FURTHER ASTRONOMICAL FINE-TUNING OF THE OLD ASSYRIAN AND OLD BABYLONIAN CHRONOLOGIES

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Abstract

Recently much progress has been made in the absolute dating of the Old Assyrian and Old Babylonian chronologies by combining a new critical edition of the Old Assyrian eponym lists found at Kültepe-Kaneš (Revised Eponym List) with radiocarbon and astronomical dating techniques. This has led to narrowing down the absolute dating of the Old Babylonian chronology to the two Middle Chronologies (Ammī-ṣaduqa year 1 = 1646 or 1638 BC) and to reducing the candidates for the solar eclipse recorded in the Mari Eponym Chronicle (REL 127) to three eclipses (in 1845 BC, 1838 BC, and 1833 BC). In this paper I use the results of a recent study of the intercalation of the Old Assyrian calendar at Kaneš (REL 81–110) to further refine the absolute dating of the chronology of the first half of the second millennium BC. The new evidence suggests that astronomical intercalation criteria like the heliacal rising of the bright star Sirius may have played an important role in establishing the intercalation pattern of the Old Assyrian calendar. Using the REL to create three different solutions of the Old Assyrian calendar at Kaneš (REL 81–110), one for each candidate solar eclipse, I propose that the observed intercalation pattern provides an additional independent argument in support of the Low Middle Chronology. According to the absolute dating of the Old Assyrian chronology proposed here Šamšī-Adad was born in 1839 BC (REL 126), in the year preceding the partial solar eclipse of 24 March 1838 BC (REL 127) and he died in December 1767 BC (REL 197), during the eighteenth year of the reign of king Hammurabi of Babylon. This chronology proposal implies that the beginning of the reign of the Old Assyrian king Erišum (REL 1) may be dated to 1964 BC.

1. *Introduction*

Recently much progress has been made in the absolute dating of the Old Assyrian and Old Babylonian chronology by combining a new critical edition of the Old Assyrian eponym lists found at Kültepe (Revised Eponym List) with radiocarbon and astronomical dating techniques (Barjamovic, Hertel, and Larsen 2012; de Jong 2013; Nahm 2013; de Jong 2016; Manning et al. 2016). The Revised Eponym List (REL) constructed by Barjamovic, Hertel, and Larsen (2012, henceforth BHL) now provides a continuous sequence of eponyms covering 255 years of Old Assyrian history[1] with an internal uncertainty margin of at most a few years. BHL also showed that the uncertainty in the absolute dating of the REL amounts to about ± 10 years. This estimate is based on constraints derived from radiocarbon dating of timber used for the building of the Waršama palace in Kültepe, and of the Sarıkaya palace near Acemhöyük, both situated in central Anatolia, Turkey (Manning et al. 2010). Quite recently Manning et al. (2016) have revised their dendrochronological dating for Kültepe and associated sites resulting

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[1] The Revised Eponym List begins with eponym Šu-Ištar (REL 1), the accession year of king Erišum I, and it ends with Anāku-ana-Aššur (REL 255), the last eponym in the Kültepe Eponym List G (Günbattı 2008).

in a backward shift of about 15 years in absolute time. This leads to new dates for the felling of timbers used for the building of the Waršama palace (1855–1839 BC) and for the Sarıkaya palace (1797–1781 BC). While this revised dating no longer supports the simultaneity of the destruction of the Old Palace and the Kārum in Kaneš it still provides sufficiently tight constraints to only allow the High Middle Chronology (HMC) or the Low Middle Chronology (LMC) as possible solutions for the chronology of the Old Babylonian period (de Jong 2016, Manning et al. 2016).

Within the REL the lifetime of Šamšī-Adad which covers the period REL 126–197 may be used to further reduce the chronological uncertainty and to more firmly anchor the REL to absolute time by using astronomical dating techniques (de Jong 2013; Nahm 2013). Since we know that Šamšī-Adad died during the eighteenth year of the reign of Hammurabi (Charpin and Ziegler 2003, p. 174) the date of his death is constrained by the Venus observations of Ammī-ṣaduqa to 1775 BC (HMC) or 1767 BC (LMC).[2] It is also possible to independently date the birth of Šamšī-Adad using the solar eclipse that has been reported in the Mari Eponym Chronicle (Birot 1985, p. 228; Glassner 2004, p. 163; BHL, p. 32) in the year after his birth (REL 127). Three candidate solar eclipses have been proposed to explain this report, two in accordance with the Low Middle Chronology:

- the total eclipse of 24 June 1833 BC (Michel and Rocher 2000; Nahm 2013), and
- the partial (94%) eclipse at sunrise on 24 March 1838 BC (de Jong 2013),

and one in accordance with the High Middle Chronology:

- the partial (80%) eclipse at sunset on 5 August 1845 BC (de Jong 2013).

Once the birth and the death of Šamšī-Adad are independently dated his age can be determined and compared to the number of eponyms covering his lifetime from REL 126 to REL 197. For the LMC we have two possibilities: the 1833 BC eclipse implies that Šamšī-Adad was born in 1834 BC and that he was 67 years old when he died in 1767 BC so that four eponyms have to be removed between REL 126 and REL 197 and the 1838 BC eclipse implies that he was 72 when he died so that one additional eponym must be inserted. For the HMC we have an eclipse candidate in 1845 BC so that Šamšī-Adad was born in 1846 BC and died in 1775 at an age of 71 years, in exact agreement with the REL. According to a recent reappraisal of the uncertainties in the REL by Barjamovic (2015) and by Veenhof (2016) the scratching of four eponyms within the lifespan of Šamšī-Adad is more than can be accommodated within the uncertainties so that the 1833 BC eclipse may not qualify as a candidate for the event reported in REL 127.

Although the 1838 BC eclipse is the more spectacular and the more probable one of the two remaining candidate eclipses, in 1845 BC (HMC) and in 1838 BC (LMC), this is not a strong enough argument to exclude the High Middle Chronology (de Jong 2013). A more convincing argument in support of the Low Middle Chronology has been put forward by de Jong and Foertmeyer (2010). They suggested that the enhanced extinction in the atmosphere of Babylon detected in the Venus observations during the twelfth and thirteenth year of king Ammī-ṣaduqa is most naturally explained by a strong volcano eruption in 1628 BC. Traces of this eruption have been found in tree rings at several locations on the Northern Hemisphere

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[2] These dates are computed for Ammī-ṣaduqa year 1 = 1646/45 BC (HMC) or 1638/37 BC (LMC) using a time span of 146 years between the beginning of the reigns of Hammurabi and Ammī-ṣaduqa according to the Babylonian King List (Pruzsinszky 2009, p. 93).

(Pearson et al. 2009). A probable candidate is the violent eruption that destroyed the Greek island Thera (Friedrich et al. 2006).

In this paper I will attempt to date the birth of Šamšī-Adad by combining the solar eclipse reported in the year after his birth with the results of a study of the intercalation pattern of the Old Assyrian calendar in REL 81–110 by Stratford (2015). It will turn out that of the three solar eclipse candidates mentioned above, the one in 1838 BC leads to a calendar calibration in which the observed intercalation pattern is consistent with a calendar regulated by the heliacal rising of Sirius, the brightest star in the sky. This result provides another independent argument in favour of the Low Middle Chronology. At the same time it allows a firm absolute calibration of the Old Assyrian chronology with the accession of the Old Assyrian king Erišum I dated to 1964 BC.

