Mercury in 1062 at Palenque.

Visibility of all three planets at Palenque after sunset, above the Western horizon, is demonstrated in Figure 10, where the greatest elongation of Mercury is also clearly seen. The corresponding GMT date is 27 August 95, and it offered only a greatest elongation of Mercury on 30 August, as shown in Table 2.

Close to the Maya date N (6 June 520) there were two conjunctions, of Mercury and Mars on 26 May and Venus and Jupiter on 2 June. They were accompanied by the greatest elongation of Mercury on 29 May. The situation in the ecliptical coordinate system is graphically displayed in Figure 11. Mars, Venus and Jupiter were moving almost in parallel, with Mercury intersecting their orbits.

Visibility of these planets at Palenque in horizontal coordinates is depicted in Figure 12, in which the greatest elongation of Mercury from the Sun is also evident. In contrast to these complex phenomena, 14 June 416 corresponded to the GMT correlation, but was accompanied only by a conjunction of Venus and Saturn on 18 June, as seen in Table 2.

4 DISCUSSION AND CONCLUDING REMARKS

On just four pages of the Dresden Codex we discovered 21 new records of dates, which we were able to identify, by using the BB correlation, with quite a number of different astronomical phenomena, and confirm that they were visible from Maya territory. They are conjunctions of all of the planets, and greatest elongations of Mercury and Venus from the Sun. On the other hand, we were not very successful in finding identifications when we used the GMT correlation: the closest phenomena that we did find fell rather far (typically two weeks or more, with only a few exceptions) from the DC dates.

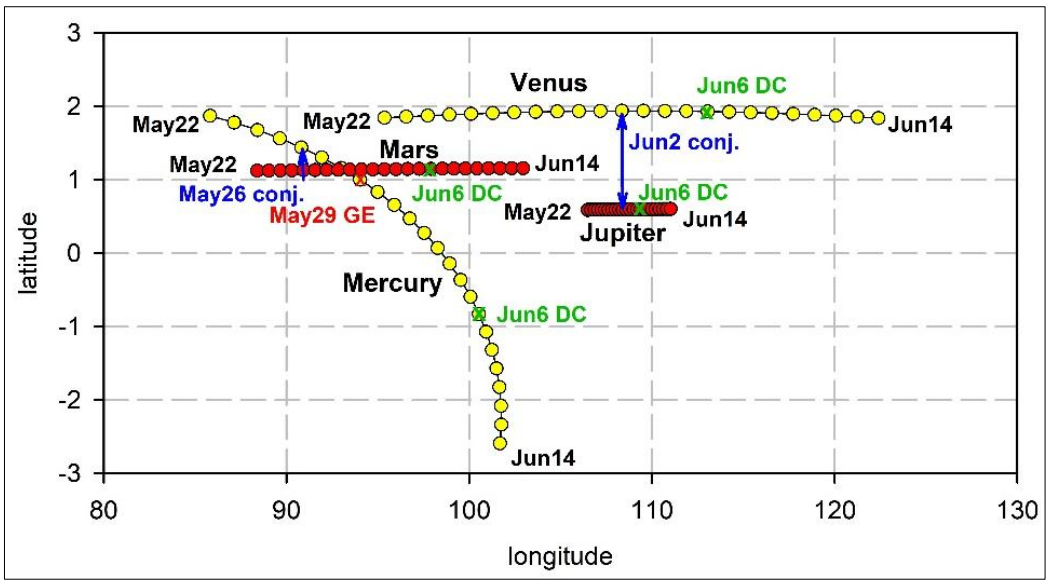

Figure 11: Conjunctions of Mercury with Mars and Venus with Jupiter, and greatest elongation of Mercury in 520.

