Archimedes

Volume 4
New Studies in the History and Philosophy of Science and Technology

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Observations and Predictions of Eclipse Times by Early Astronomers

by

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KLUWER ACADEMIC PUBLISHERS
DORDRECHT / BOSTON / LONDON

2000

2.6 Accuracy of the Observed Times

Of the many reports of lunar and solar eclipses in Late Babylonian history, more than one-hundred contain a measurement of either the time interval between the beginning

of the eclipse and sunrise or sunset, or the duration of the phases of the eclipse, or in some cases both. These times, we assume, were measured using some form of clepsydra. By comparing these measurements with modern computations it is possible to evaluate the accuracy with which the Babylonian astronomers were able to time the eclipses, and to note any trends in the errors in the clocks that they used. Previously, Stephenson & Fatoohi (1993) have analysed many of the lunar eclipse timings and found some evidence for clock drifts of about 13%. However, their analysis contains significant errors, in part caused by the use of a preliminary approximation to the Earth's rotational clock error, ΔT, and in part by double counting some of their data. In addition to the times measured using a clepsydra, 16 reports dating between 225 BC and 80 BC mention that the eclipse began as a particular *ziqpu*-star (or occasionally a point so many degrees in front of or behind a star) was culminating.[95]

Tables 2.4 and 2.5 list respectively the lunar and solar eclipses for which at least one timing of either the beginning of the eclipse or a phase duration by a clepsydra is preserved. Also given are the equivalent times as deduced from modern computations, rounded to the nearest 0.25°. As I mentioned in Section 2.5 above, a number of records of partial lunar eclipses contain estimates of the duration of a maximal phase when no apparent change in the extent of the eclipse could be detected. However, as this is a physiological effect dependent on the observer, these phases cannot be compared with computation. Instead, if the onset and clearing phases have also been reported, then the three intervals have been added together to give the total duration of the eclipse. If the total duration and all of the phases of an eclipse are reported, then only the individual phases are given, except as noted above. In all cases, times in these tables are given in UŠ, even if the original record quotes the times in *bēru*.

It is immediately evident from Table 2.4 that before about 570 BC, most of the measured times appear to have been rounded to the nearest 5°. This suggests that the Babylonian astronomers had a growing confidence in their timing methods after this period. However, from Figure 2.7, which shows the error in all of the measured lunar and solar eclipse times, it is clear that there was no corresponding improvement in the accuracy of the times. This implies that any changes in the clocks used by the Babylonian astronomers around 570 BC resulted only in an improvement in precision of quoted measurement and not in real accuracy. In fact, from Figure 2.7 it is clear that over the whole of the Late Babylonian period, there was no improvement in the accuracy of the eclipse timings. Furthermore, there is no significant difference between the accuracy of the solar eclipse timings and the lunar eclipse timings. This suggests that the same devices were used to time both types of event, and that it was these devices, and not factors such as the difficulty in determining lunar eclipse contacts due to the diffuse nature of the Earth's shadow, which was the limiting factor in the accuracy of timing eclipses.