2. *The Old Assyrian calendar at Kaneš*

The discovery of Old Assyrian eponym lists among the ruins of the Assyrian trade post (*Kārum*) in ancient Kaneš (present-day Kültepe, Turkey) by Veenhof (2000; 2003) has stimulated a renewed interest in the Old Assyrian calendar (for a recent review of the Middle and Old Assyrian calendar see Cancik-Kirschbaum and Johnson 2011/12). While it has long been thought that the Old (and Middle) Assyrian lunar calendar was not intercalated (Hunger 1980) and thus slowly running through the seasons, it now appears that this view has to be abandoned.

A convincing case in support of a consistent intercalation practice in the Old Assyrian calendar was presented by Veenhof (2000) based on his analysis of the Kaneš level II texts (REL 60–140). In addition Dercksen (2011a) found evidence for six intercalations in the period covered by REL 191–243 and he has also been able to establish that the first month of the Old Assyrian year fell in winter time, probably close to the Winter Solstice (Dercksen 2011b).

Based on a detailed analysis of a large corpus of about 1000 commercial texts (mostly debt notes) from Kaneš level II that can now be dated using the known order of the eponyms (REL) Stratford (2015) has recently been able to reconstruct the Old Assyrian calendar and its intercalation pattern for the period REL 81–110. Although his reconstruction is rather schematic in the sense that it uses a calendar with alternating 29- and 30-day months it is sufficiently realistic to be able to derive the intercalation pattern. Stratford confirms the suggestion made by Veenhof (2000) that intercalations occur by introducing a second month XII which is listed as the first month of the next year.

This practice can be understood by realizing that in Kaneš communication with the central administration in Assur was often prevented during winter time when the mountain passes southeast of the Halys were inaccessible due to ice and snow so that the name of the new eponym of the next year was not known when it began. This problem was overcome by introducing the concept of ‘successor eponym’[3] which was used during the first few months of the next year as long as the new eponym had not yet reached Kaneš. From the textual evidence it

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[3] The way to indicate a year in the Assyrian calendar was by using eponyms, names of a royal official (*limmum*) after which the year was named. The phrasing of a successor eponym was usually “*limmum ša qāti* PN”, the “official who took over from PN” (Stratford 2015, p. 302).

further appears that in years in which an intercalated second month XII (month XIIb in Stratford's notation) was planned, this month was included at the beginning of the successor eponym year. This implies that the instruction from Assur that a second month XII had to be intercalated in the next year had reached Kaneš before communication was interrupted, say by month XI at the latest, so that the decision to intercalate was probably made sometime during the summer.

From his analysis of the dated texts over a continuous period of thirty years Stratford finds attested intercalations in seven years and he infers intercalations in four more years from the transition of successor eponym to new eponym (in month IV at the latest) when the actual eponym for that year was finally communicated to Kaneš after reopening of the mountain passes in the spring (around 1 April). The derived intercalation pattern is fairly regular with four 2-year intervals, five 3-year intervals and one 5-year interval between intercalations.

In Stratford's schematic calendar alternating months of 29 and 30 days are assumed while in reality there are fifty-three 30-day months and forty-seven 29-day months per one hundred lunar months (because one synodic month equals 29.53 days) so that his calendar runs short by about 11 days after 30 years. To improve on Stratford's approach a full set of New Crescent dates during the 30 years covered by REL 81–110 is needed.

Since the sequence of eponyms between REL 80 and REL 130 is well established and uncontroversial (BHL, p. 4–5) it is possible to directly link the solar eclipse in REL 127 to the period REL 81–110 for which we know the intercalation pattern from the work of Stratford. For the HMC we have the solar eclipse candidate in 1845 BC (de Jong 2013) and for the LMC I will consider two eclipse candidates, the one in 1838 BC (de Jong 2013) and the one in 1833 BC (Nahm 2013). The latter eclipse is included because it is by far the most impressive one, in spite of the fact that it violates the uncertainty margin of the REL (see above). These three eclipses are linked by the REL to 30-year calendar periods starting 46 years earlier (REL 81), i.e. in 1891 BC, 1884 BC, and 1879 BC, respectively.

Using a set of computed New Crescent dates between 1900 and 1850 BC[4] and adopting the intercalation pattern derived by Stratford (2015) I have constructed the three 30-year calendars displayed in Tables 1, 2, and 3 in chronological order. The layout of the Tables is as follows:

- Each line represents one year labeled by its REL number in the first column and by the associated Julian year in the last column.
- Each year contains twelve or thirteen months labeled by Roman numerals.
- Following Stratford (2015) the thirteenth (intercalated) month is labeled XIIb.

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[4] The computation of these New Crescent dates is based on solar and lunar ephemerides computed with algorithms given by Bretagnon and Simon (1986) and Chapront-Touzé and Chapront (1991) using a secular acceleration of the Moon of 26 arc seconds per century^2 and a clock time correction advocated by Huber (2006) of $\Delta T = 32.5\ T^2$ seconds (where T is the number of centuries counted from 1800 AD). New crescent visibility dates were computed according to the PVN criterion (for a recent discussion see Huber 2011). New crescent dates and month lengths resulting from my programs have been tested against Neo- and Late-Babylonian new crescent dates collected by Fatoohi et al. (1991) from the Astronomical Diaries and against the collection of attested Neo- and Late-Babylonian 30-day months listed in Huber et al. (1982, Appendix A-1) with results virtually identical to those of the tests performed by Huber et al. (1982).

Table 1. The Old Assyrian calendar at Kaneš for "darkening of the Sun" in 1845 BC (= REL 127).

