PERSONAL OBSERVATIONS OF HELIACAL PHASES OF MERCURY
A Detailed Account

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The ability to compute the heliacal phases of the planets is of critical importance to researchers of the Babylonian Astronomy.

How successful will be the dating of certain texts or the identifying of the babylonian stars, depends ultimately on the reliability of the methods used to compute heliacal phenomena.

For this purpose, in the last 2000 years (!), the scholars have used the arcus visionis method invented by Ptolemy[1] and different arcus visiones tables.

The ones mostly used recently were compiled by Schoch in 1927[2].

The arcus visionis method is, however, flawed in principle[3] and the values given by Schoch were never compared with real observations[4].

Since the time of Ptolemy no observations of heliacal phenomena have been published[5]!

Consequently and very logically, there is no reliable heliacal theory...[6]

To amend this unfortunate fact, first the publication of a vast corpus of observations made at different locations is indispensable.

Here I will present and discuss my eight personal observations of different heliacal phenomena of Mercury. I made them in Seattle, USA and Varna, Bulgaria. These two places have very different atmospheres. The air in Seattle had an extinction[7] of around 0.16 +-0.04 in the period 2001-2004 and then 0.20 +-0.04 in 2005-2006. The extinction in Bulgaria around the Black Sea coast, where I live, is 0.36 +-0.12. I assessed the extinctions by observing the visual night-rise (or night-set) of stars.

The predicted dates, using Schoch's tables, always gave Mercury a longer visibility period than the observed one.

The real Morning and Evening First were always later than the computed dates and the real Last appearances were always earlier.

The mean deviation for all phases is 2.13 days. The observed two Evening Lasts occurred 3 and 4 days earlier than the Schoch's predictions.

In the end a caveat for the whole analysis is the still unresolved question with the magnitude of Mercury which is addressed in the end.

MF ☿ Seattle, 19-20 August 2005, extinction~ 0.20

Queen Anne Hill (5th Ave. N and Lynn str.), 122° 19′ W, 47° 39′ N, TimeZone: 8 W.

	19 AUG	**20 AUG MF**	
Visibility	clear	clear, thin clouds up to 4°	Visibility
Magnitude	+0.8	+0.6	Magnitude
AV	-12.9°, +14.0°	-13.5°, +14.6°	AV
ΔAZ	10°	12°	ΔAZ
	not seen	time alt☼ alt☿ ΔAZ	
first seen	see discussion	5:15 -9.5° : +4.4° : 12°	first seen
best seen		5:19 -8.9° : +5.1°	best seen
last seen		5:32 -7.0° : +7.2°	last seen
standard AV -9°	-9° : 4.4° : 10°	-9.0° : +5.0° : 12°	standard AV -9°
standard AV -7°	-7° : 6.5°	-7.0° : +7.2°	standard AV -7°
time		17 min	time

Observation 1 (Table 1) MORNING FIRST Schoch MF date (AV=-13.0): 20 Aug.

Explanations: The Arcus Visionis for the day is given in its 2 possible values. Let's take those for 19th of Aug.,i.e. -12.9°, +14.0°.

The first (-12.9°) is the altitude of the ☼ when ☿ is exactly on the horizon. The second (+14.0°) is the altitude of ☿ when the ☼ is on the horizon. Historically only the first AV has been used.

The '**ΔAZ**' row tells the azimuthal distance between the Sun and Mercury.

In the row '**first seen**' for the 20th of Aug. we have:

5:15 -9.5° : +4.4° : 12°.

5:15 is the time, -9.5° is the altitude of the Sun, +4.4° is the altitude of ☿ and 12° is the ΔAZ between them- all these data for the given time (5:15).

The row '**standard AV -9°**' gives the altitude of Mercury when the Sun is -9° in altitude.

For the 20th of Aug. it is -9.0° : +5.0° : 12°.

-9.0° is the alt. of ☼, +5.0° is the alt.of ☿ and 12° is the ΔAZ between them.

The standard AV is useful to compare hel. phases of different stars.

The row '**time**' shows the duration of the visibility.

The date of the h.phase acc. to the arcus visionis of C.Schoch is also given in the very beginning.

Discussion of Observation 1:

On the 19th of Aug. I saw Mercury first with binoculars and then I watched for some time with my naked eyes at the spot where it was, until at time 5:22 AM it happened as if I saw maybe something... There is no question whether this can be counted as the heliacal rise of Mercury... It cannot, because I hardly saw something and this only because I knew exactly where to watch...

