Babylonian Mathemagics: Two Mathematical Astronomical-Astrological Texts

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The two tablets published here combine aspects of mathematics, astronomy and astrology and so they were an obvious choice when we came to decide upon the subject of this article in honour of David Pingree. It is with the greatest of respect that we offer this small contribution towards the study of the astral sciences to a scholar who has done so much to elucidate their history throughout ancient and medieval Europe and Asia.

BM 96258 and BM 96293 were brought to our attention by Christopher Walker during a visit to the British Museum in September 2000. He kindly supplied a preliminary transliteration from which we were able to identify the numerical scheme contained on the tablets. We thank the Trustees of the British Museum for granting permission to publish the tablets.

1 *The texts*

BM 96258 (1902-4-12, 370) and BM 96293 (1902-4-12, 405) come from a purchased collection which contains a substantial number of Neo-Babylonian tablets from Babylon and (predominantly) Borsippa covering the time range from Nebuchadnezzar to Artaxerxes.[1] The tablets are similar in shape and size; when complete each tablet would have been about 4 cm wide by 7 cm high.

The two tablets were almost certainly written by the same scribe, as is evident from the fact that he writes the number nine using both the old (9 vertical wedges) and new (3 slanting wedges) forms, the use of light vertical guide lines for each column of numbers, the horizontal rulings after each 5 lines, and the general similarity of script and style. From their contents (see

[1] C. B. F. Walker, private communication.

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below), it is likely that these were the first two tablets in a series of twelve.

BM 96258 (1902-4-12, 370)
Size: 4 × 4.5 cm.
Top, left and right edges are preserved.

Obverse:

	I	II	III	IV
#1	10	7	⌜1⌝	[1]
#2	7	14	1	2
#3	4	21	1	⌜3⌝
#4	1	28	1	⌜4⌝
#5	11	5	1	⌜5⌝
#6	8	12	1	6
#7	5	19	1	7
#8	2	29	1	8
#9	12	3	1	9
#10	[9]	[10]	[1]	⌜10⌝

Reverse:

	I	II	III	IV
#1′	[12]	⌜4⌝	⌜1⌝	22
#2′	9	11	[1]	⌜23⌝
#3′	6	⌜18⌝	[1]	⌜24⌝
#4′	⌜3⌝	25	[1]	[25]
#5′	⌜1⌝	⌜2⌝	⌜1⌝	[26]
#6′	⌜10⌝	[9]	⌜1⌝	[27]
#7′	7	⌜16⌝	[1]	[28]
#8′	4	[23]	[1]	[29]
#9′	1	[30]	[1]	[30]

Critical Apparatus:

Obv. 7: 19 written with new style 9.
Obv. 8: 29 written with new style 9. Error for 26.
Obv. 9: 9 written old style.
Rev. 2′: 9 written old style.

BM 96293 (1902-4-12, 405)
Size: 4 x 5.25 cm.
Bottom, left and right edges are preserved.

Obverse:

	I	II	III	IV
#1′	3	26	⌜2⌝	[8]
#2′	1	3	2	[9]
#3′	10	10	2	⌜10⌝
#4′	⌜7⌝	17	2	11
#5′	4	⌜24⌝	2	12
#6′	[1]	1	2	13
#7′	[11]	⌜8⌝	2	14
#8′	[8]	⌜15⌝	2	15

Reverse:

	I	II	III	IV
#1	5	22	2	⌜16⌝
#2	2	29	2	⌜17⌝
#3	12	6	2	18
#4	9	13	2	19
#5	6	20	2	⌜20⌝
#6	3	27	[2]	21
#7	1	4	[2]	⌜22⌝
#8	10	11	[2]	23
#9	7	18	2	24
#10	4	⌜25⌝	⌜2⌝	[25]

Critical Apparatus:
Rev. 2: 29 written with old style 9.
Rev. 4: 9 written new style, 19 written with new style 9.

2 *Commentary*

Both tablets are divided into 4 columns. Column I contains numbers between 1 and 12, and column II numbers between 1 and 30. Normally, column I decreases line by line by 3 (mod. 12), and column II increases by 7 (mod. 30). However, if the increase in column II would take the value beyond 30, then the number in column I is only reduced by 2. This implies that columns I and II are linked such that 30 units of column II are equal to one unit of column I. For simplicity, let us call column I 'signs' since there are twelve of them and column II 'degrees' since there are thirty. Moving on one line, therefore, we move back three signs and forward seven degrees (i.e., -83°), or alternatively we move forward nine signs and seven degrees (i.e., +277°), since $-83 \equiv 277$ (mod. 360). Column III contains a constant number: 1 on BM 96258, 2 on BM 96293. Finally column IV contains a number that increases line by line by 1 from 1 to 30. Once again, for convenience we can call column III 'signs' and column IV 'degrees'. The question of whether these actually represent signs and degrees will be discussed below. Mathematically we can formulate this scheme as follows: If we have in columns III and IV a number n degrees within sign s, then the associated position in columns I and II is equal to $277n$ from the beginning of the same sign s.

The mathematical scheme presented on BM 96258 and BM 96293 is identical to that found on a group of texts called by Weidner '*Kalendertexte*'.[2] These texts associate entries from a numerical *Kalendertext* scheme with trees, stones, animal parts and various other items probably used in rituals. Six *Kalendertexte* have previously been published:[3]

VAT 7816 and VAT 7815, both from Uruk, were edited in [Weidner *GDBT*, 41-49], with an explanation of the numerical scheme by van der Waerden on pp. 50-52. VAT 7815 was owned

[2] [Weidner *GDBT*, 41].