REL	I	II	III	IV	V	VI	S*	VII	S*	VIII	S*	IX	X	XI	XII	XIIb	Year
81	11-Jan	9-Feb	11-Mar	10-Apr	9-May	8-Jun		7-Jul	**16**	6-Aug		4-Sep	4-Oct	2-Nov	2-Dec	**31-Dec**	1891 BC
82	30-Jan	28-Feb	30-Mar	28-Apr	28-May	27-Jun	26	26-Jul		25-Aug		23-Sep	23-Oct	21-Nov	21-Dec		1890 BC
83	19-Jan	18-Feb	18-Mar	16-Apr	16-May	15-Jun		14-Jul	9	13-Aug		11-Sep	11-Oct	10-Nov	10-Dec		1889 BC
84	8-Jan	6-Feb	8-Mar	6-Apr	5-May	4-Jun		3-Jul	**20**	2-Aug		31-Aug	30-Sep	30-Oct	29-Nov	**29-Dec**	1888 BC
85	27-Jan	25-Feb	27-Mar	25-Apr	24-May	22-Jun		22-Jul	1	20-Aug		19-Sep	20-Oct	19-Nov	18-Dec		1887 BC
86	17-Jan	15-Feb	16-Mar	15-Apr	14-May	12-Jun		11-Jul	12	10-Aug		9-Sep	9-Oct	8-Nov	7-Dec		1886 BC
87	6-Jan	4-Feb	5-Mar	3-Apr	2-May	1-Jun		30-Jun	23	29-Jul		28-Aug	27-Sep	27-Oct	25-Nov		1885 BC
88	*25-Dec*	23-Jan	22-Feb	24-Mar	22-Apr	21-May		20-Jun		19-Jul	**4**	18-Aug	16-Sep	16-Oct	15-Nov	**14-Dec**	1884 BC
89	13-Jan	11-Feb	13-Mar	11-Apr	11-May	9-Jun		9-Jul	14	7-Aug		6-Sep	6-Oct	4-Nov	3-Dec		1883 BC
90	2-Jan	31-Jan	2-Mar	31-Mar	30-Apr	29-May		28-Jun	25	28-Jul		27-Aug	25-Sep	25-Oct	23-Nov	22-Dec	1882 BC
91	21-Jan	19-Feb	19-Mar	18-Apr	18-May	16-Jun		16-Jul	7	15-Aug		14-Sep	13-Oct	12-Nov	11-Dec		1881 BC
92	9-Jan	7-Feb	9-Mar	7-Apr	7-May	5-Jun		5-Jul	**18**	4-Aug		3-Sep	3-Oct	1-Nov	1-Dec	**30-Dec**	1880 BC
93	28-Jan	26-Feb	28-Mar	26-Apr	26-May	24-Jun	29	24-Jul		23-Aug		22-Sep	22-Oct	20-Nov	19-Dec		1879 BC
94	18-Jan	16-Feb	17-Mar	16-Apr	15-May	14-Jun		13-Jul	10	12-Aug		11-Sep	10-Oct	9-Nov	9-Dec		1878 BC
95	7-Jan	6-Feb	6-Mar	5-Apr	4-May	2-Jun		2-Jul	21	31-Jul		30-Aug	28-Sep	28-Oct	27-Nov	26-Dec	1877 BC
96	25-Jan	24-Feb	25-Mar	24-Apr	23-May	21-Jun		21-Jul	2	19-Aug		18-Sep	17-Oct	16-Nov	15-Dec		1876 BC
97	14-Jan	13-Feb	14-Mar	13-Apr	12-May	11-Jun		10-Jul	13	9-Aug		7-Sep	6-Oct	5-Nov	4-Dec		1875 BC
98	3-Jan	2-Feb	4-Mar	2-Apr	2-May	31-May		30-Jun	**23**	29-Jul		28-Aug	26-Sep	25-Oct	24-Nov	**23-Dec**	1874 BC
99	22-Jan	21-Feb	21-Mar	20-Apr	19-May	18-Jun		18-Jul	5	16-Aug		15-Sep	14-Oct	12-Nov	12-Dec		1873 BC
100	10-Jan	9-Feb	10-Mar	9-Apr	8-May	7-Jun		7-Jul	**16**	5-Aug		4-Sep	4-Oct	2-Nov	2-Dec	**31-Dec**	1872 BC
101	30-Jan	28-Feb	29-Mar	28-Apr	27-May	26-Jun	27	25-Jul		24-Aug		23-Sep	23-Oct	21-Nov	21-Dec		1871 BC
102	19-Jan	18-Feb	19-Mar	17-Apr	17-May	15-Jun		14-Jul	9	13-Aug		12-Sep	12-Oct	11-Nov	11-Dec		1870 BC
103	9-Jan	7-Feb	8-Mar	6-Apr	5-May	3-Jun		3-Jul	20	1-Aug		31-Aug	30-Sep	30-Oct	29-Nov	28-Dec	1869 BC
104	27-Jan	25-Feb	27-Mar	25-Apr	24-May	22-Jun		22-Jul	1	20-Aug		19-Sep	19-Oct	18-Nov	18-Dec		1868 BC
105	16-Jan	15-Feb	16-Mar	14-Apr	14-May	12-Jun		11-Jul	12	10-Aug		8-Sep	8-Oct	7-Nov	7-Dec		1867 BC
106	5-Jan	4-Feb	5-Mar	4-Apr	3-May	2-Jun		1-Jul	22	30-Jul		29-Aug	28-Sep	27-Oct	26-Nov	25-Dec	1866 BC
107	24-Jan	22-Feb	23-Mar	22-Apr	21-May	20-Jun		19-Jul	4	18-Aug		16-Sep	16-Oct	14-Nov	14-Dec		1865 BC
108	12-Jan	10-Feb	12-Mar	11-Apr	10-May	9-Jun		8-Jul	**15**	7-Aug		6-Sep	6-Oct	4-Nov	3-Dec	***2-Jan***	1864 BC
109	31-Jan	1-Mar	31-Mar	29-Apr	29-May	28-Jun	25	27-Jul		26-Aug		25-Sep	25-Oct	23-Nov	22-Dec		1863 BC
110	20-Jan	19-Feb	20-Mar	18-Apr	18-May	17-Jun		16-Jul	7	15-Aug		14-Sep	14-Oct	13-Nov	12-Dec		1862 BC

Table 2. The Old Assyrian calendar at Kaneš for “darkening of the Sun” in 1838 BC (= REL 127).