However, this fact means that this **could have been the Morning First** of Mercury provided that the atmospheric extinction was somewhat lower or the observer had much sharper eyes....

Observations of the heliacal rise of stars that have bearing on Observation 1

In Seattle I have observed the Morning First of the star Aldebaran, which with +0.85 mag. has similar brightness as that of Mercury on the 19th of Aug. (+0.8). I saw Aldebaran with standard AV: -9.0° : +4.6° : 30°

Let us compare the standard AV of Mercury on 19th of August with that of the rising Aldebaran:

Aldebaran h.rise, +0.85 mag.: -9.0° : +4.6° : 30°	year 2003 ex =0.16
Mercury 19 Aug, +0.80 mag.: -9.0° : +4.4° : 10°	year 2005 ex =0.20

We see that the altitude of Mercury is lower and that it is also closer to the solar halo, only 10° apart from the Sun in azimuth.

Also the observation of the MF of Aldebaran is from the year 2003 when the extinction was smaller.

Mercury is worse than Aldebaran in altitude, azimuthal distance and extinction...

This all meaning that Mercury could not have been seen on the 19th of Aug. at the same place by the same observer.

Again in Seattle I observed the heliacal rise of Betelgeuse (+0.5 mag.) with standard AV: -9.0° : +4.0° : 36°. This could be compared with Mercury on the 20th of Aug. with magnitude of +0.6:

Betelgeuse h.rise, +0.50 mag.: -9.0° : +4.0° : 36°	year 2005 ex =0.20
Mercury 20 Aug, +0.60 mag.: -9.0° : +5.0° : 12°	year 2005 ex =0.20

Betelgeuse is with 0.1 mag brighter and further away from the solar halo. That's why it could be seen with 1° lower in altitude.

ML ☿ **Seattle,** 5-7 September 2005, extinction~ 0.20
5 Sep.: Green Lake, 122° 18′ W, 47° 42′ N, TimeZone: 8 W.
7 Sep.: Queen Anne Hill, 122° 19′ W, 47° 39′ N, TimeZone: 8 W.

	5 Sep ML	6 Sep ***ML?***	7 Sep
Visibility	clear	clouds	clear
Magnitude	-1.3	-1,3	-1.3
AV	-10.9°, +11.0°	-10.2°, +10.3°	-9.5°, +9.5°
ΔAZ	4°	3°	2°
	time alt☼alt☿ Δ	**not observed**	**observed, not seen**
first seen	5:39 -9.7:+1.3: 4	see	
best seen	5:50 -7.9:+3.1	discussion	
last seen	6:01 -6.2:+4.9		
standard AV -9°	-9° : +2.0° : 4°	-9° : +1.2° : 3°	-9.0° : +0.5° : 2°
standard AV -7°	-7° : +4.1°	-7° : +3.2°	-7.0° : +2.5°
time	22 min		

Observation 2 (Table 2) MORNING LAST Schoch ML date (AV= -9.5): 6 Sep.

Discussion of Observation 2:

On the 7th of Sep. between 5:55 AM and 6:02 AM I saw Mercury first with binoculars and then with naked eyes... This cannot be counted as the Morning Last of Mercury since I saw it only because I knew exactly where to watch...

However, this fact means that **the Morning Last** of Mercury has some probability to have occurred on the 6th of Sep.

Observations of the heliacal rise of stars and planets that have bearing on Observation 2

With Mercury here being -1.3 of magnitude, we can use only observations of Jupiter and Sirius, all in Seattle:

♃	MF, -1.7 mag.: -7.0° : +3.5° : 4°	Seattle	year 2003 ex =0.16
♃	EL, -1.7 mag.: -7.0° : +2.9° : 15°	Seattle	year 2003 ex =0.16
Sirius	MF, -1.5 mag.: -7.0° : +1.5° : 55°	Seattle	year 2005 ex =0.20
Sirius	MF, -1.5 mag.: -7.0° : +1.2° : 55°	Seattle	year 2003 ex =0.16

The 5th of September, judging from the Jupiter data, turns out to be the most probable date of the ML of Mercury.

EL ☿ **Seattle,** 2-5 April 2004, extinction~ 0.20
Magnolia, 122° 26′ W, 47° 40′ N, TimeZone: 8 W.