[3] In addition to the published *Kalendertexte*, we can add the unpublished tablet W.20030/133, a *Kalendertext* for month V cited by [Hunger 'Kalendertext', 43], and a small fragment in the British Museum, BM 36995, edited below, which contains *Kalendertexte* for months II and VIII:

by Anu-Belšunu and written by his son, Anu-abi-utterri,[4] on the 14th of Month X, year 120. The colophon of VAT 7816 is mostly broken away, but it is quite possible that both tablets were part of the same archive. Beside each numerical entry in the texts are two or three lines which give the name of a tree, a plant, a stone, a place name, and some prescribed action. After the 30th entry in the *Kalendertext* scheme, VAT 7816, Rev. 17′ begins LAL 1 TA UD-1-KAM EN UD-30-KAM... 'Subtract (?) 1. From the 1st day to the 30th day...' Similarly VAT 7815, Rev. 9′ begins ⌜LAL⌝ [...][5] TA UD-1-KAM EN UD-30-KAM. On these two texts, therefore, we should understand the fourth number in an entry as a day number, and so presumably the third number as the month. It is not immediately clear whether we should read the first two numbers in an entry as month and day as well.

LBAT 1586+1587,[6] from Babylon, is a *Kalendertext* for the first 15 days of Month III. This is clear from Rev. 11 which reads *šal-šú* [*ár*]-*ḫu* 'third month'. Once more, there is no indication of whether we should also read the first two numbers in an entry as month and day. Accompanying each numerical entry in the *Kalendertext* scheme there is often a statement that the moon is 'in' (*ina*) a star or constellation, a statement concerning the star MÚL.SIPA, and various names. In his edition of the text, Hunger remarked that the first of these was 'astronomische Angaben über die Stellung des Mondes in verschiedenen Sternbildern'.[7] Not all

Obv.

[...] x	ŠID?	BE x	[...]
11	7	2	1
⌜8⌝	14	2	⌜2⌝
[5]	21	2	⌜3⌝
[2	2]8	2	[4]

Rev.

[7	3]	8	[9]
[4]	⌜10⌝	8	10
[1]	17	8	1[1]
[10]	24	8	1⌜2⌝
[8]	1	⌜8⌝	[13]

[4] Both Anu-Belšunu and Anu-abi-utterri are well known from astronomical and other texts. See [Steele 'A3405', 131].

[5] [Weidner *GDBT*, 46] restores [30] here. Why?

[6] [Hunger 'Kalendertext'].

[7] [Hunger 'Kalendertext', 41].

of the entries are preserved. From what does remain, however, we can see that these cannot represent the (approximate) position of the moon on days during the month. Instead, the stars and constellations relate to the zodiacal signs given by the *Kalendertext* scheme. This is made clear by the following table:[8]

Kalendertext entry	*Sin ina...*	Identification	Zodiacal sign
4 26 3 8	M[Ú]L.NAGAR	Cancer	Cancer
2 3 3 9	[*is l*]*e-e*	α Tau + Hyades	Taurus
11 10 3 10	MÚL.GU.LA	Aquarius	Aquarius
5 24 3 12	MÚL.GU.LA	Aquarius	Aquarius
3 1 3 13	MÚL.MAŠ	Gemini	Gemini
12 8 3 14	MÚL.SÌM.MAḪ	Western fish of Pisc. with some of the W. part of Pegasus	Pisces
9 15 3 15	MÚL.PA	Sagittarius	Sagittarius

For example, on days 13, 14 and 15, the moon is said to be in Gemini, Pisces and Sagittarius respectively. Astronomically this makes no sense since the moon moves approximately 13 degrees per day. As a consequence, many of the lunar positions are impossible. For instance on day 13 of month 3, the moon is said to be in sign 3. This might have been the case on day 1 where the moon was near the sun (which in month 3 approximately will be in sign 3). On day 13 (shortly before opposition), however, the moon must be near sign 8 or 9. It can never be in sign 3 on day 13 of month 3. Thus we must conclude that what is written here is astronomically impossible.

However, if we compare the zodiacal signs with the first number of the *Kalendertext* scheme, we find that in all but one case they agree. The exception is for day 12 where we should have Leo instead of Aquarius, but since Leo may be written as MÚL.UR.GU.LA, it is not hard to imagine that this is just a simple scribal error. The entry for day 11 is damaged. Hunger read MÚL.PA? (Sagittarius?) and indeed this looks quite possible from the copy in *LBAT*. However, if we are correct to link

[8] The identifications of stars and constellations are generally taken from [Reiner & Pingree *BPO 2*].

these stars and constellations with the entries in the *Kalendertext* scheme, we would expect Scorpio.

We do not know whether to read the statement concerning MÚL.SIPA as part of the clause refering to the moon, or as a separate statment. MÚL.SIPA is generally used as the name for Orion, although it is also a name for Saturn.[9] We might possibly translate entries such as that for day fourteen: *Sin ina* MÚL.SIM.MAḪ KI MÚL.SIPA GUB as 'The moon (which was) in Pisces stood with Orion/Saturn', but this is by no means certain. Nevertheless, it does seem clear that this text is associating the moon with its position according to the *Kalendertext* scheme, rather than even approximating its actual motion.

W.20030/127,[10] from Uruk, gives no indication as to whether we should interpret the numbers as months and days or signs and degrees. The 'month' number is 2.

W.22704 and W.22619/6+22554/2b,[11] from Uruk, are *Kalendertexte* for Months IV and VIII respectively. The colophons to both texts indicate that they belonged to Iqīša, who lived around the end of the 4th century BC. In contrast to all of the above texts, however, month names and the names of the zodiacal signs replace some of the numbers in the *Kalendertext* scheme. Furthermore, the order of the entries in the scheme is different on these two texts. First we have a month name (or the repetition sign MIN after line 1) and the day number from 1 to 30, and then a sign of the zodiac and what we must interpret as the degrees within that sign. These are not always the normal signs of the zodiac, however.[12] For example, BAR[13] (Month I) is used in both texts for the sign Aries, and ŠU (Month IV) is used for Cancer as well as the month name. In the first line of W.22704, NE (Month V) is used for Leo, although UR.A is used consistently elsewhere. Nevertheless, it is likely that the zodiacal signs, and not the months, were meant since the associated text for each entry lists ingredients that are usually linked to the corresponding zodiacal sign.[14] For example, when the sign is Cancer, these are

[9] [Hunger 'Kalendertext', 42].
[10] [van Dijk *Texte*, no. 79].
[11] [von Weiher *SpTU*, nos. 104–5].
[12] [Reiner *Astral Magic*, 115].
[13] BAR, not MAŠ as read by von Weiher.
[14] [Reiner *Astral Magic*, 116–17]. Interestingly, these associations can only

the blood and fat of a crab.