REL	I	II	III	IV	V	VI	VII	S*	VIII	S*	IX	X	XI	XII	XIIb	Year
81	*25-Dec*	23-Jan	22-Feb	24-Mar	22-Apr	21-May	20-Jun		19-Jul	**4**	18-Aug	16-Sep	16-Oct	15-Nov	**14-Dec**	1884 BC
82	13-Jan	11-Feb	13-Mar	11-Apr	11-May	9-Jun	9-Jul	14	7-Aug		6-Sep	6-Oct	4-Nov	3-Dec		1883 BC
83	2-Jan	31-Jan	2-Mar	31-Mar	30-Apr	29-May	28-Jun	25	28-Jul		27-Aug	25-Sep	25-Oct	23-Nov		1882 BC
84	*22-Dec*	21-Jan	19-Feb	19-Mar	18-Apr	18-May	16-Jun		16-Jul	**7**	15-Aug	14-Sep	13-Oct	12-Nov	**11-Dec**	1881 BC
85	9-Jan	7-Feb	9-Mar	7-Apr	7-May	5-Jun	5-Jul	18	4-Aug		3-Sep	3-Oct	1-Nov	1-Dec		1880 BC
86	*30-Dec*	28-Jan	26-Feb	28-Mar	26-Apr	26-May	24-Jun	29	24-Jul		23-Aug	22-Sep	22-Oct	20-Nov		1879 BC
87	*19-Dec*	18-Jan	16-Feb	17-Mar	16-Apr	15-May	14-Jun		13-Jul	10	12-Aug	11-Sep	10-Oct	9-Nov		1878 BC
88	*9-Dec*	7-Jan	6-Feb	6-Mar	5-Apr	4-May	2-Jun		2-Jul	**21**	31-Jul	30-Aug	28-Sep	28-Oct	**27-Nov**	1877 BC
89	*26-Dec*	25-Jan	24-Feb	25-Mar	24-Apr	23-May	21-Jun		21-Jul	2	19-Aug	18-Sep	17-Oct	16-Nov		1876 BC
90	*15-Dec*	14-Jan	13-Feb	14-Mar	13-Apr	12-May	11-Jun		10-Jul	13	9-Aug	7-Sep	6-Oct	5-Nov	4-Dec	1875 BC
91	3-Jan	2-Feb	4-Mar	2-Apr	2-May	31-May	30-Jun	23	29-Jul		28-Aug	26-Sep	25-Oct	24-Nov		1874 BC
92	*23-Dec*	22-Jan	21-Feb	21-Mar	20-Apr	19-May	18-Jun		18-Jul	**5**	16-Aug	15-Sep	14-Oct	12-Nov	**12-Dec**	1873 BC
93	10-Jan	9-Feb	10-Mar	9-Apr	8-May	7-Jun	7-Jul	16	5-Aug		4-Sep	4-Oct	2-Nov	2-Dec		1872 BC
94	*31-Dec*	30-Jan	28-Feb	29-Mar	28-Apr	27-May	26-Jun	27	25-Jul		24-Aug	23-Sep	23-Oct	21-Nov		1871 BC
95	*21-Dec*	19-Jan	18-Feb	19-Mar	17-Apr	17-May	15-Jun		14-Jul	9	13-Aug	12-Sep	12-Oct	11-Nov	11-Dec	1870 BC
96	9-Jan	7-Feb	8-Mar	6-Apr	5-May	3-Jun	3-Jul	20	1-Aug		31-Aug	30-Sep	30-Oct	29-Nov		1869 BC
97	*28-Dec*	27-Jan	25-Feb	27-Mar	25-Apr	24-May	22-Jun		22-Jul	1	20-Aug	19-Sep	19-Oct	18-Nov		1868 BC
98	*18-Dec*	16-Jan	15-Feb	16-Mar	14-Apr	14-May	12-Jun		11-Jul	**12**	10-Aug	8-Sep	8-Oct	7-Nov	**7-Dec**	1867 BC
99	5-Jan	4-Feb	5-Mar	4-Apr	3-May	2-Jun	1-Jul	22	30-Jul		29-Aug	28-Sep	27-Oct	26-Nov		1866 BC
100	*25-Dec*	24-Jan	22-Feb	23-Mar	22-Apr	21-May	20-Jun		19-Jul	**4**	18-Aug	16-Sep	16-Oct	14-Nov	**14-Dec**	1865 BC
101	12-Jan	10-Feb	12-Mar	11-Apr	10-May	9-Jun	8-Jul	15	7-Aug		6-Sep	6-Oct	4-Nov	3-Dec		1864 BC
102	2-Jan	31-Jan	1-Mar	31-Mar	29-Apr	29-May	28-Jun	25	27-Jul		26-Aug	25-Sep	25-Oct	23-Nov		1863 BC
103	*22-Dec*	20-Jan	19-Feb	20-Mar	18-Apr	18-May	17-Jun		16-Jul	7	15-Aug	14-Sep	14-Oct	13-Nov	12-Dec	1862 BC
104	10-Jan	8-Feb	9-Mar	7-Apr	6-May	5-Jun	4-Jul	19	3-Aug		2-Sep	2-Oct	1-Nov	30-Nov		1861 BC
105	*30-Dec*	28-Jan	26-Feb	28-Mar	26-Apr	25-May	24-Jun	29	24-Jul		22-Aug	21-Sep	21-Oct	19-Nov		1860 BC
106	*19-Dec*	17-Jan	16-Feb	17-Mar	16-Apr	15-May	13-Jun		13-Jul	10	12-Aug	10-Sep	10-Oct	8-Nov	8-Dec	1859 BC
107	7-Jan	5-Feb	7-Mar	5-Apr	5-May	3-Jun	3-Jul	20	1-Aug		31-Aug	29-Sep	28-Oct	27-Nov		1858 BC
108	*27-Dec*	25-Jan	24-Feb	25-Mar	23-Apr	23-May	21-Jun		21-Jul	**2**	19-Aug	18-Sep	17-Oct	15-Nov	**15-Dec**	1857 BC
109	13-Jan	12-Feb	14-Mar	12-Apr	12-May	11-Jun	10-Jul	13	9-Aug		7-Sep	6-Oct	5-Nov	4-Dec		1856 BC
110	3-Jan	1-Feb	3-Mar	1-Apr	1-May	31-May	30-Jun	23	29-Jul		28-Aug	26-Sep	25-Oct	24-Nov		1855 BC

Table 3. The Old Assyrian calendar at Kaneš for "darkening of the Sun" in 1833 BC (= REL 127).

REL	I	II	III	IV	V	VI	VII	S*	VIII	S*	IX	X	XI	XII	XIIb	Year
81	*30-Dec*	28-Jan	26-Feb	28-Mar	26-Apr	26-May	24-Jun	**29**	24-Jul		23-Aug	22-Sep	22-Oct	20-Nov	**19-Dec**	1879BC
82	18-Jan	16-Feb	17-Mar	16-Apr	15-May	14-Jun	13-Jul	10	12-Aug		11-Sep	10-Oct	9-Nov	9-Dec		1878BC
83	7-Jan	6-Feb	6-Mar	5-Apr	4-May	2-Jun	2-Jul	21	31-Jul		30-Aug	28-Sep	28-Oct	27-Nov		1877BC
84	*26-Dec*	25-Jan	24-Feb	25-Mar	24-Apr	23-May	21-Jun		21-Jul	**2**	19-Aug	18-Sep	17-Oct	16-Nov	**15-Dec**	1876BC
85	14-Jan	13-Feb	14-Mar	13-Apr	12-May	11-Jun	10-Jul	13	9-Aug		7-Sep	6-Oct	5-Nov	4-Dec		1875BC
86	3-Jan	2-Feb	4-Mar	2-Apr	2-May	31-May	30-Jun	23	29-Jul		28-Aug	26-Sep	25-Oct	24-Nov		1874BC
87	*23-Dec*	22-Jan	21-Feb	21-Mar	20-Apr	19-May	18-Jun		18-Jul	5	16-Aug	15-Sep	14-Oct	12-Nov		1873BC
88	*12-Dec*	10-Jan	9-Feb	10-Mar	9-Apr	8-May	7-Jun		7-Jul	**16**	5-Aug	4-Sep	4-Oct	2-Nov	**2-Dec**	1872BC
89	*31-Dec*	30-Jan	28-Feb	29-Mar	28-Apr	27-May	26-Jun	27	25-Jul		24-Aug	23-Sep	23-Oct	21-Nov		1871BC
90	*21-Dec*	19-Jan	18-Feb	19-Mar	17-Apr	17-May	15-Jun		14-Jul	9	13-Aug	12-Sep	12-Oct	11-Nov	11-Dec	1870BC
91	9-Jan	7-Feb	8-Mar	6-Apr	5-May	3-Jun	3-Jul	20	1-Aug		31-Aug	30-Sep	30-Oct	29-Nov		1869BC
92	28-Dec	27-Jan	25-Feb	27-Mar	25-Apr	24-May	22-Jun		22-Jul	**1**	20-Aug	19-Sep	19-Oct	18-Nov	**18-Dec**	1868BC
93	16-Jan	15-Feb	16-Mar	14-Apr	14-May	12-Jun	11-Jul	12	10-Aug		8-Sep	8-Oct	7-Nov	7-Dec		1867BC
94	5-Jan	4-Feb	5-Mar	4-Apr	3-May	2-Jun	1-Jul	22	30-Jul		29-Aug	28-Sep	27-Oct	26-Nov		1866BC
95	*25-Dec*	24-Jan	22-Feb	23-Mar	22-Apr	21-May	20-Jun		19-Jul	4	18-Aug	16-Sep	16-Oct	14-Nov	14-Dec	1865BC
96	12-Jan	10-Feb	12-Mar	11-Apr	10-May	9-Jun	8-Jul	15	7-Aug		6-Sep	6-Oct	4-Nov	3-Dec		1864BC
97	2-Jan	31-Jan	1-Mar	31-Mar	29-Apr	29-May	28-Jun	25	27-Jul		26-Aug	25-Sep	25-Oct	23-Nov		1863BC
98	*22-Dec*	20-Jan	19-Feb	20-Mar	18-Apr	18-May	17-Jun		16-Jul	**7**	15-Aug	14-Sep	14-Oct	13-Nov	**12-Dec**	1862BC
99	10-Jan	8-Feb	9-Mar	7-Apr	6-May	5-Jun	4-Jul	19	3-Aug		2-Sep	2-Oct	1-Nov	30-Nov		1861BC
100	*30-Dec*	28-Jan	26-Feb	28-Mar	26-Apr	25-May	24-Jun	**29**	24-Jul		22-Aug	21-Sep	21-Oct	19-Nov	**19-Dec**	1860BC
101	17-Jan	16-Feb	17-Mar	16-Apr	15-May	13-Jun	13-Jul	14	12-Aug		10-Sep	10-Oct	8-Nov	8-Dec		1859BC
102	7-Jan	5-Feb	7-Mar	5-Apr	5-May	3-Jun	3-Jul	20	1-Aug		31-Aug	29-Sep	28-Oct	27-Nov		1858BC
103	*27-Dec*	25-Jan	24-Feb	25-Mar	23-Apr	23-May	21-Jun		21-Jul	2	19-Aug	18-Sep	17-Oct	15-Nov	15-Dec	1857BC
104	13-Jan	12-Feb	14-Mar	12-Apr	12-May	11-Jun	10-Jul	13	9-Aug		7-Sep	6-Oct	5-Nov	4-Dec		1856BC
105	3-Jan	1-Feb	3-Mar	1-Apr	1-May	31-May	30-Jun	23	29-Jul		28-Aug	26-Sep	25-Oct	24-Nov		1855BC
106	*23-Dec*	22-Jan	20-Feb	22-Mar	20-Apr	20-May	18-Jun		18-Jul	5	17-Aug	15-Sep	15-Oct	13-Nov	13-Dec	1854BC
107	11-Jan	10-Feb	10-Mar	9-Apr	8-May	6-Jun	6-Jul	17	5-Aug		3-Sep	3-Oct	2-Nov	2-Dec		1853BC
108	*31-Dec*	30-Jan	28-Feb	29-Mar	27-Apr	27-May	25-Jun	**28**	25-Jul		23-Aug	22-Sep	22-Oct	21-Nov	**21-Dec**	1852BC
109	19-Jan	18-Feb	19-Mar	17-Apr	16-May	15-Jun	14-Jul	13	13-Aug		11-Sep	11-Oct	10-Nov	10-Dec		1851BC
110	9-Jan	7-Feb	9-Mar	7-Apr	6-May	4-Jun	4-Jul	19	2-Aug		31-Aug	30-Sep	30-Oct	29-Nov		1850BC