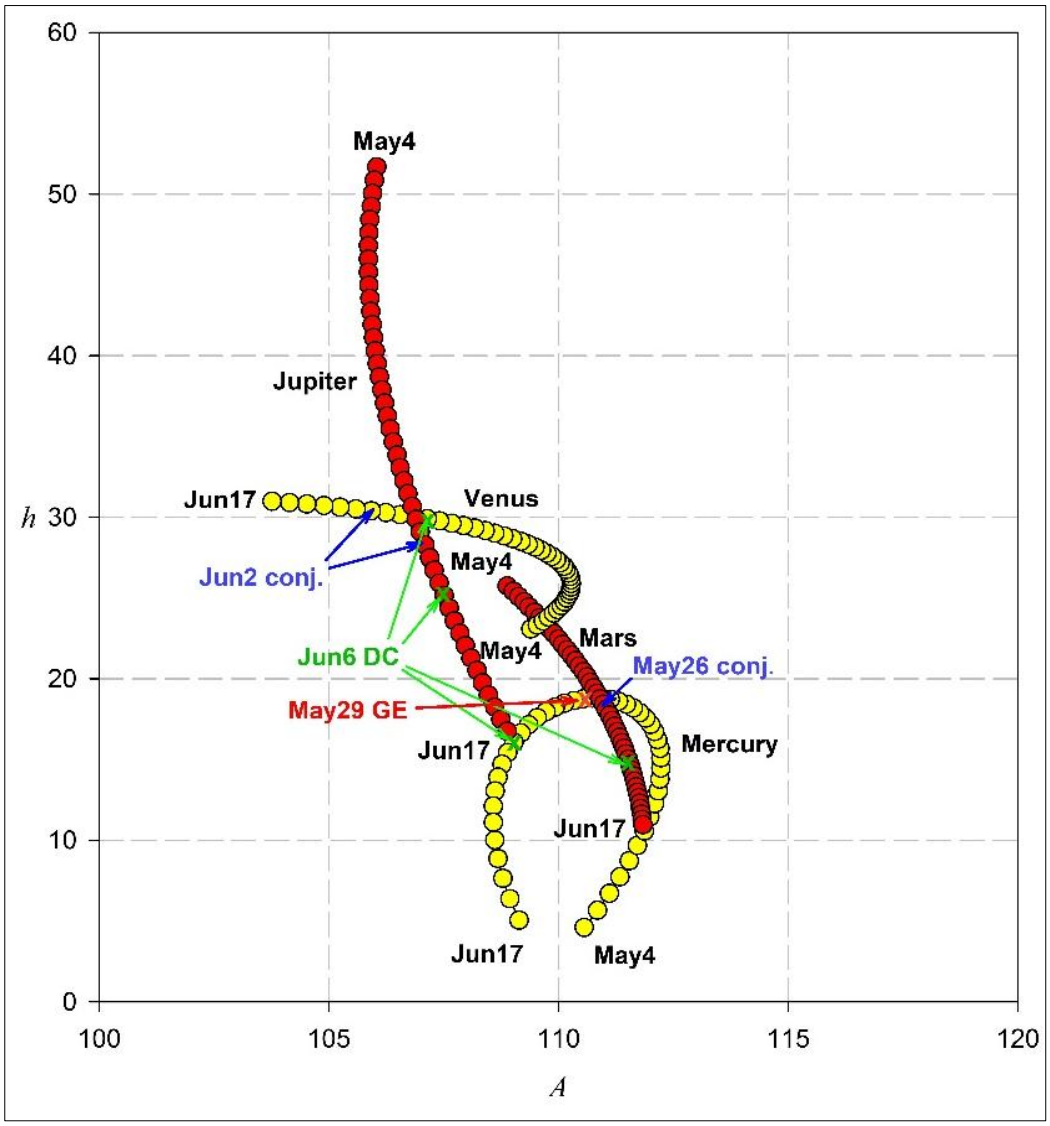

Figure 12: Visibility of Mercury, Mars, Venus, and Jupiter in 520 at Palenque.

Considering that all these observations were made only with the naked eye, the Maya records fit well the real appearance of the astronomical phenomena in question. Our admiration belongs to the Maya for their ability to observe different astronomical phenomena with high accuracy. Their records of these events that survived the Spanish invasion, help us discover their amazing skills in conducting systematic astronomical observations. There is no doubt that there still remain (in the Dresden Codex and inscribed on stelae and on the walls of Maya buildings) many thus-far undiscovered records of astronomical observations made by old Mayans.

