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ANCIENT ECLIPSES AND DATING THE FALL OF BABYLON

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Abstract. The formation of an absolute chronology for the ancient Near East depends upon identifying the recorded observations of ancient astronomers. The author investigates connection between the Venus observations and nine ancient solar and lunar eclipses. The Middle Chronology for the fall of Babylon 1595 BC is too long; the Ultra-Low chronology (1499 BC) is too short. The new chronology is proposed starting with 1547 BC.

1. INTRODUCTION

Our investigation of the ancient eclipses is based on Assyrian and Babylonian King Lists. The earliest records of astronomical omens date from the Dynasty of Akkad. However, the most valuable collection of celestial observations was collected during the Kassite period and developed into a series known as Enuma Anu Enlil (EAE). Several eclipse observations found in EAE are considered as essential for the absolute dating of the early dynasties of Mesopotamia and among them the eclipses of Ur III and Old Babylon Dynasty.

Assyrian and Babylonian King Lists do not give the exact answer when Babylon fell. The Long Chronology, which puts the end of Babylon in 1659 BC, is not supported by any evidence except the astronomical data. The discovery of the Kani Eponym List and the Mari Eponym Chronicle is very important for the reconstruction of the Old Assyrian chronology, but it gives only a relative chronology. Three-ring dates are more specific, but they are approximate. The political situation was very complicated. The appearance of a new state Mittani and coming to power of the Eighteenth Dynasty in Egypt forced Hittite king Murili I to attack Alalakh and Babylon. After a short time, he returned to Hatua (the capital of the Hittites) and was murdered. The Hittites were unable to hold on to Babylon after they sacked it because of the great distance, so they abandoned it, leaving a power vacuum. They were replaced with the Kassites, an Iranian tribe and the rulers of Mari. The Kassites were an indigenous Iranian tribe from the central Zagros region south of Hamadan. They were organized into a nation of warriors by an Aryan aristocracy. They eventually took control of all of Sumer and Akkad. The Kassite kings ruled a unified Mesopotamia longer than any other dynasty and Babylon became the political and cultural center of the ancient world under them.

2. THE DECELERATION OF THE EARTH'S ROTATION RATE

The discrepancy in time ΔT was detected when ancient observations were compared with modern calculations. We have two opposing forces: tidal friction slowing down the rate of rotation and 'non tidal mechanisms' speeding it up. The resultant of these processes is a gradual slowing down of the Earth's rotation, but at an irregular rate. The earliest observations of eclipses come from China and Babylon. According to the Shang dynasty oracle bone eclipse records

$$\Delta T = (30 \pm 2.5) \cdot t^2 \tag{1}$$

where t is measured in centuries since 1800 AD. The rate of change in the length of day (l.o.d.) is 1.64 ± 0.14 ms/cy (Pang et al., 1996). Lunar orbital acceleration is $-26''/\mathrm{cy}^2$. Something different result obtained by Stephenson and Morrison (2003: 26) where the mean value c = 31 s/cy^2 appears to be satisfactory. The rate of change in l.o.d. is 1.7 ± 0.1 ms/cy. According to the relation between ΔT and l.o.d (Stephenson and Morrison, 1984: 56), where the second derivative of ΔT is

$$\frac{d^2(\Delta T)}{dt^2} = 2c \tag{2}$$

which is equivalent to rate of change in l.o.d.

$$\frac{d(\text{l.o.d.})}{dt} = 2c \left(\frac{1000}{36525}\right) = 0.0548\ c \tag{3}$$

(in ms/d/cy, usually written ms/cy) we find

$$\Delta T = (31 \pm 1.8) \cdot t^2 \quad (-700 < y < 1620) \tag{4}$$

where t is measured in centuries since 1820 AD. No ΔT curve will capture all eclipses over all epochs of time. We assume t to be measured in centuries since 1800 AD for our calculations.

3. ASTRONOMICAL EVIDENCE

Venus tablets. Among the more reliable EAE astronomical texts, we can include the observations of the appearance and disappearance of the planet Venus covering 21 years of the First Babylonian Dynasty. They are believed to belong to the reign of king Ammisaduqa. The currently favoured dates are 1702 BC, 1646 BC, 1582 BC and 1550 BC for the first year of Ammisaduqa. The corresponding chronologies are 'High', 'Middle', 'Low' and 'Ultra-Low' respectively. Huber (2000: 173) has concluded that the High Chronology provides the best fits to the data. The periodicity of Venus is 8 sidereal years. Nevertheless, this is only approximate because there is a -4.10 day shift in the 8-sidereal period or 99 synodic months. Babylonian astronomers also used a second calculation which assumes a -4 day shift for the period (Gasche et al., 1998: 73). Besides, any solution using the data in omens 11 to 21 and 34 to 37 must drastically emend the text (Hunger and Pingree, 1999: 37). Therefore, we should

take only the first 10 omens for our calculation. Only the relative sequence of the inferior and superior conjunctions is reflected in the tablet and not the absolute lunar calendar (contra Huber). They lie at the base of the approach to the 8-year cycles. This approach opens several possibilities for the fall of Babylon (Gurzadyan, 2000: 181). The interval for our calculations is between 1595 and 1499 BC.

