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EARLY MESOPOTAMIAN INTERCALATION SCHEMES AND THE SIDEREAL MONTH

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ABSTRACT

This paper examines the two intercalation schemes found in the Mesopotamian astronomical compendium MUL.APIN from the beginning of the first millenium BCE, and the lunar theory that they imply. It demonstrates that the two schemes do not agree with each other. Two intercalation rules in the second scheme use the conjunction of the moon and the Pleiades. This paper concludes that the intercalation rules are based on the assumption of a 28-day ideal sidereal month. These rules work with a triennial cycle of intercalating one additional month every third lunar year. Two similar intercalation schemes from other compositions, likewise dating from the beginning of the first millenium BCE, are known: a seventh-century intercalation scheme from Babylonia that also assumes a 28-day ideal sidereal month and an intercalation scheme from an unpublished astronomical commentary that, like the scheme in MUL.APIN, uses a triennial cycle. Previous scholars believed that discrepancies exist between the dates of the conjunctions of the moon and the Pleiades across all three schemes. However, this paper proposes that the astronomical assumptions of the three schemes are identical.

KEYWORDS: Sidereal Month, MUL.APIN, Intercalation Scheme.

1. INTRODUCTION

Lunar observations and calculations were the highlight of Mesopotamian astronomy. Their importance was both theoretical and practical, especially for the establishment of the calendar. Nearly all of the civil and cultic calendars in Mesopotamia were luni-solar calendars whose months were determined by the lunar cycle, and were therefore 29 or 30 days long. However, since 12 lunar months have approximately 11 fewer days than solar and sidereal years, an additional intercalary 13th month was added every two or three years. During most of the periods these intercalations were performed ad-hoc.[1]

Because the flexibility of the luni-solar calendar made it highly unpredictable, another schematic calendar was developed for long-term calculations. This calendar contained 12 months of 30 days each, for a total of 360 days a year. It was not used as a civil calendar to determine dates, and was considered an ideal calendar. Evidence of the ideal calendar exists already in third-millennium BCE tablets dealing with administrative calculations (Englund, 1988). Later, beginning in the Old Babylonian period, the ideal calendar was used in astronomical texts such as Enuma Anu Enlil and MUL.APIN (for a discussion of the ideal calendar in all periods see Brack-Bernsen, 2007). This calendar was not only practical for calculations, but also became the standard against which astronomical phenomena were examined in order to predict good or bad omina. In addition, it was used to established intercalation rules. These rules use predictions of cyclic behaviour of certain luminaries throughout the 360-day year. When the relevant celestial bodies appear in the expected position at the expected time during the luni-solar year, it is a normal year. If these phenomena are late according to the luni-solar calendar, the year should be intercalated.

Whether or not these rules were followed in practice, they can teach us about the advancements in astronomical understanding of lunar, solar, and sidereal cycles. One such cycle is the sidereal month, the time period necessary for the moon to return to the same position in relation to the stars. Every night the moon is seen against a background of different stars. After approximately $27\frac{1}{3}$ days, the moon completes a 360° rotation around the earth after which, from the vantage point of an observer standing on Earth, it is seen against a background of the same group of stars as when the cycle began. This paper will demonstrate that, as early as the beginning of the first millennium BCE, Babylonian astronomers not only noticed this phenomenon, but also used an approximation of its length to determine intercalation cycles. However, the texts describing this phenomenon did not attempt to suggest improvements to the computation of the intercalation cycles using observations, as some scholars claim, but were still using schematic cycles.

[1] This was true until the discovery of the so called "Metonic Cycle," probably during the fifth-century BCE (Hunger and Pingree, 1999; Britton, 2007). The 19-year cycle was put into practice gradually, thus turning the Mesopotamian calendar from a flexible calendar to a fixed one.

2. TEXTUAL EVIDENCE: THE INTERCALTION SCHEMES OF MUL.APIN

Two early intercalation schemes were preserved in the astronomical compendium MUL.APIN from the beginning of the first millennium BCE (Hunger and Pingree, 1989).