- The entry for each month lists the Julian date (counted from midnight to midnight) of the first day of that month defined by the first evening appearance of the lunar crescent.
- Julian dates of the first day of the month that fall in the previous or in the next Julian year are shown in italic script.
- Entries in columns labeled S* (Sirius rising dates) and XIIb in years with attested intercalations are shown in bold face.

Upon inspection of the data in Tables 1, 2, and 3, we see that, as expected, the first day of the year falls close to the Julian date of the Winter Solstice (January 5 in the period from 1900 to 1850 BC). From the dates of the first day of month I in the Tables we find that on average the first day of the year fell on 16 January, 30 December, and 3 January, for the three calendar solutions (11 days after, and 6 and 2 days before the Winter Solstice). If, on the other hand, we would have taken the year to begin with the second month XII (XIIb) in the intercalated years, as suggested by the use of the successor eponyms in Kaneš, the average beginning of the year would have fallen 11 days earlier.

3. *Intercalation of the Old Assyrian calendar*

The reconstruction of the calendar employed in ancient Kaneš over thirty consecutive years during the first half of the nineteenth century BC by Stratford (2015) clearly demonstrates that the Old Assyrian calendar was an intercalated lunar calendar. Although this calendar shows that the beginning of the year was roughly kept lined up with the Winter Solstice, it is not at all clear that the Winter Solstice was the driver of the intercalation process. On the contrary, the evidence suggests that the Winter Solstice may have had nothing to do with it since, as we have seen above, the decision to intercalate was apparently made sometime in the preceding summer. In this section I will investigate whether the intercalation pattern inferred by Stratford (2015) from the textual material can be used to choose between the three calendar solutions so that in this way the solar eclipse and the year of the birth of Šamšī-Adad can be dated.

In ancient Mesopotamia intercalation was proclaimed by royal decree. A well-known example from the second millennium BC is the letter sent by Hammurabi (1784–1742 BC)[5] to Sîn–iddinam, governor of Larsa, in which Hammurabi announces that in that year a second month Ulūlu will be intercalated (Frankena 1966, p. 11). In deciding when to intercalate the king let himself be advised by astronomical experts. Although this is only documented in correspondence of the Neo-Assyrian kings with their court astronomers during the seventh century BC (Parpola 1970, nos. 38, 190, 277, 285, 287, and 235) it seems plausible to assume that this kind of advice was already available to the Old Assyrian kings.[6] Shortly after 500 BC, during Achaemenid rule, the calendar became rigorously structured in 19-year cycles with 7 intercalations at fixed intervals distributed over 19 years (Britton 2007).

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[5] Unless explicitly mentioned otherwise all historical dates in this paper follow the Low Middle Chronology.

[6] That advisers with astronomical expertise were present at the court in Mari may be inferred from a letter of the diviner Asqūdum about the occurrence of a lunar eclipse to Yasmah-Addu, son of Šamšī-Adad, and king of Mari from 1787–1767 BC (Charpin 2011, p. 254). This may also be inferred from the presence of a copy of a Babylonian text containing eclipse omina in the royal archive of Mari dating from the same period (Durand 1988, no. 248).

A perfectly regulated lunar calendar requires intercalations every 2.7 years to remain lined up with the solar year. In practice this implies an intercalation at intervals of 3 or 2 years with 3-year intervals predominating. From actual records we find instances of intercalations at intervals of 2 and 3 years from the third millennium onwards. On the other hand we also find instances of successive intercalary years and no evidence of any systematic practice (Britton, 2007, p. 119).

The earliest discussion of when to intercalate an additional month appears in the astronomical compendium MUL.APIN (Hunger and Pingree 1989) which contains 31 lines in which a number of different intercalation rules are given. Since MUL.APIN is clearly composed of different sources which may have different origins in time and place it is difficult to uniquely date its content. Hunger and Pingree (1989, 10ff.) suggest that it was composed around 1000 BC in Assyria while parts of it may be older. A few years ago I managed to date the rising star list in MUL.APIN to 1300 BC ± 150 years and found that Babylon was the most probable observing site (de Jong 2007).

Some of the intercalation rules in MUL.APIN are quite crude; for example on Tablet II, section ii, line 17 we read:

> "In three years you proclaim this year to be a leap year".

This implies that on average an additional month should be intercalated once every three years. Other prescriptions contain quite detailed astronomical algorithms; for example on Tablet II, Gap A, lines 12 and 13 we find:

> "If on the 15th of Du'uzu[7] (month IV) KAK.SI.SÁ (the Arrow = Sirius) becomes visible, this year is normal. If KAK.SI.SÀ becomes visible on the 15th of Abu (month V), this year is a leap year".