Date	Observed Details					Computed Details				
	1st Contact Interval	Phase Durations				1st Contact Interval	Phase Durations			
		1st to 2nd	2nd to 3rd	3rd to 4th	1st to 4th		1st to 2nd	2nd to 3rd	3rd to 4th	1st to 4th
-685 Apr 22	100° after sunset	-	-	-	-	111.00° after sunset	-	-	-	-
-684 Oct 3	20° after sunset	-	-	-	-	16.75° after sunset	-	-	-	-
-631 May 24	-	-	-	-	20°	-	-	-	-	19.25°
-602 Oct 27	45° after sunset	-	-	-	45°	37.25° after sunset	-	-	-	38.75°
-600 Apr 11	95° after sunset	-	-	-	-	93.25° after sunset	-	-	-	-
-598 Feb 20	105° after sunset	-	-	-	-	88.25° after sunset	-	-	-	-
-593 May 23	10° after sunset	-	-	-	-	24.00° after sunset	-	-	-	-
-591 Apr 2	-	-	-	-	36°	-	-	-	-	36.00°
-587 Jan 19	20° before sunrise	-	-	-	-	30.25° before sunrise	-	-	-	-
-586 Jan 8	35° before sunrise	-	-	-	-	32.25° before sunrise	-	-	-	-
-579 Aug 15	45° after sunset	-	-	-	-	49.50° after sunset	-	-	-	-
-576 Dec 8	105° after sunset	-	-	-	-	110.00° after sunset	-	-	-	-
-575 Jun 3	40° before sunrise	-	-	-	-	31.50° before sunrise	-	-	-	-
-572 Apr 2	90° after sunset	-	-	-	-	90.25° after sunset	-	-	-	-
-561 Mar 3	90° after sunset	-	25°	18°	-	82.50° after sunset	-	26.00°	15.75°	-
-554 Oct 6	55° after sunset	17°	28°	20°	-	55.75° after sunset	16.25°	24.50°	16.25°	-
-536 Oct 17	14° before sunrise	-	-	-	-	20.00° before sunrise	-	-	-	-
-528 Nov 17	24° after sunset	-	-	-	45°	44.00° after sunset	-	-	-	43.25°
-525 Sep 17	60° after sunset	18°	14°	-	-	68.75° after sunset	14.50°	23.75°	-	-
-500 Nov 7	77° after sunset	15°	25°	25°	-	69.25° after sunset	16.75°	23.50°	16.75°	-
-482 Nov 19	10° before sunrise	-	-	-	-	6.75° before sunrise	-	-	-	-
-464 Jun 5	-	-	-	-	40°	-	-	-	-	46.25°
-423 Sep 28	50° after sunset	-	-	-	50°	53.50° after sunset	-	-	-	35.00°
-409 Dec 21	-	-	-	-	60°	-	-	-	-	47.75°
-407 Oct 31	15° after sunset	-	-	-	27°	14.25° after sunset	-	-	-	22.75°
-406 Oct 21	48° before sunrise	-	-	-	56°	49.25° before sunrise	-	-	-	55°

Table 2.4: Lunar eclipse timings.

Date	1st Contact Interval	Phase Durations 1st to 2nd	2nd to 3rd	3rd to 4th	1st to 4th	1st Contact Interval	Phase Durations 1st to 2nd	2nd to 3rd	3rd to 4th	1st to 4th
-405 Apr 15	-	25°	19°	-	-	-	16.25°	18.50°	-	-
-405 Oct 10	14° before sunrise	-	-	-	-	9.25° before sunrise	-	-	-	-
-396 Apr 5	48° after sunset	-	-	-	27°	48.75° after sunset	-	-	-	16.25°
-377 Apr 6	-	15°	21°	19°	-	-	15.75°	19.00°	15.75°	-
-370 May 17	66° after sunset	-	-	-	-	57.00° after sunset	-	-	-	-
-370 Nov 11	30° after sunset	21°	20°	21°	-	38.50° after sunset	17.00°	21.00°	17.00°	-
-363 Jun 29	40° before sunrise	-	-	-	-	33.25° before sunrise	-	-	-	-
-363 Dec 23	14° before sunrise	-	-	-	-	11.75° before sunrise	-	-	-	-
-362 Jun 18	41° before sunrise	-	-	-	-	37.00° before sunrise	-	-	-	-
-352 Nov 22	47° before sunrise	23°	18°	-	-	41.50° before sunrise	17.00°	21.00°	-	-
-345 Jan 14	-	-	-	-	23°	-	-	-	-	23.75°
-326 Jan 14	-	-	7°	16°	-	-	-	21.50°	15.00°	-
-316 Jun 18	10° after sunset	-	-	-	-	15.75° after sunset	-	-	-	-
-316 Dec 13	44° after sunset	19°	5°	16°	-	54.00° after sunset	17.00°	20.75°	17.00°	-
-307 Jul 9	10° before sunrise	-	-	-	-	9.75° before sunrise	-	-	-	-
-283 Mar 17	-	22°	22°	-	65°	-	20.00°	11.00°	-	45.25°
-272 Feb 16	-	-	19°	22°	-	-	-	19.25°	15.75°	-
-239 Nov 3	3° before sunrise	-	-	-	-	1.00° *after* sunrise	-	-	-	-
-238 Apr 28	80° after sunset	-	-	-	40°	61.25° after sunset	-	-	-	35.50°
-225 Aug 1	52° after sunset	17°	10°	15°	-	70.75° after sunset	16.75°	16.00°	16.75°	-
-214 Dec 25	15° after sunset	21°	16°	19°	-	35.00° after sunset	15.75°	20.75°	15.75°	-
-211 Apr 30	20° before sunrise	-	-	-	-	24.50° before sunrise	-	-	-	-
-211 Oct 24	28° after sunrise	-	-	-	-	62.25° after sunrise	-	-	-	-
-193 Nov 5	12° before sunrise	-	-	-	-	8.00° before sunrise	-	-	-	-
-189 Feb 28	30° before sunrise	-	-	-	-	37.75° before sunrise	-	-	-	-
-188 Feb 17	34° before sunrise	16°	-	-	-	41.75° before sunrise	18.00°	-	-	-