2.1 *First Intercalation Scheme*

The first intercalation scheme (MUL.APIN II i 9-24) is very simple. It presents predictions of heliacal rising of certain constellations, the positions of the sun and moon in relation to the stars, and the length of day and night for the four cardinal days: the equinoxes and summer and winter solstices (occurring on the 15th day of the first, fourth, seventh, and tenth months), as demonstrated in Table I, below. The intercalation rule states only that a deviation of these celestial bodies from their predicted positions on the named dates or the occurrence of these phenomena on other dates necessitate an intercalation.[2]

[2] Here I follow the common interpretation of MUL.APIN II I 22-24: "On the 15th of month I, on the 15th of month IV, on the 15th of month VII, on the 15th on month X, you observe the risings of the Sun, the visibility time of the Moon, the appearances of the Arrow, and you will find how many days are in excess" (trans. Hunger and Pingree). This interpretation is shared i.e. by (Hunger and Pingree, 1989; Chadwick, 1992; Horowitz, 1998; Watson and Horowitz, 2011), and understands the words "days in excess" to refer to the days that the year is missing. The astronomer is attempting to determine how many days are in excess in order to decide whether or not to intercalate the year. However, (Brown, 2000) contests this assumption, and explains that the purpose of the assessment of the days in excess is divinatory. (Brack-Bernsen, 2005) proposes that an additional purpose of the days in excess is to correct the values given in the scheme. I agree with Lis Brack-Bernsen that we should not reduce the motivations of the Babylonian astronomers to a single one. Therefore, even if Brown's and Brack-Bernsen's interpretations are correct, this section of MUL.APIN may still be an intercalation scheme, as is commonly believed, in addition to serving one or more other purposes.

Table I. MUL.APIN II i 9-24: First Intercalation Scheme

Date	Constellation	Sun	Moon	Day-Night Ratio
IV, 15	Arrow	Lion	-	4:2
VII, 15	-	Middle of Scales	In front of Stars and behind Aries	3:3
X, 15	Arrow	Head of Lion[3]	-	2:4
I, 15	-	In front of Stars and behind Aries, in the west	Middle of Scales, in the east	3:3

The equinoxes and solstices occur in the middle of the month, according to this calendar. On these dates, the sun and the moon are in opposition, i.e. directly opposite each other with reference to the earth. Therefore, it is not surprising that on the two equinoxes, six months apart from each other, these bodies should be in opposite positions in relation to the stars: While on the autumnal equinox the sun is in the middle of Scales and the moon is between the Pleiades (Stars) and Aries, on the vernal equinox the sun is between the Pleiades and Aries and the moon is in the middle of Scales, as illustrated in Figure 1 and Figure 2.

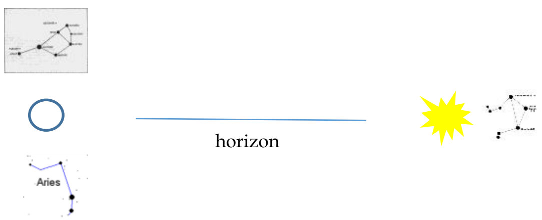

Figure 1. The sun and moon on Tešritu (VII) 15th, during sunrise and moonset. The images are not to scale, and are intended only for demonstration.

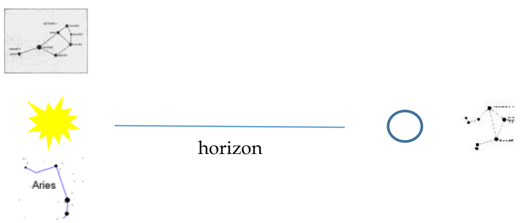

Figure 2. The sun and moon on Nisannu (I) 15th, during sunset and moonrise. The images are out not to scale, and are intended only for demonstration.

[3] Although the Head of the Lion (UR.GU.LA) is attested in both manuscripts, it is probably a mistake from $^{\text{mul}}$GU.LA, because the sun cannot be at the same position as it had been half a year earlier (Hunger and Pingree, 1989).