Early Ur eclipses. A passage from Shulgi's poem (Shulgi D) describes one of his wars against Gutium. Klein (1981: 59; 81) has noticed that the passage expresses two eclipses, of the moon and the sun respectively. The former eclipse is connected with Nanna, the god of the moon, but we have no sufficient information. The latter eclipse is connected with sun god Utu. During the battle, there was an eclipse of the sun. It was possibly preceded by the lunar eclipse, but the part of the text is damaged. We found that only five eclipses of 2053 BC, 2044 BC, 2021 BC, 2006 BC and 1973 BC satisfy these conditions. They match with 1579 BC, 1563 BC, 1547 BC, 1532 BC and 1499 BC respectively (Table 1).

The First Ur Eclipse (EAE 20). The lunar omen comes from the early part of the Dynasty of Ur III; it is generally thought to mark the end of the reign of Shulgi. The eclipse takes place on the 14^{th} day of the 3^{rd} month, beginning in the first watch in the east, and ending in the west at the beginning of the second watch. Three candidates are possible: in 2019 BC, 2002 BC and 1954 BC (Table 1).

The Second Ur Eclipse (EAE tablet 21 and 20). The following lunar omen marks the end of the Dynasty of Ur III. The eclipse is therefore attributed to Ibbi-sîn, the last king of the dynasty (Huber, 2000: 168; Rochberg-Halton 1988: 248): The eclipse takes place on the 14^{th} day of the 12^{th} month, beginning in the south during the evening watch, eventually clearing during the morning watch in the north. There are three eclipses of 1976 BC, 1962 BC and 1912 BC. The eclipse of 1976 BC begins in the south, but does not match the First Ur III eclipse. The beginning of the third eclipse is in the north-east. We propose the lunar eclipse of 1962 BC. There is another lunar omen which reports about the end of Ur (EAE 20 § II) (Rochberg-Halton, 1988: 87f). The best fit is the lunar eclipse of May 16, 1961 BC.

The Solar Eclipse of Assur. The solar eclipse over Assur during the reign of Narām-Sin was mentioned in the year of the eponym Puzur-Ishtar from the Mari eponym chronicle (MEC). According to Durand and Guichard (1997: 43) it comes one year after the birth of Shamshi-Adad. All solar eclipses magnitude higher than 0.8, from 1850 to 1750 BC were computed (Table 1).

The Eclipse of Mari (Tablet HC-A.25-115). The next eclipse record was discovered by Parrot in the city of Mari, and translated by Dossin (cit. in Rochberg-Halton 1988: 32). The lunar eclipse from Mari occurred during the eponym Asqudum which would be Year 11-12 of Hammurabi (1781 BC according to the Middle Chronology) (Warburton, 2000: 59). It was presumably total because it disturbed the writer of the letter. There is no month of the eclipse. There are several total eclipses of the moon in 1781 BC, 1748 BC, 1734 BC, 1716 BC, 1694 BC and 1684 BC.

The Eclipses of Babylon (EAE tablet 20). The next omen presages the end of the First Dynasty of Babylon. It is attributed to its last king, Samsuditana (Rochberg-Halton, 1988, 210f). The lunar eclipse on month 11, day 14, begins in the last watch in the south. It is partially eclipsed in the west. Two weeks later on month

Table 1: Eclipses of Sun and Moon according to ancient sources. There are not the eclipses of the Moon in the reign of Shulgi for the year 1563 BC and 1499 BC (*). All solar eclipses in Assur have $M > 0.8$. s-solar; l-lunar eclipses.