Table 2.4 (cont.): Lunar eclipse timings.

Date	1st Contact Interval	Phase Durations 1st to 2nd	2nd to 3rd	3rd to 4th	1st to 4th	1st Contact Interval	Phase Durations 1st to 2nd	2nd to 3rd	3rd to 4th	1st to 4th
-184 Nov 24	44° after sunset	-	-	-	-	36.75° after sunset	-	-	-	-
-162 Mar 30	85° before sunrise	-	-	-	-	96.25° before sunrise	-	-	-	-
-159 Jan 26	48° after sunset	-	-	-	-	55.25° after sunset	-	-	-	-
-156 Nov 15	-	-	42°	-	-	-	-	24.25°	-	-
-153 Mar 21	4° after sunset	-	-	-	44°	6.50° after sunset	-	-	-	49.50°
-149 Jul 2	-	20°	12°	-	-	-	20.25°	13.00°	-	-
-142 Feb 17	7° after sunset	-	-	-	-	8.75° after sunset	-	-	-	-
-135 Apr 1	30° before sunrise	-	-	-	-	63.75° before sunrise	-	-	-	-
-134 Mar 20	-	-	-	-	60°	-	-	-	-	58.25°
-133 Mar 10	9° before sunrise	-	-	-	-	13.50° before sunrise	-	-	-	-
-133 Sep 3	32° after sunset	-	-	-	-	33.50° after sunset	-	-	-	-
-130 Jul 2	-	-	-	10°	-	-	-	-	16.75°	-
-128 Nov 5	55° before sunrise	-	-	-	40°	55.50° before sunrise	-	-	-	43°
-123 Aug 13	-	19°	24°	19°	-	-	16.75°	24.50°	16.75°	-
-119 Jun 2	66° after sunset	-	-	-	54°	68.75° after sunset	-	-	-	47.75°
-109 Nov 5	25° after sunset	-	20°	-	-	22.00° after sunset	-	25.00°	-	-
-108 May 1	8° after sunset	-	-	-	-	9.25° after sunset	-	-	-	-
-105 Feb 28	66° after sunset	-	-	-	60°	61.00° after sunset	-	-	-	53.00°
-105 Aug 24	50° before sunrise	21°	21°	-	-	44.50° before sunrise	16.50°	25.50°	-	-
-95 Aug 3	57° after sunset	-	-	-	-	63.50° after sunset	-	-	-	-
-86 Feb 28	-	-	-	-	30°	-	-	-	-	33.25°
-80 Apr 21	60° after sunset	-	22°	-	-	49.50° after sunset	-	26.25°	-	-
-79 Apr 10	40° before sunrise	-	-	-	40°	39.75° before sunrise	-	-	-	21.50°
-79 Oct 5	30° after sunset	-	-	-	-	32.50° after sunset	-	-	-	-
-72 Nov 16	37° before sunrise	-	-	-	-	30.50° before sunrise	-	-	-	-
-40 Mar 2	-	21°	-	-	-	-	15.00°	-	-	-

Table 2.4 (cont.): Lunar eclipse timings.