While there is much to say about the path of the sun according to this text (see for example Hunger and Pingree, 1989), this paper focuses on the moon. According to this text, the moon's longitude changes by 180° over the course of half a year. All the details here are schematic, and thus the dating of these phenomena is not based on observations. The position of the sun in relation to the stars in the first month is opposite its position in the seventh month, and the moon in the middle of the equinoctial months is opposite that of the sun. However, assuming the ideal calendar used in MUL.APIN, an additional computation of the lunar daily displacement (the rate of change of the position of the moon relative to the stars) is simple. Since the basic calendar in MUL.APIN is a schematic calendar of 12 months consisting of 30 days each for a total of 360 days a year, a period of six months contains 180 days. A sidereal month, during which the moon encircles the earth and returns to the same position in relation to the stars, is shorter than a synodic month, according to which the calendric months are established. Therefore, in six months the moon encircles the Earth and completes a 360° rotation $k \geq 6$ times. The moon's position after six months can be computed using its daily displacement in units of degrees per day (v):

$360k+180 = 180v;\ k \geq 6$

$2k+1=v$

If $k=6$, $v=13$ degrees per day, which is in close approximation to the mean daily angular movement of the moon on the ecliptic. Despite the fact that there is no textual evidence that this further computation was actually performed by the authors of MUL.APIN, these outcomes will be useful below.

2.2 Second Intercalation Scheme

The second intercalation scheme of MUL.APIN (II A 1- II ii 20) is comprised of two sections. The second section (II ii 9-20) is simpler. It presents a triennial cycle, meaning that an intercalary month is added once every three years. An ongoing debate exists among scholars regarding the question of whether the additional month should be added to a lunar year of 354 days or to the ideal year of 360 days. (Al-bani, 1992; 1994; Horowitz, 1994; 1996; 1998) claim the former, and suggest that the intercalation scheme offers an approximation of a 364-day solar year. In support, Horowitz introduces the seventh-century *ziqpu* star text, "where an annual circuit of the *ziqpu*-stars is measured as 364°." On the other hand, (Koch, 1996; 1998), claims that MUL.APIN always uses a schematic year of 360 days, and the intercalation scheme should not be explained as an exception. He refers to evidence from the third millennium BCE that the triennial cycle had existed alongside the 360-day Sumerian administrative year (Englund, 1988).

In the first section of the second intercalation scheme (II A 1- II ii 8), seven intercalation rules appear, referring to stellar visibility and the conjunction of the moon with "the Stars" (Pleiades). The text of this section offers intercalation rules for each month. Five of these rules use the first visibility of different stars. Thus, if a star is first visible on its ideal date (after a period of absence from the night sky), the year is normal, but if that star is not visible until a month later, that year is a leap year. For example:

"[If] the Fish and the Old Man become visible on the 15th of Addaru, this year is normal.

"[If] the Fish and the Old Man become visible on the 15th of Nisannu, this year is a leap year."

(MUL.APIN II ii 5-6; trans. Hunger and Pingree)

However, most of the dates for the intercalation rules are not fully preserved, and Hunger and Pingree reconstruct them based on other lists from the compendium. The data for the intercalation rules, according to Hunger and Pingree's reconstruction, is provided in **Table II.** All reconstructed data is written between brackets.

Table II. MUL.APIN II ii 9-20: Intercalation Rules

Day	Month	Event	Type of Year
[1]	[I]	Conjunction of the moon and Stars	Normal year
3	[I]	Conjunction of the moon and Stars	Leap year
[1]	[II]	Stars become visible	Normal year
1	[III]	Stars become visible	Leap year
[15]	[IV]	[Arrow becomes visible]	[Normal year]
[15]	[V]	Arrow becomes visible	[Leap year]
[15]	[VI]	ŠU.PA becomes visible	[Normal year]
[15]	[VII]	ŠU.PA becomes visible	[Leap year]
[15]	[VIII]	Conjunction of the moon and Stars	Normal year
15	[IX]	Conjunction of the moon and Stars	Leap year
15	X	Arrow becomes visible in the east in the evening	Normal year
15	XI	Arrow becomes visible in the east in the evening	Leap year
15	XII	Fish and Old Man become visible	Normal year
15	I	Fish and Old Man become visible	Leap year