From these texts, therefore, it seems most likely that we should understand the *Kalendertext* scheme as relating a position in the ecliptic to a date in the year. However, since the months in the *Kalendertext* are always 30 days long, we are not dealing here with real calendar years, but instead the schematic or 'ideal' calendar of twelve 30-day months. This schematic calendar probably has its origins in the administrative calendar of the Uruk III period or earlier,[15] and was used in texts such as MUL.APIN. Traces of it are still evident in the mathematical astronomical texts of the Late Babylonian period with the use of 1/30 of a synodic month as a unit.[16] This schematic calendar also, of course, provided the means by which the ecliptic could be divided up. Just as the schematic year had 12 months, so there were twelve signs of the zodiac. Likewise, the division of each zodiacal sign into 30 degrees mirrored the 30 days of a month. Furthermore, in a schematic year of 360 days, the sun makes one full revolution of the zodiac, and so, assuming simple mean motion, 1 day corresponds to 1° of solar longitude. Thus a date in the schematic calendar corresponds directly to a position in the zodiac. No doubt this was the justification for the substitution of month names for some of the zodiacal signs in W.22704 and W.22619/6+22554/2b. Thus the *Kalendertext* scheme can equally be seen as relating a day in the year to a position in the ecliptic (or vice versa), a day to another day, or a position to another position. Most probably it was used in all of these ways by the Babylonian scribes.

Further evidence for the equivalence between the schematic year and the ecliptic is provided by BM 47851.[17] This text lists side by side the *Kalendertext* scheme and a similar scheme known as the *Dodekatemoria*. This latter scheme is similar to the *Kalendertext* scheme except that one moves on 13 instead of 277 each line. Instead of zodiacal signs, this text always gives the names of the months.

There is undoubtedly a close relationship between the *Kalen-*

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be understood in terms of the classical zodiac.

[15] Described in [Englund 'Administrative Timekeeping'].

[16] Conventionally called a *tithi* after the analogous unit in Indian astronomy. In cuneiform it was simply written with the sign UD meaning 'day'.

[17] [Hunger 'Zahlenschema'].

dertext and the *Dodekatemoria*. Their mathematical similarities will be discussed below, but first we can note that they seem to have had similar astrological uses. The unpublished tablet BM 36326 contains numbers from the *Dodekatemoria* scheme written in the same format as many of the *Kalendertexte*; i.e., four columns of numbers which we can interpret as sign-degree-month-day. The 'month' number is 1. Before each numerical entry is the name of one of the five planets. As in the two texts published here there is a ruling after every fifth line, and each planet is named once within each group of five. The order of the planets varies between the five groups, but we are unable to see any patern in the ordering. The tablet is broken away to the right of the *Dodekatemoria* numbers, but the other side of the tablet contains, *inter alia*, the names of various cities, so it seems that the text was probably similar to the *Kalendertexte*.

The text Clay, *BRM IV*, no. 19 associates incantations with positions in the ecliptic.[18] For each position the related *Dodekatemoria* position is also given. By associating one position on the ecliptic with another, one immediately doubles the amount of material that can be interpreted astrologically.

A pictoral representation of the *Dodekatemoria* is found on the tablets VAT 7847 and AO 6448.[19] The zodiacal sign Leo is divided into 12 micro signs, starting at (0°) with Leo and ending at (30°) with Cancer. Similarly, under sign Virgo, depicted on the reverse side of the same tablet, the 12 micro signs Virgo up to Libra are drawn. It is interesting to note that Leo is drawn standing on the back of a long snake (both looking toward left), the tail of which continues on the reverse of the tablet. After the tail of the snake (= Hydra), Virgo is drawn, looking toward the left, in direction of Hydra and Leo. This representation on a Babylonian tablet is very peculiar. In the zodiac, Virgo comes correctly after Leo, but the direction of the consecutive signs as seen from the earth is from right to left, and not the opposite way around as on these pictures. When the stars are drawn on the outside of a sphere, representing the celestial sphere, then the figures of the stellar constellations are mirror pictures of the

[18] [Ungnad 'Besprechungskunst']; [Koch-Westenholz *Mesopotamian Astrology*, 169–70].

[19] [Weidner *GDBT*].

constellations as seen on the sky from below (this might explain the name 'mirror' of Eudoxos's first book on the stars and constellations). The Babylonian drawings mentioned here are similarly mirror pictures of what one can see. This might testify to another example of Greek reimport into Babylonian astronomy such as the one claimed by Rawlins.[20]

Ungnad suggested that the *Dodekatemoria* was a crude scheme for lunar motion.[21] If the sun moves forward one degree per day, then after 30 days, it will have moved on by precisely one sign. After 30 days, however, the *Dodekatemoria* has moved on by 390 degrees, or one complete revolution plus one sign. Thus the sun and moon will once again be in the same relationship. Neugebauer-Sachs criticised this explanation, arguing that 'the simplification of the solar and lunar motion is such that already one year would suffice to make predictions based on this scheme completely wrong. Furthermore, it would be hard to understand why a scheme of this type... would have been followed during the Seleucid period, when a detailed insight into the lunar motion (was known).'[22] To our minds, dismissing the lunar origin of this scheme on the grounds that it is too crude is wrong. Most likely it did start out as a simple lunar scheme, but one which was meant to be astrologically convenient rather than astronomically accurate. Perhaps at some stage in its use the scheme came to be applied to other heavenly bodies as well. This was how the *Dodekatemoria* was utilised after being assimilated into Hellenistic astrology.[23]

The second section of the late astrological text LBAT 1593 also refers to the *Dodekatemoria* and *Kalendertext* schemes.[24] In Obv. 18′ we read 'the animal(s) (*umāmu*) of 13 and 4,37 you take one with the other, you salve, feed, and fumigate the patient with the stone, herb, and wood (respectively)',[25] which must surely be

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20 [Rawlins 'Hipparchos'].