The results of our present research confirm once again the validity of the BB correlation for the Classical Period of Maya civilization. We are convinced that the GMT correlation can only be used for events that post-date the Classical Period.

5 ACKNOWLEDGMENTS

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7 APPENDIX: CONVERSION BETWEEN THE CALENDAR ROUND AND THE LONG COUNT DATES

In Maya scripts, especially on stelae and walls of buildings, the dates are sometimes recorded not in the Long Count (LC), but as Calendar Round Dates (CRD), in cycles of *Tzolkin* and *Haab*. This means that two dates, each containing a number and a name in both cycles (e.g., 9 *Ahau*, 3 *Kankin*) are given.

Tzolkin contains twenty named days (*Imix*, Ik, *Akbal*, *Kan*, *Chikchan*, *Kimi*, *Manik*, *Lamat*, *Muluk*, *Ok*, *Chuwen*, *Eb*, *Ben*, *Ix*, *Men*, *Kib*, *Kaban*, *Etznab*, *Kawak*, *Ajaw*) and day numbers that go from 1 to 13. The days in this cycle start with 1 *Imix*, 2 *Ik*, 3 *Akbal* etc. up to 13 *Ben*, then the day numbers start again at 1 while the named-day sequence continues onwards. Thus, the combination of number/named day is unique in the whole 260-day cycle. The 365-day Haab consists of eighteen months (*Pop*, *Uo*, *Zip*, *Zotz*, *Tzec*, *Xul*, *Yaxkin*, *Mol*, *Chen*, *Yax*, *Zac*, *Ceh*, *Mac*, *Kankin*, *Muan*, *Pax*, K*ayab*, *Cumku*) of twenty days each plus five nameless days at the end of the year known as *Uayeb*. Each day of the cycle is identified by a day number in the month followed by the name of the month. The first day of the year was 0 *Pop*, followed by 1 *Pop*, 2 *Pop* as far as 19 *Pop*, then 0 *Uo*, 1 *Uo* and so on.

From this it follows that the same CRD repeats in periods 18980 days (the least common multiple of 260 and 365), which is called a Calendar Round. It is also known that the current period of the Long Count started on 4 Ahau 8 Cumku. For the dating of astronomical events, we need the date in the LC, so we must use an algorithm to convert the dates between these two systems. First of all, we need to calculate the order number of the day in both *Tzolkin* (n_T) and *Haab* (n_H).

For *Tzolkin* we construct a table of 260 rows and two columns. The left column contains 20 × 13 day numbers, and the right one 13 × 20 day names. Thus, in the n-th row of the left column will be the number equal to mod(n − 1, 13) + 1, and in the right column day name with order number mod(n − 1, 20). Then we go, step-by-step, through the table until we arrive at the given combination number/name of the day in *Tzolkin*. The order number n_T that we are looking for is then equal to the number of the corresponding row. It is not necessary to go through the whole table; it is sufficient to go only through the 20 rows that contain the given day number in the left column.

For *Haab*, the procedure is much simpler. If we denote as i_H the order number of the day in the given month, and as j_H the order number of the month, the order number of the given day in the cycle is $n_H = i_H + 20(j_H - 1) + 1$.

In the next step of the calculation of the LC we shall consider that the beginning of the cycle (date = 0) corresponds to the date 4 *Ahau* (order number in *Tzolkin* 160) 8 *Cumku* (order number in *Haab* 349). For the number of days n_{LC} must hold the equation $n_{LC} = n_T + 260m_T - 160 = n_H + 365m_H - 349$, in which m_T, m_H are integers (multiples of both cycles), which satisfy this equation. We find them by going through all combinations of their values in the interval 1 through 73 (for m_T) and 1 through 52 (for m_H), until we arrive at a solution to the equation. However, this yields only one of the multiple solutions of the equation. Remaining solutions are then given by adding multiples of 18980 days, out of which we select only the relevant ones, e.g., those occurring within the Classical Period of Maya civilization.