The reconstruction of the last two columns is obvious. According to (Hunger and Pingree, 1989), the dates of the five pairs of heliacal risings are taken from a list of heliacal risings also preserved in the same compendium (MUL.APIN I ii 36 – iii 12). This seems probable, since two of them are preserved in both lists (X 15 and XII 15) and the rest follows the structure of the table, listing one phenomenon for each month. This naturally leads to the reconstruction of the conjunction of the moon and the Pleiades on Araḫsamnu (VIII) 15 in a normal year and on Kislimu (IX) 15 in a leap year, thus completing the sequence of the months. The same applies to the conjunction of the moon and the Pleiades on Nisannu (I) 3rd in a leap year.[4] The reconstruction of the first date simply assumes that the scheme should begin on the first day of the year.

Unlike all of the rules in the second intercalation scheme, the conjunction of the moon and the Pleiades is only late by two days in the leap year and not by a full month, according to the first rule. Several scholars try to explain the astronomical rationale for this rule. (Schaumberger, 1935) computes the longitudes of the moon and the Pleiades in both cases of conjunction, on Nisannu 1st and 3rd. However, according to his computations, the days in excess during the leap year amount to only about half a month.

[4] (Schaumberger, *1935*) considered the unpublished intercalation scheme found in Virolleaud ACh II Suppl. 19,22 as evidence for reconstructing the month Nisannu. However, the text states an allegedly contradictory statement that if the moon and the Pleiades are in conjunction on Nisannu 3rd, the year is normal. Schaumberger interprets the Akkadian there differently, but see (Hunger and Reiner, 1975) about the improbability of Schaumberger's interpretation. However, see below for a possible solution to the contradiction.

In addition, the heliacal rising of the Pleiades in a normal year is supposed to occur in the middle of Ajjaru (II) rather than on the first day of that month. Schaumberger himself admits that the intercalation rules depending on the moon's conjunction with the Pleiades are less accurate than the intercalation rules depending on the stars.

(Hunger and Pingree, 1989) suggest a different explanation. Following the assumption accepted throughout MUL.APIN (for example, II i 19-21) that the spring equinox of the ideal year occurs on Nisannu (I) 15th, Hunger and Pingree compute that on Nisannu 1st the moon is after the Hired Man and before the Pleiades, and not in conjunction with the Pleiades, as the verb *šitqulū* that describes the relation between the moon and the Pleiades usually means. Therefore, they conclude that the verb *šitqulū* means "closest to" in this context. However, as (Brown, 2000) rightfully points out, the verb *šitqulū* in an astronomical context generally means that two celestial objects are either in opposition or in conjunction. Brown concludes that the verb *šitqulū* should be interpreted as the exact conjunction in this context, and that the difference between the computation and the intercalation scheme indicates that the scheme was not derived from observations, but was instead a simple "ideal intercalation scheme," working with the triennial cycle. Brown accepts Koch's interpretation that the year discussed in the second intercalation scheme is an ideal year of 360 days, in which every month is exactly 30 days. He explains the intercalation rule of the moon and the Pleiades as assuming exactly such a month. Brown uses a daily lunar displacement of 13° per day. He derives this number from "1/30th of [360° (one month's revolution) + 30° (the additional movement of the earth in the same month)]." According to Brown, during the two days between Nisannu 1st and Nisannu 3rd, the moon passes 26°; after an additional day, the moon will have passed more than 30° total. Therefore, after two days the moon has moved approximately 30°. Brown claims that "[t]his is equivalent to saying that a month should be added when the lunar calendar has fallen behind the sidereal year by 30°."

I agree with Brown regarding the interpretation of the word *šitqulū* as the exact conjunction, and with his conclusion that the scheme was merely an ideal intercalation scheme and was not based on observations. However, I have a few reservations about Brown's explanation of the specifics of the intercalation rule.

1. Thirteen degrees per day is a good approximation of reality and does not contradict the first intercalation scheme, as demonstrated above. However, even without using the modern explanation that assumes the earth's movement, Brown never demonstrates that the author of MUL.APIN had any such knowledge of lunar velocity.
2. The time interval between the conjunction of the moon and the Pleaides on Nisannu (I) 1st in a normal year and their conjunction on Nisannu 3rd in a leap year is not two days, as these two occasions occur in two different years. If Brown is correct and the rule is as precise as the rule about intercalation happening every three years, then the time interval is three years and two days, not two days.
3. Brown never offers an interpretation of how this intercalation rule relates to the triennial cycle according to his explanation.
4. Brown's explanation does not clarify the second occurrence of conjunction of the moon and the Pleiades in the same intercalation scheme, in which the year should be intercalated if the conjunction occurs 30 days after its ideal date.