There are four more similar intercalation prescriptions in MUL.APIN using the first visibility of stars: of MUL.MUL (Pleiades) in month II (normal year) or III (leap year), of ŠU.PA (Arcturus) in month VI/VII and of ŠU.GI (Mirphak) and KU (Fomalhaut) in month XII/I.[8] These intercalation rules are based on the fact that the first visibility of stars occurs each year on the same day in the solar year so that the observation of this phenomenon is indeed eminently suitable to line up the lunar calendar to the solar year. This is achieved in practice by intercalating an additional lunar month whenever a certain star becomes visible one month later than expected.

Evidence in support of the early use of the first visibility of stars as an intercalation criterion may be found in the so-called Astrolabe texts (Horowitz 2011, p. 154–166) in which for each of the twelve months (sometimes in a pictorial representation) three stars are listed whose first visibility is expected in those months.[9] According to the Astrolabe texts the Babylonian month IV (month of the god Tammuz) is associated with KAK.SI.SÁ (Sirius). Although

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[7] According to Britton (2002, p. 23) the 15th day of the month may be considered representative for the whole month. This is first attested in the Old Babylonian text BM 17175.

[8] The Pleiades is a star cluster in the constellation Taurus consisting of more than 1000 stars of which only 7 are visible with the naked eye. The star Arcturus is the brightest star of the modern constellation Bootes, Mirphak is the brightest star of Perseus and Fomalhaut of Piscis Austrinus.

[9] Of these thirty-six "stars", four turn out to be planets and a few others never rise (and set) because they are circumpolar. The majority of the remaining ones can be identified with known stars. The ones that can be identified are sometimes misplaced by being associated with other months than the one in which their first visibility is expected (see Reiner and Pingree 1981, Table II).

the earliest known Astrolabe is found on a Middle Assyrian tablet, Horowitz supposes that the first Astrolabe was composed no later than the Middle Babylonian period and perhaps as early as the Old Babylonian period. All five stars of which the first visibility is used in the intercalation rules of the much later compendium MUL.APIN (see above) are already listed in the Astrolabe texts.[10]

In principle the first visibility of any star, as long as it is not circumpolar,[11] can be used to regulate the intercalation process but in practice only bright stars are suitable for this because their first visibility is most easily observed. For that reason Sirius, the brightest star in the sky, is the prime candidate. As we have seen above, the astronomical compendium MUL.APIN bears witness of the fact that Sirius was indeed used for this purpose. That the observation of the first visibility of Sirius to decide about intercalation is a persistent tradition in Mesopotamia is confirmed by the fact that it seems to be closely related to the intercalation pattern of the rigidly structured Late-Babylonian calendar which was introduced shortly after 500 BC (Britton 2007). Sachs (1952) has shown that during the last three centuries BC all dates of Sirius' first visibility, computed according to the so-called Uruk scheme, fell in the month Du'uzu (month IV).[12]

To investigate whether already in the nineteenth century BC the intercalation of the Old Assyrian calendar could have been regulated by rules like the ones found in MUL.APIN I have included in Tables 1, 2, and 3 in columns labeled S* the lunar dates of the first visibility of Sirius.[13] Depending on the weather these dates may vary by up to ± 3 days.

The observation of the first visibility (also called first appearance or heliacal rising) of Sirius is a straightforward observation for an experienced observer. Since Mesopotamian astronomy is based on the observation of first and last appearances of stars and planets[14] we may safely assume that it was a routine observation for the scholars in ancient Assur who were involved with astronomy and calendar keeping.

To initiate the reader into the secrets of Babylonian observational practice I will now describe in some detail the observation of the heliacal rising of Sirius in July 1873 BC when Sirius was expected to reappear on one of the first days of month VIII in the year of the eponymy of Elāli (REL 92) according to the Old Assyrian calendar solution of Table 2. From the 1st day of month VIII onwards the observer(s) would be scanning the horizon at Assur in the South-East from about one hour before sunrise onwards to check for the first appearance of Sirius in the morning twilight sky. Then, after unsuccessful sightings on the first four days of the month, in the early morning of the 5th day (23 July 1873 BC) at 4:02 hours (Local

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[10] According to the Astrolabe texts the first visibility of the star ŠU.GI (Mirphak) falls in month II while in MUL.APIN it is correctly associated with month XII.

[11] Stars located within angular distance φ from the celestial North Pole, where φ is the geographical latitude of the location on Earth are said to be circumpolar. Their trajectory in the sky never crosses the horizon so that they never set (and thus also never rise). Circumpolar stars are therefore visible throughout the year during every night (if the weather permits).

[12] According to the Uruk scheme the lunar dates of the equinoxes and solstices and of the phases of Sirius are fixed within the 19-year calendar cycle. Sachs (1952) has shown that of the rising dates of Sirius eighteen occur in month IV and only one in month III (on the 29th day).

[13] These lunar dates correspond to a Julian date of 23 July, the date of the first appearance of Sirius in the morning sky at Assur between 1850 and 1900 BC under nominal atmospheric conditions, adopting a visual extinction of 0.27 magnitudes per air mass, similar to conditions in Babylon around 1300 BC (see de Jong 2007).

[14] The oldest records of observation of first and last appearances of the planet Venus date from the reign of the Old Babylonian king Ammī-ṣaduqa (see Reiner and Pingree 1975).

Time) Sirius appeared as a very weak star against the twilight sky at an altitude of about 2° above the horizon in the South-East. At that moment the Sun was still about 8° below the horizon. While the sky was gradually brightening Sirius remained visible for about 20 minutes to disappear at 4:23 hours at an altitude of 5½° above the horizon. The night ended 17 minutes later when the Sun rose at 4:40 hours. From that date onwards Sirius would be visible each clear night for the next 10 months, initially only in the early morning before sunrise, later during most of the night and finally only in the early evening after sunset. The last visibility of Sirius occurred shortly after sunset around day 27 of month IV in the year of the eponymy of Iddin-abum (5 May 1872 BC). After that date Sirius became unobservable for about 80 days because of the proximity of the Sun to reappear again at its next heliacal rising around day 16 of month VII of that year (23 July 1872 BC).

Turning to the calendar solutions in Tables 1, 2, and 3, we find that the Sirius rising dates in columns S* show an excellent correlation with the intercalation pattern in Table 2, a fair correlation in Table 3 and a poor correlation in Table 1. In the calendar solution of Table 2 all intercalations, both the attested and the derived ones, are predicted by a Sirius rising in month VIII.[15] Of the three additional rising dates in month VIII, one (day 10 in REL 87) may be understood if the required intercalation was for whatever reason not implemented at the end of that year but in the next year. The other two, on day 1 in REL 97 and on day 2 in REL 89, may be moved back to month VII by either one of two possible effects, a delay (of at most one day) in the beginning of that month due to bad weather, and/or a one to two days earlier than expected rising of Sirius due to clear skies. The Sirius risings in month VIII of the calendar solution of Table 3 correctly predict seven out of the eleven intercalations. The failure in REL 87 can again be attributed to an omission in that year. To move the Sirius dates one month forward from month VII to month VIII in the other three years (REL 81, 100 and 108) we require continuous periods of bad weather of 1 to 3 days duration at the end of month VII in those years, which is not impossible. Finally, in the calendar solution of Table 1 the distribution of the Sirius dates seems unrelated to the intercalation pattern.

In practice the Sirius intercalation rule is a fairly robust prescription because it is rather independent of the weather. If bad weather prevents the observation of Sirius it will appear on one of the next days of the same month in more than 90% of the cases so that the intercalation criterion is usually not affected.