Date	Observed Details				Computed Details			
	1st Contact Interval	Phase Durations			1st Contact Interval	Phase Durations		
		1st to Max	Max to 4th	1st to 4th		1st to Max	Max to 4th	1st to 4th
-368 Apr 11	-	6°	-	-	-	15.00°	-	-
-321 Sep 26	3° before sunset	-	-	-	3.50° before sunset	-	-	-
-280 Jan 30	6° after sunrise	-	-	20°	2.75° after sunrise	-	-	23.25°
-255 Sep 6	-	-	-	32°	-	-	-	39.25°
-253 Jan 31	56° before sunset	12°	13°	-	64.00° before sunset	16.00°	15.00°	-
-248 May 5	90° after sunrise	-	-	-	93.25°	-	-	-
-241 Jun 15	-	-	18°	-	-	-	16.25°	-
-240 Nov 28	-	-	-	30°	-	-	-	36.50°
-194 Jan 6	60° after sunrise	-	-	-	38.25° after sunrise	-	-	-
-189 Mar 14	30° after sunrise	15°	15°	-	31.25° after sunrise	17.75°	19.00°	-
-169 Jul 28	20° before sunset	12°	-	-	19.50° before sunset	11.50°	-	-
-165 May 17	-	13°	-	-	-	23.50°	-	-
-135 Apr 15	24° after sunrise	-	-	35°	26.50° after sunrise	-	-	33.50°
-132 Feb 13	51° before sunset	20°	18°	-	50.50° before sunset	21.75°	19.25°	-
-125 Sep 9	-	-	-	35°	-	-	-	41.00°
-111 Jun 18	-	-	8°	-	-	-	14.25°	-
-88 Sep 29	45° after sunrise	-	-	24°	33.50° after sunrise	-	-	31.50°
-9 Jun 30	90° before sunset	-	-	48°	95.25° before sunset	-	-	40.00°

Table 2.5: Solar eclipse timings.

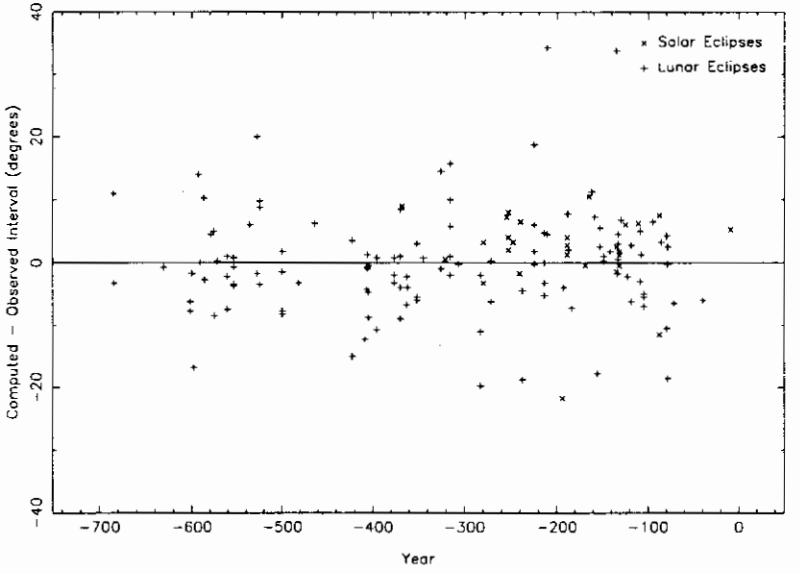

Figure 2.7: The error in the observed solar and lunar eclipse timings over the Late Babylonian period.