(Britton, 2007) has a different view of the set of intercalation rules. He agrees with Albani and Horowitz that the second intercalation scheme should be applied to the 354-day lunar year, and claims that since the triennial cycle was known to be inaccurate and required more frequent intercalations, the additional intercalation rules "amount to guides for determining when a 2-year intercalation was required." Britton's explanation is possible for the five rules that use the first visibility of the stars and constellations. If a stellar phenomenon occurs 30 days too late, it means that the date, determined by lunar observations, is 30 days too early. Therefore, intercalation of a 30-day month would resynchronize the moon with the stars. However, no such simple explanation can be attributed to the intercalation rules using the conjunction of the moon and the Stars. A simple way to determine whether or not these rules improve the precision of the triennial cycle is to actually do the computation, using the dates given in the text.

According to the scheme for the ideal calendar, the moon should be in conjunction with the Pleiades on Nisannu (I) 1st and on Araḫsamnu (VIII) 15th in normal years. If the moon returns to its original position on the 15th day of the eighth month, it has completed a whole number of cycles (k cycles of 360°) in 224 days, using the dates of the ideal 360-day year. Using the simple motion equation of distance equals the lunar daily displacement (v) times the time:

$$360k = 224v; k \geq 7$$

In this case the lunar daily displacement is not an integer. Therefore, it is easier to compute the sidereal month, the time it takes the moon to complete a cycle of 360°, which is an integer. In a schematic text like MUL.APIN, it is better to assume the usage of the rounder number of the sidereal month. We can use an approximation of the sidereal month by computing the period of time (T) it takes the moon to complete 360° at the mean daily displacement (v), as defined above.

$360/v=T$

Substituting v for $360/T$:

$k=224/T$

The length of the sidereal month (T) is dependent on how many cycles (k) the moon has completed in those 224 days. In reality, there are only two possible number of cycles:

$k=7$, $T=32$; $k=8$, $T=28$

Eight cycles is better, because 28 is closer to the true length of the sidereal month. It also aligns better with the text. Applying the 28-day sidereal month to a lunar year with alternating full and hollow months, starting from Nisannu 1st, the moon should complete a whole number of cycles (38 cycles) and return to its original position in relation to the stars after three years and two days, on Nisannu 3rd of the fourth year.

354x3+2=28x38

However, if this month is an intercalary month — an additional Addaru (XII_2) at the end of the third year — the next conjunction of the moon and Pleiades will occur on the first of Nisannu again. The same applies for the second intercalation rule: starting from Araḫasamnu (VIII) 15th, the moon should complete a whole number of cycles (39 cycles) and return to its original location in relation to the stars after three years and 30 days, in Kislimu (IX) 15th, as demonstrated by the following equation: 354*3+30=28*39

The mathematical calculations demonstrate that, unlike Britton's expectations, this intercalation rule does not improve the accuracy of the triennial cycle; the intercalation rule is exactly equivalent to it. Therefore, even though the triennial cycle is more accurate than the ideal 360-day year, the astronomy it uses is still very schematic astronomy. On the other hand, one cannot accept Brown's computation either, and it is evident that the lunar daily displacement in this scheme is not 13° per day.

Interestingly, the ideal position of the moon in relation to the stars was originally calculated with the assumption of the ideal 360-day year. Only the dates of the conjunctions in a leap year assume the triennial cycle. Moreover, a 28-day sidereal month works well with a 364-day year, as a complete number of 13 sidereal months fit into one 364-day year. This supports Horowitz and Albani's opinion that the triennial cycle should be applied to a schematic lunar calendar, and not to the ideal 360-day year.