21 [Ungnad 'Besprechungskunst'].

22 [Neugebauer & Sachs 'Dodekatemoria'].

23 [Bouché-Leclercq *L'Astrologie grecque*, 300–305.].

24 [Reiner 'Early Zodialogia'].

25 Translation of [Reiner 'Early Zodialogia', 424]. On p. 427 she 'put[s] forward the strange and surprising notion... that these *umāmu* "animals" are to be connected with the *zōa* that make up the Greek zodiac'. This notion is in fact not so strange. In W.22704 above we have seen that the ointment pertaining to a particular day is produced by means of ingredients from

a reference to the ingredients used in the preparation of medicine or other ointments used in ritual practice.[26] Indeed, it is tempting to interpret the beginning of the Obv. 19′, *bi-ib-lu šá* BAR TA 1 EN 30 'Almanac/handbook of Month I from (day) 1 to (day) 30', as referring to *Kalendertext* and *Dodekatemoria* texts such as the examples described above. The 'animals of 13' and 'animals of 4,37' are also mentioned in a similar context in Obv. 15′–17′, and in Obv. 15′ we find the numbers 1,1,1,13 (the tablet apparently reads 1,2,13, but this must surely be a simple scribal error) and 1,2,1,26. If we interpret these numbers as month-day-sign-degree, we have the first two entries from the *Dodekatemoria*.

The two texts published here differ from all of the *Kalendertexte* described above in that there is no text to accompany the mathematical scheme. Possibly the texts functioned as a template for the scribe when he was making a *Kalendertext*, or as an *aide-mémoire*; the shape of the tablets might even indicate that they were a scribal exercise, which would have interesting consequences for how we understand the role of astronomy and astrology in scribal education.[27] In any case, it seems practically certain that these two tablets were part of a series of twelve which covered each month in the schematic calendar.

Although we must be wary of dating the two tablets on the basis of other material in the same collection (especially since this collection was acquired by purchase), it is nevertheless interesting to note that a date of 5th century BC or before is significantly earlier than the other known *Kalendertexte*. Indeed, such a date would place the development of the *Kalendertext* scheme very soon after the first attested use of the zodiac.

3 *The mathematical structure of the* Kalendertext *scheme*

As mentioned above, the numerical schemes we are concerned with can be interpreted and used in different ways: as a date

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the animal whose zodiac sign is connected to that day by the Kalendertext scheme.

[26] We remind the reader that 13 is the number of degrees from day to day in the *Dodekatemoria* scheme, and $4,37 = 277$ is the daily change in position in the *Kalendertext* scheme.

[27] For a scribal exercise containing parts of *Enūma Anu Enlil*, see [Mauer 'Ein Schülerexcerpt'].

(month, day) associated with a date (month, day), as a date (month, day) associated with a position in the zodiac (sign, degree), as a position associated with a position, or finally as a position associated with a date. We shall now investigate the *Kalendertext* scheme more closely, and for this purpose we will first consider a concrete example, namely the version where positions are associated to dates.[28]

month	day	zodiacal sign	degree
I	1	10 = ♑	7
I	2	7 = ♎	14
I	3	4 = ♋	21
I	4	1 =	28
I	5	11 = ♒	5
I	6	8 = ♏	12
I	7	5 = ♌	19
I	8	2 = ♉	26
I	9	12 = ♓	3
I	10	9 = ♐	10
I	11	6 = ♍	17
I	12	3 = ♊	24
I	13	1 =	1
I	14	10 = ♑	8
I	15	7 = ♎	15
I	16	4 = ♋	22
I	17	1 =	29
I	18	11 = ♒	6
I	19	8 = ♏	13
I	20	5 = ♌	20
I	21	2 = ♉	27
I	22	12 = ♓	4
I	23	9 = ♐	11
I	24	6 = ♍	18
I	25	3 = ♊	25
I	26	1 =	2
I	27	10 = ♑	9
I	28	7 = ♎	16
I	29	4 = ♋	23
I	30	1 =	30
II	1	11 = ♒	7

Table 1: The *Kalendertext* scheme for month I.

[28] The well preserved tablets W.22704 and W.22619/6+22554/2b are examples of this type of *Kalendertext*.

For our example we have chosen month I. The basic structure is the same for all months and thus what follows also applies to the other months as well. Because of the ideal mean motion of the sun, there is an obvious connection between month M and sign M. This is shown by the substitution of the name of month M for sign M in some texts. We will therefore call sign M the 'special sign' of month M.

We remind the reader how the *Kalendertext* scheme is constructed: from one line to the next, the position in the zodiac is shifted by 277 degrees (which equals -83 degrees (modulo $360°$)). The rule is then: go 9 zodiacal signs and 7 degrees forward or go 3 signs back and 7 degrees forward, applying the appropriate correction in the case where the degrees become larger than 30. Once the starting point is known the whole scheme is uniquely determined.

Day 1 of month I is associated with ♉ 7 degrees. We would however rather see month XII, day 30 $\rightleftharpoons$ (associated with) the thirtieth degree of sign 12, ♓ 30 degrees, as the starting point of month I, and similarly for the other months. The last day of a month equals day zero of the next month, and degree 30 of a sign can be seen as degree 0 of the next sign:

So we would see	month I, day 0 $\rightleftharpoons$	0 degrees
written as	month XII, day 30 $\rightleftharpoons$	♓ 30 degrees

as the starting point of our scheme, which is reproduced in Table 1. Similarly, the last (30th) day of month I is associated with the thirtieth degree of sign 1, ( ) 30 degrees, which is then the starting point of the scheme for month II. The scheme for month II will therefore for each day associate the same number of degrees within a sign as for month I, and the sign number will simply be larger by one in each case (i.e., representing the following sign).