	2 Apr.	3 Apr	**4 Apr EL?**	5 Apr.
Visibility	clear	clouds	clouds	clear
Magnitude	+0.9	+1,1	+1.4	+1.6
AV	-16.6°:+17.1°	-16.1°:+16.6°	-15.5°:+15.9°	-14.8°:+15.2°
ΔAZ	5°	5°	4°	4°
	time alt☼alt☿ Δ			
first seen	7:20 -7.1:+9.9: 5	**not observ.**	**not obs.**	**observed,**
best seen	.			**not seen**
last seen	7:55 -12.6:+4.2			
std. AV -9°	-9° : 7.9° : 5°	-9°: 7.3°: 5°	-9°: 6.7°: 4°	-9° : 6.0° : 4°
std. AV -7°	-7° : 9.9°	-7°: 9.4°	-7°: 8.8°	-7° : 8.0°
time	35 min			

Observation 3 (Table 3) EVENING LAST Schoch EL date (AV= -11.0): 8 Apr.

Observations of the heliacal rise of stars that have bearing on Observation 3

Pollux MF, 1.1 mag.: -9.0° : +5.6° : 5° Seattle, year 2003 ex =0.16
Castor MF, 1.3 mag.: -9.0° : +6.5° : 2° Seattle, year 2003 ex =0.16
El Nath MF, 1.6 mag.: -9.0° : +7.7° : 15° Seattle, year 2003 ex =0.16

The 4th of April seems to be the day of the EL.

MF ☿ Varna, Bulgaria 3-5 Sept. 2004, extinction~ 0.36

3 Sep: TV tower, Franga hill north of Varna, 27° 57′ E, 43° 14′ N, TimeZone: 2 E
5 Sep: Varna, 27° 55′ E, 43° 12′ N, TimeZone: 2 E. extinction: ~ 0.46

3 Sep.	4 Sep.	**5 Sep MF**	
fair	clouds	very clear	Visibility
+1.2	+0.9	+0.7	Magnitude
-13.1°:+13.6°	-14.0°:+14.4°	-14.7°:+15.2°	AV
7°	7°	7°	ΔAZ
		time alt☼alt☿ Δ	
observed,	**not observ.**	5:33 -12 :+2.8: 8	first seen
not seen		5:45 -10 :+4.9	best seen
		6:00 -7.4:+7.6	last seen
-9° : 4.3° : 7°	-9°: 5.2°: 7°	-9° : 6.0°: 8°	std. AV -9°
-7° : 6.4°	-7°: 7.3°	-7° : 8.0°	std. AV -7°
		27 min	time

Observation 4 (Table 4) MORNING FIRST Schoch MF date (AV= -13.0): 3 Sep.

Observations of the heliacal rise of stars that have bearing on Observation 4

Aldebaran EL, 0.85 mag.: -9.0° : +7.3° : 8° Varna ex =0.36

ML ☿ Kamen Briag, Bulgaria 19 Dec. 1999, extinction~ 0.36

Kamen Briag, 100 km. north of Varna, 28° 33′ E, 43° 27′ N, TimeZone: 2 E

	19 Dec. ML?	20 Dec.
Visibility	very clear	clouds
Magnitude	-0.5	-0.5
AV	-11.9°:+10.7°	-11.3°:+10.1°
ΔAZ	10°	10°
	time alt☼alt☿ Δ	
first seen	6:47-8.3 :+3.3: 10	**not observ.**
best seen		
last seen	7:00 -6.2:+5.2	
std. AV -9°	-9° : 2.7°: 10°	-9°: 2.2°: 10°
std. AV -7°	-7° : 4.5°	-7°: 4.0°
time	13 min	

Observation 5 (Table 5) MORNING LAST Schoch ML date (AV= -9.5): 23 Dec.

Observations of the heliacal rise of stars that have bearing on Observation 5

♃	MF, -1.7 mag.: -7.0° : +4.8° : 24°	K. Briag	2004 year, ex =0.36
Sirius	MF, -1.5 mag.: -7.0° : +3.8° : 55°	Varna, TV tower	2000 year, ex =0.36
♄	MF, +0.2 mag.: -7.0° : +6.7° : 24°	Varna	2000 year, ex =0.36
Procyon	MF, +0.3 mag.:-7.0° : +8.0° : 27°	Varna, TV tower	2000 year, ex =0.36

Discussion of Observation 5:

The morning last was probably on the 19th judging from the short time-period of visibility. The real magnitude of Mercury should have been much brighter than the -0.5 value (derived with the Mueller's formula) because the AV is too small for the usual extinction in Bulgaria. The real brightness of Mercury should be at least-1.7.