3. TEXTUAL EVIDENCE: THE BABYLONIAN INTERCALATION SCHEME

Additional evidence for a 28-day sidereal month is found in a scheme for intercalation from 7th-century BCE Babylonia, published by (Hunger and Reiner, 1975).[5] The scheme lists 12 dates for the conjunction of the moon and Stars (Pleiades) in the following pattern: "If in month X on the Yth day you observe the Pleiades and the moon, and they have the same longitude, then this year is normal; if they fall down- it is left behind" (trans. Hunger and Reiner). The list of dates is summarized in Table III below.

Table III. Dates of Babylonian Intercalation Scheme

Month	Day
XII	25
I	23
II	21
III	19
IV	17
V	15
VI	13
VII	11
VIII	9
IX	7
X	5
XI	3

Hunger and Reiner analyzed the pattern of this scheme as follows: $\lambda_p = \lambda_0 + v(a + 26 - 2n)$; when λ_p is the longitude of the Pleiades, λ_0 the longitude of the sun at the preceding conjunction of the sun and moon, v the velocity of the moon in degrees per day (now commonly referred to as daily displacement), n the number of the month in question, and a the time between the conjunction of the sun and moon and the first appearance of the moon following it. Although their computation is accurate, it is unnecessarily complicated, and has nothing to do with the method that the authors of the intercalation scheme used. The authors assumed a 28-day sidereal month, during which the moon returns to the same position in relation to the stars (i.e. in conjunction with the Pleiades).[6]

[5] The edition is based on tablets K. 3923 + 6140 + 83-1-18, 479 (A); K. 9260 (B); and K. 12759 (C).

[6] In addition, later in their paper, Hunger and Reiner compute the dates of the beginning of the year according to the scheme. In their computation they use v=13;10,35 (written sexagesimally). Unfortunately, their computations reveal a discrepancy between the times for the beginning of the new year, as they are implied by each line in the text, and none of these times meet the historical data. They attribute these problems to the schematization of the intercalation rules. However, although the value that they used for lunar velocity is approximately the true value, it contradicts the value of lunar velocity assumed by the scheme. If the

Note that this scheme begins with Addaru, the 12th month. The dates seem to contradict the intercalation scheme of MUL.APIN. However, the contradiction may be attributed to the fact that this scheme comes from Babylonia. According to the Old Babylonian system, the equinoxes and the solstices fall in months XII, III, VI, and IX (van der Waerden, 1951; George, 1991; Al-Rawi and George, 1991/2; Horowitz, 1996). This system reappears in the Late Babylonian period (Britton, 1993). MUL.APIN uses the Neo-Assyrian system, in which the equinoxes and solstices fall in months I, IV, VII, and X. Therefore, an astronomical event that MUL.APIN dictates should occur on the first of Nisannu (I) would occur one month earlier, on the first day of Addaru (XII), if the Old Babylonian system were consulted. If we extrapolate the Babylonian scheme to an additional month beyond the calculations the scheme provides, the next conjunction of the moon and the Pleiades would fall, indeed, on the first day of Addaru. It seems as if the Babylonian scheme simply calculated the conjunctions backward from the beginning of Addaru. Although there is only evidence for this system from the Old and Late Babylonian periods, it does not seem to have been forgotten in the periods in between (although it was likely not practiced during the Neo-Assyrian reign). Indeed, this scheme published by Hunger and Reiner may be evidence of the use of the Babylonian system during the time between the two attested periods.

Another difference between the Babylonian intercalation scheme and the scheme in MUL.APIN is the structure of the rules. Intercalation rules are structured around two types of scenarios: A. If a correct phenomenon occurs on a later date than predicted, or B. An alternate phenomenon occurs on the anticipated date. While the rule in MUL.APIN follows the first structure (the conjunction occurs on Nissanu 3rd instead of Nissanu 1st), the Babylonian scheme follows the second structure (identifying the specific dates on which the moon and Pleiades are still apart, but should not be according to the predictions).