Ur (s.l)	I Ur (l)	II Ur (l)	Tell Muh. (l)	Assur (s)	Mari (l)	Bab.
-2052.04.13 -2052.04.29				-1832.06.24		1579
-2043.04.20*	-2018.06.26	-1975.03.04	-1520.03.13	-1817.09.06	-1747.05.31	1563
-2020.07.17 -2020.08.01	-2001.07.18	-1961.05.27 -1960.05.16	-1505.05.26	-1807.08.16	-1733.08.23	1547
-2005.09.29 -2005.10.14				-1790.09.07	-1715.03.10	1531
			-1466.04.15	-1763.10.08	-1693.07.03	1507
-1972.01.17	-1953.06.27	-1911.03.16	-1458.05.16		-1683.12.06	1499

Table 2: Solar eclipse of Babylon. M_1 and M_2 are magnitudes of the solar and lunar eclipses.

Fall of Babylon	M_1	Date	M_2
-1546.02.15	0.81	-1546.01.31	0.25
-1531.04.29	0.44	-1531.04.14	0.81
-1507.12.26	0.41	-1507.12.10	-0.11

11, day 28, a solar eclipse occurs and is visible throughout its course. In this case, the sun eclipse could have been predicted because it was preceded by the lunar eclipse in the previous syzygy. There is also the claim in Tablet 23(24) that certain features of the appearance of the Sun on the first day of the month allow one to predict a solar eclipse at the end of the month (Hunger and Pingree, 1999: 44). We found only three eclipse pairs between 1600 and 1490 BC: in 1547 BC, 1532 BC and 1508 BC. According to 8-year cycle of Venus, the first eclipse pair best fits the evidence (Table 2).

The Eclipses of Tell Muhammad. The lunar eclipses are found in the economic texts from Tell Muhammad, a site near Tell Harmal in Baghdad. One tablet mentions the lunar eclipse; the other has a year-name 38^{th} year after Babylon was resettled. These texts are from months Abu and Nisan (Gasche et al., 1998: 86). The first lunar eclipse from the month Abu has an impossible day, 10, which is not compatible with the day of lunar calendar (14-15). A few of years is assumed after Babylon was occupied by the Hittites before Kassite's arrival. As we do not have the time of the eclipse, it is not conclusive for the chronology. There are several eclipses of the moon which are compatible with alternative chronologies (1521 BC, 1506 BC, 1466 BC and 1459 BC).

4. ANALYSIS OF ASTRONOMICAL OBSERVATIONS

Gurzadyan (2000) takes into the consideration the exit angle and watch time, which is more objective argument than the beginning of the eclipse. In EAE 20 almost every eclipse begin "above" and end "below" (Huber, 2000: 169). The following description of the area of obscuration is given in the omen protases of the eclipse series: "If the eclipse, in its middle, becomes dark all over and clears all over" (Rochberg-Halton, 1988: 49). This omen obviously refers to the total eclipse. The second Ur eclipse (EAE 21) was probably partial one. If we analyze the Table 1 the best score gives year 1547 BC for the end of Babylon. The first solar eclipse of August 1, 2021 BC is from the poem of Shulgi. It was central-annular eclipse with M=0.79 at Ur (46.2 E, 31 N). The solar eclipse was possibly preceded by the lunar eclipse. He destroyed Simurrum and Harshi up to his Year 26. He also waged war at Simurrum, Lullubum, Urbillum and Karahar between Year 43 and 44 (Sigrist and Damerow, 2001). If we take the northern location, near Kirkuk and Lower Zab River (44.39 E, 35.47 N) the magnitude of the solar eclipse would be 0.7. According to our chronology, Shulgi began his reign 2048/47 BC which is also compatible with the fall of Babylon in 1547 BC. There were also pairs of eclipses in 2013 BC and 2006 BC. The latter eclipse could have happened in his 43rd year, which would be compatible with our source. The latter solar eclipse was annular-total with M=0.9. The solar eclipse from Assur in 1808 BC begins at 7:05 and ends at 10:01. It was central-annular eclipse with magnitude 0.89. The solar eclipse of Ur (in 2021 BC) has magnitude 0.7 for ΔT=46370 s (c=31.78). For ΔT=42770, which is 3600 s less than calculated value, M=0.8 and c=29.31. The Babylonian solar eclipse of 15 February 1547 BC has a relatively high magnitude, M=0.81. It begins at 12:10 and ends at 15:24. It is central-annular eclipse with M=0.81 for ΔT=35978 s. For ΔT=33798, which is 2180 s less than a calculated value, M=0.96 and c=30.19. More important factor is that the Babylonian eclipse coincided with the 8-year cycle of Venus. Shamshi-Adad appears to have lived between 1809 and 1728 BC. He died between Year 12 and Year 18 of Hammurabi, possibly in Year 17 (Charpin and Durand, 1985: 306-308). Hammurabi's reign began in 1744 BC. The year matches with Venus cycle for year 1547 BC. The interval from the beginning of his reign and the end of Babylon is 197 years. The first lunar eclipse of Ur III of July 18, 2002 BC started on the east (117°) at 20:24 and ended on the west (242°) at 23:46 (North = 0°, East=90°, South=180° and West=270°). According to recension A the eclipse 'touches' the middle watch (the first watch (19:00-23:00), the middle watch (23:00-03:00), the last watch (03:00-07:00)). The beginning of the first watch is after sunset. The interval between the end of Ur III and the end of Babylon is 409-412 years. We should search the second lunar eclipse of Ur III in that interval according to alternative chronologies. There is also problem with the month of the eclipse. There is prediction in EAE 20 for the second month, given for Ur, which describes its destruction. This was the total lunar eclipse of May 16, 1961 BC, started on the south-east (107°) before sun set, ending on the south-west (257°) at 19:02 about half an hour after sun set. If we include standard error σ of approximately. 60 min for ΔT the result is better. Moon was seen with the sun in its rising. The lunar eclipse had to start later to have been seen with the sun