I	II	III	IV	V	VI
(1	2	3	4	5	6
10	**11**	**12**	**1**	**2**	**3**
7	**8**	**9**	**10**	**11**	12
4	**5**	**6**	**7**	**8**	9
1	**2**	**3**	**4**	**5**	6
11	**12**	**1**	**2**	**3**	4
8	**9**	**10**	**11**	**12**	1
5	**6**	**7**	**8**	**9**	10
2	**3**	**4**	**5**	**6**	7
12	**1**	**2**	**3**	**4**	5
9	**10**	**11**	**12**	**1**	2
6	**7**	**8**	**9**	**10**	11
3	**4**	**5**	**6**	**7**	8
1	**2**	**3**	**4**	**5**	6
10	**11**	**12**	**1**	**2**	3
7	**8**	**9**	**10**	**11**	12
4	**5**	6	**7**	**8**	9
1	**2**	3	**4**	**5**	6
11	**12**	1	**2**	**3**	4
8	**9**	10	**11**	**12**	1
5	**6**	7	**8**	**9**	10
2	**3**	4	**5**	**6**	7
12	**1**	2	**3**	**4**	5
9	**10**	11	**12**	**1**	2
6	**7**	8	**9**	**10**	11
3	**4**	5	**6**	**7**	8
1	2	3	**4**	**5**	6
10	11	12	**1**	**2**	3
7	8	9	**10**	**11**	12
4	5	6	**7**	**8**	9
1	2	3	**4**	**5**	6

VII	VIII	IX	X	XI	XI	degree	day
7	8	9	10	11	12	0	0)
4	**5**	**6**	**7**	8	9	**7**	1
1	**2**	**3**	4	5	6	**14**	2
10	**11**	**12**	1	2	3	**21**	3
7	**8**	**9**	10	11	12	**28**	4
5	**6**	**7**	8	9	10	**5**	5
2	**3**	**4**	5	6	7	**12**	6
11	**12**	**1**	2	3	4	**19**	7
8	**9**	**10**	11	12	1	**26**	8
6	**7**	**8**	9	10	11	**3**	9
3	**4**	**5**	6	7	8	**10**	10
12	**1**	**2**	3	4	5	**17**	11
9	**10**	**11**	12	1	2	**24**	12
7	**8**	**9**	10	11	12	**1**	13
4	**5**	**6**	7	8	9	**8**	14
1	**2**	**3**	4	5	6	**15**	15
10	**11**	**12**	1	2	3	**22**	16
7	**8**	**9**	10	11	12	**29**	17
5	**6**	**7**	8	9	10	**6**	18
2	**3**	**4**	5	6	7	**13**	19
11	**12**	**1**	2	3	4	**20**	20
8	**9**	**10**	11	12	1	**27**	21
6	**7**	**8**	9	10	11	**4**	22
3	**4**	**5**	6	7	8	**11**	23
12	**1**	**2**	3	4	5	**18**	24
9	**10**	**11**	12	1	2	**25**	25
7	**8**	**9**	10	11	12	**2**	26
4	**5**	**6**	7	8	9	**9**	27
1	**2**	**3**	4	5	6	**16**	28
10	**11**	**12**	1	2	3	**23**	29
7	8	**9**	10	11	12	**30**	30

Table 2: The complete *Kalendertext* scheme. For a each day in a year of 12 months with 30 days, the corresponding zodiacal positions are written: the first line gives the months, the last column the day number, the second last column gives the position in degrees within the signs, and columns 1 to 12 record the number of the zodiacal signs. The bold numbers indicate which parts of the scheme have been found in cuneiform texts.

One can ask which number X of degrees (other than $277° \equiv -83°(\text{mod. } 360)$) will result in a similar scheme. If we start at 0 degrees for day 0 of month I, and go X degrees forward each day, then after 30 days, the position will be shifted by $30 \times X$ degrees. We want the position on day 30 to be 30, i.e. 30° further and n complete circuits through the zodiac. This will be the case if $30X$ equals $n \times 360 + 30$. Therefore, for X we must claim that

$$30 \cdot X = 30 + 360n, \quad n \in N_0, \quad \text{hence} \quad X = 1 + 12n, \quad n \in N_0.$$

We see X must be of the form $X = 1 + 12n$ where n is a natural number (or 0). Van der Waerden has already remarked that only numbers of this form will result in the position shifting by one sign each month.[29] This means that all the (29) numbers $X = 1, 13, 25, 37, 49, \ldots, 277, \ldots, 337, 349$ would be possible candidates for constructing a *Kalendertext* type scheme. We will therefore go a little further and ask why $X = 277° \equiv -83°$, corresponding to $n = 23$, was chosen? What is special about the distribution of positions resulting from this choice of X?

A glance at Table 1 shows us that all possible degree numbers, 1 to 30, occur during the 30 days of our month, and also that all 12 zodiacal signs are represented, and are nicely distributed. Thus the *Kalendertext* scheme for the whole ideal year (see Table 2) gives a one-to-one correspondence between the 360 days of the ideal year and the 360 degrees (positions) of the zodiac.

[29] van der Waerden *apud* [Weidner *GDBT*, 50–52].