4. TEXTUAL EVIDENCE: ACH SUPPLEMENT II 19, 21-23

A similar intercalation rule concerning the conjunction of the moon and Pleiades, and using the second structure, is found in the unpublished tablet K. 3123, copied by (Virolleaud, 1905-1912) as Ach Suppl. II 19, 21-23 among other texts concerning the moon. It was probably the fourth tablet of the astrological commentary *Sîn ina tāmartišu* (Henceforth SIT 4), composed in the beginning of the first millennium BCE in Babylonia (Frahm 2011). An intercalary rule is found in lines 21-23:

21: If the Pleiad]es is in front, and the moon is behind – this year is right (normal); If the Pleiades is behind and the moon is in front – this year is left behind (intercalated).

22: If in Nisannu, on the third day, you observe the Pleiades and the moon, and they are in conjunction – this is right (normal);

23: If they fall down (not in conjunction) – left behind (intercalated)…

(Schaumberger, 1935) naturally assumed that this rule would agree with the intercalation rules of MUL.APIN, and therefore interchanged the interpretations of the terms *ezbet* (left behind) and *ešret* (right). (Hunger and Reiner, 1975) and (Brown, 2000) agree with each other that the intercalation rule from SIT 4 contradicts entirely the second intercalation rule of MUL.APIN. While in MUL.APIN a conjunction of the moon and the Pleiades indicates that a month should be intercalated, the rule from SIT 4 states the exact opposite, and defines such a year as normal. Here, I offer a different interpretation, reconciling the alleged contradiction without necessitating a reinterpretation of the terms.

All previous scholarly analyses of these lines read line 21 separately from lines 22-23. The rule of line 21 does not refer to a specific date, as the latter two lines do. However, without a date, line 21 has no meaning. The rule states that if the moon is to the west (in front) of the Pleiades, the year should be intercalated. However, every year includes a time at which the moon is to the west of the Pleiades. Schaumberger assumes that this rule refers to the time of the heliacal rising of the Pleiades, although it is not mentioned specifically in the text. However, if line 21 is connected to lines 22-23, then its rule must refer to Nisannu 3rd, as their rules do. Reading the two intercalation rules together, if on Nisannu 3rd the moon is to the west and the Pleiades are to the east, that year is a leap year. If, on the contrary, the moon is to the east and the Pleiades are to the west on Nisannu 3rd, the year is normal. The limit between these two situations is the moment at which the moon and Pleiades are in conjunction. A conjunction can be regarded in this sense as an infinitesimal moment between the different orders of the moon and Pleiades. This means that both MUL.APIN and SIT 4 agree that the day on which the astronomer should examine the relation between the moon and Pleiades is Nisannu 3rd. Both texts agree that the moment at which the moon passes the Pleiades is the determining factor in whether the year should be intercalated. The texts only disagree regarding the

moon passes 360° in 28 days, then its velocity is only approximately 12;51,25 degrees per day. Of course the value assumed by the scheme is not an accurate value, due to the schematic nature of the intercalation rules.

exact moment of the conjunction, a moment which is too short in reality to affect the actual calendar. It seems that the main difference between the two texts is the phrasing of the rule. While MUL.APIN is phrased according to the first structure, which examines the same phenomenon on different dates, SIT 4 is phrased according to the second structure, which examines different positions of the luminaries on the same date. It is not surprising, therefore, that SIT 4 also presents a triennial cycle right after these intercalation rules, as is the case for the second intercalation scheme in MUL.APIN.

5. CONCLUSION

I have demonstrated that the three early intercalation schemes, using the conjunction of the moon and the Pleiades, are in agreement with each other. All three have a schematic nature. Both the second intercalation scheme of MUL.APIN and the Babylonian scheme use the assumption of a 28-day ideal sidereal month to compute their rules. Both MUL.APIN and SIT 4 support a triennial cycle with the intercalation rule, a cycle that adapt an ideal 354-day lunar year with a 364-day approximated solar year. Since these rules are schematic, they do not fit other intercalation rules found in MUL.APIN. Despite the fact that in reality the conjunction of the moon and the Pleiades was used by Assyrian kings and their astronomers to determine if the year required an intercalation (Parpola, 1970-1983, letter n. 325), there is no evidence for the use of a certain attested scheme. Although these intercalation rules are improvements over the 360-day ideal year, they are still schematic in nature, are not based on observations, and do not improve the accuracy of the triennial cycle.

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