(at twilight). It is significant for the history of astronomy because ΔT demonstrates smaller growth at the beginning of the second millennium than we would expect. The exit angle agrees with the eclipse report. More detail that is important is conjunction of Moon and Mars on the same day (2.2°). This eclipse fits perfectly the report. There is also the total lunar eclipse of May 27, 1962 BC which might have matched our sequence. The latter eclipse started on the south-east (115°) at 22:16, ending on the south-west (249°) at 2:00. The exit angle of the eclipse does not provide a good fit (it should be $> 260°$). There might have been two lunar eclipses which presaged the end of Ur. The end of Ur III could have happened in the next three years. The Mesopotamian year officially started with the first appearance of the moon in month 1. In certain texts, particularly from the Old Babylonian period, the 15^{th} of month 12 (or full moon) was ideally vernal equinox (Brown, 2000: 107). In the particular case, the vernal equinox was around April 8. If two months were intercalated (April-May), the eclipse would fit. The lunar eclipse of February 31, 1547 BC begins in the last watch in the south and is partially eclipsed in the west. It started on the north-east (65°) at 1:18 and ended on the north-west (294°) at 3:06. Magnitude of the eclipse is 0.26. The moon is seen with the sun in the last watch (03:00-07:00). For the first contact, the typical accuracy of the prediction is 1.12 hours, improving to 0.95 hours after 550 BC. The mean error of the lunar eclipse times predicted by the Babylonians in last contact is 2.63 hours (between 731 and 77 BC) (Steele and Stephenson, 1997: 125-128). The error for earlier predictions was greater. If we include standard error of approximately. 30 min for ΔT it is obvious that the lunar eclipse started very close to the last watch and ended at dawn. Tell Muhammad eclipse matches perfectly 1547 BC. It was the total lunar eclipse of May 26, 1506 BC which started at 21:40 and ended at 1:36. It occurred 41 years after the end of Babylon and 38 years after its resettlement.

5. CONCLUSION

Analyzing the Ur and Babylonian solar eclipses of August 01, 2021 BC and January 31, 1547 BC gave ΔT values of 12.54 ± 0.34 hr and 9.69 ± 0.3 hr, respectively. This is consistent with (1). Including new results of solar eclipse dating (Xu Zhen-tao et. al. 1995) from 'oracle bone' inscriptions we conclude that solar eclipses at Anyang of 1250 BC and 1176 BC fit into formulae (1) and (4). Calculating of the two solar eclipses from Xia dynasty 2072 BC and 2019 BC yields the similar result for ΔT as the Ur solar eclipse. Including two double-dawn solar eclipses of 976 BC and 899 BC with total eclipse of 709 BC from Qufu gave the best fit:

$$\Delta T = (30.86 \pm 0.96) \cdot t^2, \quad (-2020 < y < -700) \tag{5}$$

and $t = (y - 1800)/100$ for the lunar tidal acceleration $n = -26''/\text{cy}^2$ (Stephenson and Morrison, 1984: 50). The average trend in l.o.d is $+1.69 \pm 0.05$ ms/cy where t is measured in centuries since 1800 AD. This is slightly different result from (4).

If we analyze Tables 1 and 2, we find that the Middle Chronology should be excluded. Only one solar eclipse in 1847 BC with a small magnitude is not sufficient for accepting it. Our chronology has two advantages: the first is agreement with the

Assyrian King List, the second is the great solar eclipse in 1547 BC which happened before the end of Babylon.

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