Kalendertext scheme							*Dodekatemoria* scheme			
month (I)	day (0)	zodiac (1)	=	sign ( )	° (0)		sign ( )	° (0)	month (I)	day (0)
I	1	10	=	♑	7			13	I	1
I	2	7	=	♎	14			26	I	2
I	3	4	=	♋	21		♉	9	I	3
I	4	1	=		28		♉	22	I	4
I	5	11	=	♒	5		♊	5	I	5
I	6	8	=	♏	12		♊	18	I	6
I	7	5	=	♌	19		♋	1	I	7
I	8	2	=	♉	26		♋	14	I	8
I	9	12	=	♓	3		♋	27	I	9
I	10	9	=	♐	10		♌	10	I	10
I	11	6	=	♍	17		♌	23	I	11
I	12	3	=	♊	24		♍	6	I	12
I	13	1	=		1		♍	19	I	13
I	14	10	=	♑	8		♎	2	I	14
I	15	7	=	♎	15		♎	15	I	15
I	16	4	=	♋	22		♎	28	I	16
I	17	1	=		29		♏	11	I	17
I	18	11	=	♒	6		♏	24	I	18
I	19	8	=	♏	13		♐	7	I	19
I	20	5	=	♌	20		♐	20	I	20
I	21	2	=	♉	27		♑	3	I	21
I	22	12	=	♓	4		♑	16	I	22
I	23	9	=	♐	11		♑	29	I	23
I	24	6	=	♍	18		♒	12	I	24
I	25	3	=	♊	25		♒	25	I	25
I	26	1	=		2		♓	8	I	26
I	27	10	=	♑	9		♓	21	I	27
I	28	7	=	♎	16			4	I	28
I	29	4	=	♋	23			17	I	29
I	30	1	=		30			30	I	30
=		=					=		=	
(II)	(0)	(0)	=	(♉)	(0)		(♉)	(0)	(II)	(0)

Table 3: The *Kalendertext* and *Dodekatemoria* schemes for month I.

Let us imagine the schemes which would be produced by a different choice of X. Choosing 25, 85, 145, etc. would result in a distribution of positions with only 5, 10, 15, 20, 25, and 30 degrees within the signs. This is not a one-to-one correspondence between the 360 days and 360 degrees, so we understand why these numbers were not chosen. The choice $X = 1$ results in the (boring) distribution Month M day d $\rightleftharpoons$ Sign M degree d, which represents the ideal movement of the sun during the ideal year. However, the next possible choice, $X = 13$, does result in a distribution with a one-to-one correspondence (see table 3). This is the *Dodekatemoria* described above.

From Table 3 we see that on day 0 of a month M the position (sign M, 0 degrees) given by the *Kalendertext* scheme is the same as that given by the *Dodekatemoria* scheme, i.e., the ideal position of sun and moon at conjunction, and that the position corresponding to day 15 of month M in both schemes is the ideal position of the moon at opposition, namely 15 degrees in sign $M + 6$. This must be one of the reasons why the number $X = 277$ was chosen for the *Kalendertext* scheme. We can therefore ask the question: in what other ways is the scheme with $X = 277$ special? Does it in some way results in a 'better" distribution of positions than other possible numbers? Some of the numbers $X = 12n + 1$ can be excluded because they result in a scheme in which not all zodiacal signs are represented in a month, or in which the distribution of signs is rather boring.[30]

Another remarkable feature of the *Kalendertext* scheme concerns the zodiacal signs. A special structure becomes apparent when we consider how often and on which days the zodiacal signs occur. In each month M, its special sign M occurs 5 times: on the days 4, 13, 17, 26, and 30 (i.e., at intervals of 9, 4, 9, and 4 days).[31] Each other sign occurs at intervals of 13 days. The 3

[30] We remind the reader that the purpose of the *Kalendertexte* W.22704 and W.22619/6+22554/2b was to determine the ingredients of substances to be used on the 30 days of month IV and VIII, respectively. If a day corresponds to a position in Aries, then the medical substance for that day should contain blood, fat, and hair of a sheep. The greater the diversity of signs, the more substances could be used. There are also several examples of Greek texts in which connections between astral and meterological phenomena and medical care are apparent. See [Bowen and Goldstein 1988].

[31] Just as the astrological significance of a planet was apparently increased when it was in its 'secret house' (*bīt niṣirti*), one might speculate that the

signs which together with the special sign constitute a quadrangle occur 3 times, whilst the remaining 8 signs occur only twice. This structure is demonstrated in Table 4: the zodiacal signs are reproduced together with the days within month I to which the signs are associated. Aries, being the first sign of the zodiac, is the special sign of month I. This is shown more clearly in Table 5.

Month I

sign	day		sign	day		sign	day
	4, 13, 17, 26, 30		♉	8, 21		♊	12, 25
♋	3, 16, 29		♌	7, 20		♍	11, 24
♎	2, 15, 28		♏	6, 19		♐	10, 23
♑	1, 14, 27		♒	5, 18		♓	9, 22

Table 4: Zodiacal signs and days on which they occur in month I.

M	d	sign	°	M	d	sign	°	M	d	sign	°
(I)	(0)	(	0)	I	13		1	I	26		2
I	1	♑	7	I	14	♑	8	I	27	♑	9
I	2	♎	14	I	15	♎	15	I	28	♎	16
I	3	♋	21	I	16	♋	22	I	29	♋	23
I	4		28	I	17		29	I	30		30
I	5	♒	5	I	18	♒	6				
I	6	♏	12	I	19	♏	13				
I	7	♌	19	I	20	♌	20				
I	8	♉	26	I	21	♉	27				
I	9	♓	3	I	22	♓	4				
I	10	♐	10	I	23	♐	11				
I	11	♍	17	I	24	♍	18				
I	12	♊	24	I	25	♊	25				
I	30		30								
=		=									
(II)	(0)	(♉)	(0)	II	13	♉	1	II	26	♉	2
II	1	♒	7	II	14	♒	8	I I	27	♒	9
.	.	.	.	.	.	.	.				

Table 5: Here the structure of the *Kalendertext* scheme becomes a little more transparent. Each sign will occur at intervals of 13 days, the position within the sign being enlarged by 1 degree. Only the special sign of the month occurs more often, namely at intervals of 4 and 9 days (which adds up to 13 days).

ingredients etc. relating to sign M would be especially effective when they were applied in month M. If this was the case, it is an advantage of the *Kalendertext* scheme that in each month M its special sign M is given 5 times.