Dr. Jan Vondrák was born in 1940 at Písek (Czechoslovakia), graduated in geodesy in 1962 and obtained a CSc (equivalent to PhD) degree in geodetic astronomy from the Czech Technical University in Prague in 1973, and a DrSc from the Czech Academy of Sciences in 1985. He worked at the Geodetical Observatory Pecný from 1962 to 1977), and from 1977 at the Astronomical Institute of the Czech Academy of Sciences, initially as the Head of the Department of Dynamical Astronomy (1991–2000) and during 2000–2005 as Vice-Director for Foreign Relations.

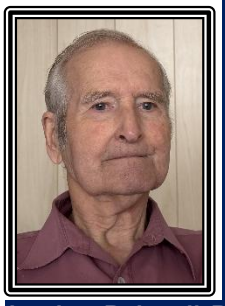
He was awarded the Ernst Mach Medal from the Czech Academy of Sciences for contributions in the physical sciences in 2003; the Nušl Prize from the Czech Astronomical Society for lifelong work in astronomy in 2007; and a Doctor Honoris causa from Paris Observatory in 2011. Since 2005 he has been an Emeritus Scientist of the Czech Academy of Sciences.

Jan's research interests lie in fundamental astronomy (astrometry, celestial mechanics, time, ephemerides), and he has mostly worked on the problems of the rotation of the Earth and geophysical effects in its variations. He became well-known for his method of numerical smoothing of observational data, published in 1969 and 1977, which relate to his most often cited papers (more than thousand citations).

He was also the first to derive and publish planetary effects in precession and nutation in 1982 and 1983. Between 1981 and 2026 he was the co-author of the Czech annual astronomical ephemeris book (*Hvězdářská Ročenka*) for which he computed fundamental ephemerides of Solar System bodies. In 1988–1997 Jan Chaired the IAU Working Group on Earth Rotation in the Hipparcos Reference Frame that prepared the reanalysis of worldwide astrometric observations of latitude and Universal time changes to derive Earth Orientation Parameters between 1897 and 1992. In total, he published more than 300 scientific papers.

Following his retirement in 2005 Jan became more and more involved, in cooperation with Böhm brothers, in studying Maya records of astronomical observations and their use in determining a correlation between Maya and our calendars.

Jan has been a member of the IAU since 1979, in which he was the President of Commission 19 Rotation of the Earth (1994–1997) and President of IAU Division I Fundamental Astronomy (2006–2009). He also served as the Chairman of the Directing Board of the International Earth Rotation and Reference Systems Service in 2000–2004. Domestically, Jan held the position of Chairman of the Czech National Committee for Astronomy (1998–2004) and Chairman of the Czech Astronomical Society (2010–2017). In 2008 asteroid No. 35356 was named 'Vondrak' by the IAU.



Vladimír Böhm was born at Žilina (Czechoslovakia) in 1938. He graduated from the University Hradec Králové in 1971 (History, Psychology, Russian), and from the Escuela International in Málaga in 2000 (Spanish), ending up with an MSc. He worked as a teacher of Russian and Psychology at the Integrated High School at Kolín, and, after 1989, Spanish and History at the Business High School at Kolín, until 2021 when he retired. In parallel to this, he lectured at the University of Political and Social Sciences at Kolín.

Already as a high school student, Vladimír was deeply interested in Spanish and the history of Mesoamerica. He started to study this by collecting information from the libraries in Prague, such as the Czech National Library and the library of Mexican Embassy. Later on, he studied Mexican literature downloaded from the internet.

This interest in the history of Mesoamerica led to a long collaboration with his elder brother Bohumil Böhm (a computer scientist), and they studied aspects of Maya history and culture, including the relation between the Maya and Western Calendars. Later on, they established a close collaboration with researchers at the Astronomical Institute of the Czech Academy of Sciences (Jaroslav Klokočník and Jan Vondrák) in studying the Maya calendar and astronomy, and together they published a range of scientific papers.