Now the question arises whether one can use the prediction of intercalations in the Old Assyrian calendar by astronomical algorithms as a criterion to discriminate between different calendar solutions and (implicitly) between different solar eclipse candidates. If I interpret the successful prediction of the intercalation pattern in the calendar of Table 2 (and to a somewhat lesser extent of Table 3) as a confirmation of my suggestion[16] that already during the Old Assyrian period the heliacal rising of Sirius was used for calendar synchronization this question can be answered in the affirmative sense. Then it follows that on this basis the eclipse of 1845 BC may be excluded as a candidate for the "darkening of the Sun" in

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[15] Notice that the Old Assyrian year is three months out of phase with the Old Babylonian year, which began around the Spring Equinox, so that month VIII corresponds to month V in the Old Babylonian calendar, in agreement with the intercalation algorithm of MUL.APIN.

[16] The hypothesis that intercalation of the Assyrian calendar was based on the concept that the heliacal rising of certain stars should preferentially take place in their 'own month' (as listed in the Astrolabe texts) has been advanced for the Middle Assyrian calendar by Koch (1989, p. 135).

REL 127 so that the Low Middle Chronology is the only one of the two remaining chronologies that passes this new chronological test.[17] Which of the two candidate solar eclipses, the one in 1833 BC or in 1838 BC, is referred to in REL 127 remains to be decided.

4. *The Old Babylonian calendar during the reign of Ammī-ṣaduqa*

As we have seen in the preceding section the suggestion by Veenhof (2000; 2003) that the Old Assyrian calendar was kept lined up with the seasons by intercalation, has been confirmed by the analysis of Stratford (2015) and is further supported by my more detailed astronomical reconstruction of a 30-year section of the Old Assyrian calendar. While my suggestion that the intercalation was regulated by using astronomical observations is consistent with the attested intercalation pattern, it would gain in strength if we could find independent evidence for the existence of similar intercalation practices elsewhere in Mesopotamia. One potential source for such independent evidence is the calendar during the reign of the Old Babylonian king Ammī-ṣaduqa because all intercalations during this period are known and independently corroborated by the Venus observations.[18]

In their study of the Venus observations Huber et al. (1982) listed eight implied and attested intercalations during Ammī-ṣaduqa's reign. This list was recently updated by Huber (2016, Appendix A.2) and now counts six well-established intercalations during the first eighteen years of his reign and two uncertain ones during the last three years. Using the secure intercalations and New Crescent dates computed for Babylon between 1650 and 1600 BC I have reconstructed in Table 4 the Old Babylonian calendar during the first eighteen years of the reign of Ammī-ṣaduqa for the Low Middle Chronology. The data in Table 4 show that sometimes a second month Ulūlu (VI_2) and at other times a second month Addaru (XII_2) was intercalated. Similar to Tables 1, 2, and 3, I have also listed, in columns labeled S*, the lunar dates of the heliacal rising of Sirius, adopting a Julian date of 20 July for the heliacal rising of Sirius in Babylon during the second half of the seventeenth century BC.[19]

From the calendar data in Table 4 we find that during the Old Babylonian period the heliacal rising of Sirius may indeed have played a role in deciding for intercalation. All attested intercalations are preceded by a month IV heliacal rising date[20] and never by a month III date. On the other hand, if indeed a month IV helical rising date is the criterion used, three of the

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[17] It is important to point out that this conclusion hinges on the precise definition of the Sirius intercalation rule. Based on the formulation in MUL.APIN one might be tempted to think that intercalation was supposed to take place when the rising of Sirius took place after the 15th day of month VII (IV) rather than in month VIII (V). In that case the calendar data in Table 1 would provide the best fit and the High Middle Chronology would be supported by the reconstructed intercalation pattern of Old Assyrian calendar. However, Britton (2002, p. 23) notes that whenever in Old and Middle Babylonian texts celestial phenomena are said to take place on the 15th day of some month it should be understood to mean that they occurred in that month "since the actual dates of the phenomena in the civil calendar would range throughout the month, assuming appropriate intercalation". This is consistent with the finding that according to the "Uruk scheme" after 300 BC Sirius always rises in Month IV (Sachs 1952).

[18] The fact that each attested intercalation is in exact agreement with the addition of one month required by the astronomically determined length of the invisibility interval of Venus is a strong argument in support of the historicity of the Venus observations.

[19] This date has been computed for Babylon in 1625 BC adopting a visual extinction of 0.27 magnitudes per airmass (see de Jong 2007).

[20] The only heliacal rising date in Table 4 that falls in month V of Ammī-ṣaduqa year 10 may in reality have been observed on one of the last days of month IV if the sky happened to be clearer than average.

Table 4. The Old Babylonian calendar during the first 18 years of the reign of Ammī-ṣaduqa (LMC).

yr	I	II	III	S*	IV	S*	V	S*	VI	VI2	VII	VIII	IX	X	XI	XII	XII2	Year
1	2-May	1-Jun	30-Jun	20	30-Jul		28-Aug		27-Sep		27-Oct	25-Nov	25-Dec	*23-Jan*	*22-Feb*	*23-Mar*		1638BC
2	21-Apr	20-May	19-Jun		18-Jul	2	17-Aug		15-Sep		15-Oct	13-Nov	13-Dec	*11-Jan*	*10-Feb*	*12-Mar*		1637BC
3	10-Apr	10-May	8-Jun		8-Jul	12	6-Aug		5-Sep		4-Oct	3-Nov	2-Dec	31-Dec	*30-Jan*	*1-Mar*		1636BC
4	31-Mar	29-Apr	29-May		27-Jun	**23**	27-Jul		25-Aug		24-Sep	23-Oct	21-Nov	21-Dec	*19-Jan*	*18-Feb*	***20-Mar***	1635BC
5	18-Apr	18-May	17-Jun		16-Jul	**4**	15-Aug		13-Sep	**13-Oct**	11-Nov	10-Dec	*9-Jan*	*7-Feb*	*8-Mar*	*6-Apr*		1634BC
6	6-May	5-Jun	4-Jul	16	3-Aug		2-Sep		1-Oct		31-Oct	29-Nov	28-Dec	*27-Jan*	*25-Feb*	*27-Mar*		1633BC
7	25-Apr	25-May	23-Jun	27	23-Jul		22-Aug		20-Sep		20-Oct	19-Nov	18-Dec	*17-Jan*	*15-Feb*	*16-Mar*		1632BC
8	15-Apr	14-May	12-Jun		12-Jul	8	11-Aug		9-Sep		9-Oct	8-Nov	8-Dec	*6-Jan*	*5-Feb*	*6-Mar*		1631BC
9	4-Apr	4-May	2-Jun		1-Jul	19	31-Jul		29-Aug		28-Sep	28-Oct	27-Nov	27-Dec	*25-Jan*	*24-Feb*		1630BC
10	24-Mar	22-Apr	22-May		20-Jun		19-Jul	**1**	18-Aug	**16-Sep**	16-Oct	15-Nov	15-Dec	*13-Jan*	*12-Feb*	*14-Mar*		1629BC
11	12-Apr	11-May	10-Jun		9-Jul	**11**	7-Aug		6-Sep	**5-Oct**	4-Nov	4-Dec	*3-Jan*	*1-Feb*	*3-Mar*	*1-Apr*		1628BC
12	1-May	30-May	29-Jun	21	28-Jul		26-Aug		25-Sep		24-Oct	23-Nov	23-Dec	*21-Jan*	*20-Feb*	*21-Mar*		1627BC
13	20-Apr	20-May	18-Jun		17-Jul	**3**	16-Aug		14-Sep		14-Oct	13-Nov	12-Dec	*11-Jan*	*9-Feb*	*9-Mar*	***8-Apr***	1626BC
14	8-May	6-Jun	6-Jul	14	4-Aug		3-Sep		3-Oct		1-Nov	1-Dec	30-Dec	*28-Jan*	*27-Feb*	*28-Mar*		1625BC
15	27-Apr	26-May	25-Jun	25	25-Jul		23-Aug		22-Sep		22-Oct	21-Nov	20-Dec	*18-Jan*	*16-Feb*	*18-Mar*		1624BC
16	16-Apr	15-May	14-Jun		14-Jul	6	13-Aug		12-Sep		12-Oct	10-Nov	10-Dec	*8-Jan*	*6-Feb*	*7-Mar*		1623BC
17	6-Apr	5-May	3-Jun		3-Jul	**17**	2-Aug		1-Sep		1-Oct	30-Oct	29-Nov	28-Dec	*27-Jan*	*25-Feb*	***25-Mar***	1622BC
18	24-Apr	23-May	21-Jun	29	21-Jul		20-Aug		19-Sep		18-Oct	17-Nov	17-Dec	*15-Jan*	*14-Feb*	*15-Mar*		1621BC