We once more ask the question, is the value $X = 277$ especially chosen, or would other choices be as good? I.e., would other X values induce schemes with the special features of the *Kalendertext* scheme? In Table 6, for all the possible numbers X, we have analyzed the resulting scheme: are all signs and all degrees represented in each month, does the position on day 15 give the ideal moon position, and does its special sign occur frequently within each month? If a scheme fails one of these requirements it is rejected.

X	$\bar{X}$	all signs each month	all degrees each month	'full moon position' on day 15	special sign occurring n times
1	- 359	–	+	–	30
13	- 347	+	+	+	5
25	- 335		–		
37	- 323	+	+	+	3
49	- 311	+	+	–	2
61	- 299	–			
73	- 287	–	+	–	6
85	- 275		–		
97	- 263	+	+	–	4
109	- 251	+	+	–	2
121	- 239	–			
133	- 227	+	+	+	3
145	- 215		–		
157	- 203	+	+	+	3
169	- 191	+	+	–	1
181	- 179	–			
193	- 167	+	+	–	3
205	- 155		–		
217	- 143	–			
229	- 131	–	+	+	0
241	- 119	–			
253	- 107	+	+	+	3
265	- 95		–		
277	- 83	+	+	+	5
289	- 71	–	+	–	6
301	- 59	–			
313	- 47	+	+	–	2
325	- 35		–		
337	- 23	+	+	–	2
349	- 11	–	+	+	0

Table 6: The suitability of other schemes.

Except for the numbers 13 (*Dodekatemoria*) and 277 (*Kalendertext*) only the numbers 37, 133, 157, and 253 will produce schemes which have all of these fine features. But in all these imagined schemes the special sign occurs only 3 times within the month. The numbers $X = 73$ and 289 result in schemes in which the special sign occurs more often, namely 6 times, but here not all signs are represented within each month.

These results have demonstrated the very special and fine structure of the *Kalendertext* and *Dodekatemoria* schemes.

4 *An intimate connection between the* Kalendertext *and* Dodekatemoria *schemes*

We return to Table 2 and remember that some of the cuneiform schemes only have numbers and do not differentiate between dates and positions. That we have identified some numbers with signs or months and others with degrees or days is our choice and interpretation (although it is based on the two tablets W.22704 and W.22619/6+22554/2b.) We shall now demonstrate a very special feature of the two schemes.

If in the *Kalendertext* scheme (Table 2) we exchange all the roman month numbers for arabic numbers to be understood as signs, and exchange the signs for month numbers, and likewise swap the degrees and days, we end up with table 7.[32] What we have in this new table is simply a rearrangement of the *Dodekatemotria* scheme. We can enter the table with a position in the zodiac and we find a corresponding date. This date is the date in the ideal year on which the ideal moon would be at that position according to the *Dodekatemoria* scheme.

[32] This idea was suggested by the curious fact that the number sequences 1, 1, 1, 13 and 1, 2, 1, 26 (from the text LBAT 1593) could also be found in the *Kalendertext* scheme.

1	2	3	4	5	6
(I	II	III	IV	V	VI
X	XI	XII	I	II	III
VII	VIII	IX	X	XI	XII
IV	V	VI	VII	VIII	IX
I	II	III	IV	V	VI
XI	XII	I	II	III	IV
VIII	IX	X	XI	XII	I
V	VI	VII	VIII	IX	X
II	III	IV	V	VI	VII
XII	I	II	III	IV	V
IX	X	XI	XII	I	II
VI	VII	VIII	IX	X	XI
III	IV	V	VI	VII	VIII
I	II	III	IV	V	VI
X	XI	XII	I	II	III
VII	VIII	IX	X	XI	XII
IV	V	VI	VII	VIII	IX
I	II	III	IV	V	VI
XI	XII	I	II	III	IV
VIII	IX	X	XI	XII	I
V	VI	VII	VIII	IX	X
II	III	IV	V	VI	VII
XII	I	II	III	IV	V
IX	X	XI	XII	I	II
VI	VII	VIII	IX	X	XI
III	IV	V	VI	VII	VIII
I	II	III	IV	V	VI
X	XI	XII	I	II	III
VII	VIII	IX	X	XI	XII
IV	V	VI	VII	VIII	IX
I	II	III	IV	V	VI

7	8	9	10	11	12	day	degree
VII	VIII	IX	X	XI	XII	0	0)
IV	V	VI	VII	VIII	IX	7	1
I	II	III	IV	V	VI	14	2
X	XI	XII	I	II	III	21	3
VII	VIII	IX	X	XI	XII	28	4
V	VI	VII	VIII	IX	X	5	5
II	III	IV	V	VI	VII	12	6
XI	XII	I	II	III	IV	19	7
VIII	IX	X	XI	XII	I	26	8
VI	VII	VIII	IX	X	XI	3	9
III	IV	V	VI	VII	VIII	10	10
XII	I	II	III	IV	V	17	11
IX	X	XI	XII	I	II	24	12
VII	VIII	IX	X	XI	XII	1	13
IV	V	VI	VII	VIII	IX	8	14
I	II	III	IV	V	VI	15	15
X	XI	XII	I	II	III	22	16
VII	VIII	IX	X	XI	XII	29	17
V	VI	VII	VIII	IX	X	6	18
II	III	IV	V	VI	VII	13	19
XI	XII	I	II	III	IV	20	20
VIII	IX	X	XI	XII	I	27	21
VI	VII	VIII	IX	X	XI	4	22
III	IV	V	VI	VII	VIII	11	23
XII	I	II	III	IV	V	18	24
IX	X	XI	XII	I	II	25	25
VII	VIII	IX	X	XI	XII	2	26
IV	V	VI	VII	VIII	IX	9	27
I	II	III	IV	V	VI	16	28
X	XI	XII	I	II	III	23	29
VII	VIII	IX	X	XI	XII	30	30

Table 7: This table is obtained by swapping dates and positions in the *Kalendertext* scheme (Table 2). By entering the table with a position, we find the date on which the moon was at that position according to the *Dodekatemoria* scheme.

We can now construct Table 8 by rearranging Table 7 so that we enter the table with a date and we find the associated position according to the *Dodekatemoria* scheme.

We have therefore been able to derive the *Dodekatemoria* scheme by simply swapping the dates and positions in the *Kalen-*

dertext scheme.[33] Of course, we could also work the other way, and obtain the *Kalendertext* scheme from the *Dodekatemoria*. Indeed, we believe this is how the *Kalendertext* scheme was in fact constructed. This investigation has once again illustrated how careful one has to be in interpreting ancient texts: having found all the special and nice features of the *Kalendertext* scheme, we initially concluded that the number of 277 degrees was the result of a purposeful search for a very special one to one correspondence between (360) dates and (360) positions. Now it is evident that such a conclusion is totaly wrong. The very special distribution of positions in the *Kalendertext* scheme is a direct consequence of the way it was constructed.

The *Kalendertext* scheme has no inherent astronomical or other significance (such as the duration of pregnancy). Instead it comes from playing around with the numbers in another astrological scheme, the *Dodekatemoria*.[34] The *Dodekatemoria*, however, does have astronomical significance: it represents the mean motion of the moon during the ideal year of 360 days.

This shows an interest on the part of the Babylonian astrologers in increasing the astrological potential of a date or position in the zodiac by mathematical manipulation — a procedure which we term 'mathemagics'.

[33] The reason why 13 and 277 give inverse schemes comes from the fact that $13 \times 277 = 3601 = 1\text{SAR} + 1$ ($= 10 \times 360 + 1 \equiv 1$ (modulo 360)).

[34] Learned numerical and philological arguments linking one idea with another are common in cuneiform. For example, numerical games are played with the cunieform signs of dates in the explanatory work i.NAM.giš.ḫur.an.ki.a. K2164 + 2195 + 3510, Obv. 16–17 reads 'The 22nd day: the 14th day. You multiply 14 and 10. $14 \times 10 = 140$. It becomes 22 reversed.' (translation of [Livingstone *Explanatory Works*, p. 23]). The author of this text uses the following argument to relate the 22nd and the 14th day: Separate 14 (which is written with one Winkelhaken followed by 4 stacked vertical wedges) into 10 and 4. Then multiply 10 by 14 to give 140, which is written sexagesimally 2,20. In cuneiform 2,20 is written with two vertical wedges followed by two Winkelhaken ($\|\ \ll$). Reversing their order to get 20,2, we have two Winkelhaken followed by 2 vertical wedges ($\ll\ \|$) which can be read together as 22. Thus, we have been able to transform the number 14 into the number 22 simply by rearranging the constituent signs, and performing some simple arithmetic. See also [Brown 2000, pp. 127–8].

I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	°	d
(1	2	3	4	5	6	7	8	9	10	11	12	0	0)
1	2	3	4	5	6	7	8	9	10	11	12	13	1
1	2	3	4	5	6	7	8	9	10	11	12	26	2
2	3	4	5	6	7	8	9	10	11	12	1	9	3
2	3	4	5	6	7	8	9	10	11	12	1	22	4
3	4	5	6	7	8	9	10	11	12	1	2	5	5
3	4	5	6	7	8	9	10	11	12	1	2	18	6
4	5	6	7	8	9	10	11	12	1	2	3	1	7
4	5	6	7	8	9	10	11	12	1	2	3	14	8
4	5	6	7	8	9	10	11	12	1	2	3	27	9
5	6	7	8	9	10	11	12	1	2	3	4	10	10
5	6	7	8	9	10	11	12	1	2	3	4	23	11
6	7	8	9	10	11	12	1	2	3	4	5	6	12
6	7	8	9	10	11	12	1	2	3	4	5	19	13
7	8	9	10	11	12	1	2	3	4	5	6	2	14
7	8	9	10	11	12	1	2	3	4	5	6	15	15
7	8	9	10	11	12	1	2	3	4	5	6	28	16
8	9	10	11	12	1	2	3	4	5	6	7	11	17
8	9	10	11	12	1	2	3	4	5	6	7	24	18
9	10	11	12	1	2	3	4	5	6	7	8	7	19
9	10	11	12	1	2	3	4	5	6	7	8	20	20
10	11	12	1	2	3	4	5	6	7	8	9	3	21
10	11	12	1	2	3	4	5	6	7	8	9	16	22
10	11	12	1	2	3	4	5	6	7	8	9	29	23
11	12	1	2	3	4	5	6	7	8	9	10	12	24
11	12	1	2	3	4	5	6	7	8	9	10	25	25
12	1	2	3	4	5	6	7	8	9	10	11	8	26
12	1	2	3	4	5	6	7	8	9	10	11	21	27
1	2	3	4	5	6	7	8	9	10	11	12	4	28
1	2	3	4	5	6	7	8	9	10	11	12	17	29
1	2	3	4	5	6	7	8	9	10	11	12	30	30

Table 8: The *Dodekatemoria* scheme, constructed by rearranging Table 7.

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Abbreviations

AO	Tablets in the Antiquités orientales collection, Musée du Louvre
BM	Tablets in the collection of the British Museum, London
LBAT	[Sachs LBAT]
VAT	Tablets in the Vorderasiatisches Abteilung Tontafeln collection, Berlin
W	Tablets excavated at Warka by the Deutsche Orient-Gesselschaft

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Plate 1: BM 96258 Obverse (courtesy of the Trustees of the British Museum)

Plate 2: BM 96258 Reverse (courtesy of the Trustees of the British Museum)

Plate 3: BM 96293 Obverse (courtesy of the Trustees of the British Museum)

Plate 4: BM 96293 Reverse (courtesy of the Trustees of the British Museum)