six intercalations are belated by one or two years. The fact that these intercalations are always later and never earlier than expected may be explained by poor observational discipline and/or administrative inertia. A somewhat less disciplined calendar practice in the Old Babylonian period is consistent with the fact that during the reigns of Hammurabi and Ammī-ditana intercalations in four consecutive years are attested (Huber et al. 1982, p. 35–36).

For the calendar reconstruction in Table 4 I have adopted the Low Middle Chronology where Ammī-ṣaduqa year 1 = 1638 BC. I would like to emphasize that the calendar reconstruction would have turned out almost identical if I had assumed the High Middle Chronology because these chronologies are exactly 99 lunar months apart (the Venus 8-year period) which corresponds to a difference of 8 solar years plus only one or two days in the Julian calendar.

From the Julian dates of the first crescent visibility in month I in Table 4 we find that during Ammī-ṣaduqa's reign on average the year started on 20 April, 15 days after the date of the spring equinox.[21] This is as expected because we know that during the Old Babylonian period the Spring Equinox was meant to fall in the month XII of the schematic calendar, the month of the barley harvest (see Britton 2007, p. 118). After the Assyrian calendar reform during the reign of Tiglath-Pileser (1114–1076 BC) the calendar was shifted one month backwards so that the spring equinox fell in month I in the Assyrian calendar. Britton (2007) shows that after about 750 BC during the Neo-Assyrian period and later during the Neo-Babylonian empire intercalation was applied in such a way that the beginning of the year was gradually shifted back to the Old Babylonian situation where the Spring Equinox fell in month XII. Around 500 BC the calendar was stabilized and intercalation was regulated within a 19-year cycle in such a way that the heliacal rising of Sirius always fell in month IV.[22] Sachs (1952) has shown that this is indeed the case for the Babylonian calendar during the last three centuries BC.

5. *Discussion*

The reconstruction of the Old Assyrian calendar during REL 81–110 and the analysis of the intercalation pattern in section 3 has led me to conclude that the Low Middle Chronology is the preferred chronology for the Old Babylonian period but I left the question undecided which of the two candidate solar eclipses is responsible for the "darkening of the Sun" in REL 127, the one in 1833 BC or the one in 1838 BC. The choice between these two candidate eclipses is important because it anchors the Old Assyrian chronology (REL 1–130) to absolute time.

According to the Mari Eponym Chronicle Šamšī-Adad died late in the year of the eponymy of Ṭāb-ṣilli-Aššur (REL 197) during the 18th year of Hammurabi, i.e. in November/December 1767 BC according to the Low Middle Chronology. If the solar eclipse of 1833 BC was the one

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[21] In the second half of the 17th century BC the Spring Equinox fell on 5 April.

[22] In considering changes in the synchronization of the lunar calendar to the solar year during Mesopotamian history we must take into account that the date of the heliacal rising of Sirius moves forward with respect to the spring equinox by one day in about 120 years (see de Jong 2006, p. 438). This causes the distance in days between the date of the spring equinox and the date of the heliacal rising of Sirius to increase by about 10 days between 1700 BC and 500 BC. If the heliacal rising of Sirius in month IV was used as the intercalation criterion this effect all by itself already pushes the Spring Equinox back from month I to month XII in the course of time.

taking place in the year after his birth, he was 67 years old when he died, so that one would expect 67 eponyms from REL 126 to REL 197, while 71 are listed. To explain this discrepancy Nahm (2013) has argued that BHL (p. 44ff.) in their reconstruction of the REL (following Birot 1985) have misplaced four eponyms (on fragment D of the Mari Eponym Chronicle) by including them in their eponym list as REL 178–181 while they were already listed elsewhere (REL 167–170 = KEL G 57–60, Günbattı 2008). This suggestion has recently been rejected by Barjamovic (2015) and Veenhof (2016) based on a renewed analysis of the texts.

Barjamovic (2015) and Veenhof (2016) also reconfirm that the internal uncertainty of the REL in the interval REL 125–200 amounts to at most one or two eponyms. One uncertainty is related to the eponym Ahiyaya (REL 193) which most probably has to be removed because it is part (as co-eponym) of either eponym Awiliya (REL 194, see Lacambre 2013), or Ilī-ellitī (REL 188, see Charpin and Ziegler 2003, p. 83), or Aššur-imittī (REL 187, see Bloch 2014, p. 205). Taking all things together, it seems that Nahm's suggestion must be rejected so that the only remaining solar eclipse candidate is the one in 1838 BC which corresponds to the calendar solution in Table 2, the one for which the astronomical intercalation rules provide the best fit to the observed intercalation pattern.

If indeed Šamšī-Adad was born in 1839 BC, one year before the solar eclipse of 1838 BC, he was 72 when he died in 1767 BC so that we expect 72 eponyms from REL 126 to REL 197 while only 71 are listed. If, in addition, eponym Ahiyaya has to be removed from the REL we need two more eponyms in the interval REL 126–197. It may be fortuitous, but in his recent reconstruction of the Mari Eponym Chronicle Veenhof (2016) has suggested that two additional eponyms (part of fragment MEC D) may have to be included between REL 179 and 180.

Finally, I note that adopting the 1838 BC solar eclipse as the one taking place in the year after Šamšī-Adad was born also provides the closest fit to the 'distanzangaben'. Veenhof (2000; 2003) has argued repeatedly that according to the 'distanzangaben' there are 199 years between the accession year of Erišum I (REL 1) and the death of Šamšī-Adad (REL 197) in 1767 BC. For the 1838 BC eclipse in REL 127 we find that REL 1 = 1964 BC and for the 1833 BC eclipse we find REL 1 = 1959 BC, corresponding to 197 and 192 years for this interval, respectively.

I conclude that the intercalation pattern of the Old Assyrian calendar discussed in this paper provides an additional independent argument in favour of the Low Middle Chronology with the lifetime of Šamšī-Adad marked by the solar eclipse of 24 March 1838 BC in the year after he was born in 1839 BC (REL 126) and with his death in December 1767 BC (REL 197).

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