ML ☿ Varna, Bulgaria 10-11-12 Aug. 2000, extinction~ 0.36
TV tower, Franga hill north of Varna, 27° 57′ E, 43° 14′ N, TimeZone: 2 E

	10 Aug.	**11 Aug. ML**	12 Aug.
Visibility	clear	very clear	fair, clouds
Magnitude	-1.2	-1.3	-1.4
AV	-11.0°:+11.4°	-10.3°:+10.7°	-9.6°:+9.8°
ΔAZ	6°	5°	4°
	time alt☼alt☿ Δ	time alt☼alt☿ Δ	
first seen	4:21:-8.5 :+2.6: 6	4:25:-8.1 :+2.3: 5	**not seen**
best seen	4:26:-7.8 :+3.4	4:38:-6.4 :+4.1	
last seen	4:36:-6.2:+5.1	4:41:-5.6:+5.0	
std. AV -9°	-9°:+2.1°: 6°	-9°:+1.4°: 5°	-9°:+0.7°: 4°
std. AV -7°	-7°:+4.2°	-7°:+3.5°	-7°:+2.7°
time	15 min	16 min	

Observation 6 (Table 6) MORNING LAST Schoch ML date (AV= -9.5): 12 Aug.

Observations of the h. rise of stars that have bearing on Obs. 6

♃ MF, -1.7 mag.: -7.0° : +4.8° : 24° K. Briag 2004 year, ex =0.36
Sirius MF, -1.5 mag.: -7.0° : +3.8° : 55° Varna, TV tower 2000 year, ex =0.36

Discussion of Observation 6:

The morning last was observed without doubt on the 11th.

Here, again I think that the real magnitude of Mercury should have been -1.85 since Sirius has almost the same AV (in its 2000 MF apparition at the same place few days later), being -1.5 mag. and 55° apart in azimuth form the Sun. The Jupiter data confirms this.

If we accept that Mercury here is only -1.3 mag. then we cannot explain how Mercury with 0.2 magnitudes dimmer than Sirius and 50° closer in azimuth to the solar halo, should be seen with the same AV as Sirius!

Nor can we explain the Jupiter data.

Neither can we explain this with variation in the atmospheric extinction. With -1.3 brightness Mercury could be seen with such AV only if the extinction is around 0.16. A variation of 0.20 in the extinction in the course of few days is very improbable. I have also never observed extinction in Bulgaria lower than 0.24!

EF ☿   **Varna, Bulgaria** 20, 21 May 2000, extinction~ 0.46
Varna, 27° 55′ E, 43° 12′ N, TimeZone: 2 E

20 May	**21 May EF**	
clouds	fair clear	Visibility
-1.1	-1.0	Magnitude
-11.2°:+12.0°	-11.8°:+12.8°	AV
7°	7°	ΔAZ
not	time alt☼alt☿ Δ	
observed	8:12:-7.0 :+5.3: 7	first seen
		best seen
	8:26:-9.0:+3.1	last seen
-9°:+2.4°: 7°	-9°:+3.1°: 7°	std. AV -9°
-7°:+4.6°	-7°:+5.3°	std. AV -7°
	14 min	time

Observation 7 (Table 7) EVENING FIRST Schoch EF date (AV= -10.2): 19 May.

Observations of the heliacal rise of stars that have bearing on Observation 7

Sirius MF, -1.5 mag.: -7.0° : +3.8° : 55° Varna, TV tower 2000 year, ex =0.36

Discussion of Observation 7:

The 19th was a day with clouds on the western horizon up to 10°. The 20th was all cloudy and nothing could be seen. The 18th was a clear sunset. I observed on that day and could not see Mercury even with binoculars. This all and also the short visibility makes me believe that the EF was on the 21st of May.

The observations were conducted in the center of the city of Varna where an extinction of 0.46 is in the norm.

EL ☿ **Varna, Bulgaria** 21 Feb.- 3 March 2006, extinction~ 0.46

Varna, 27° 55′ E, 43° 12′ N, TimeZone: 2 E

21 Feb	3 March	
clear	clear	Visibility
-0.7	+1.4	Magnitude
-16.9°:+16.6°	-14.1°:+14.1°	AV
6°	2°	ΔAZ
time alt☼alt☿ Δ	**not**	
6:12:-5.3 :+11.4: 6	**seen**	first seen
		best seen
6:58:-13.7:+3.2		last seen
-9°:+7.9°: 6°	-9°:+5.1°: 2°	std. AV -9°
-7°:+9.8°	-7°:+7.1°	std. AV -7°
46 min		time

Observation 8 (Table 8) EVENING LAST Schoch EL date (AV= -11.0): 5 March.

Discussion of Observation 8:

On the 27th Mercury is around 0.0 mag. bright. From this day on it starts to fall with 0.3 mag. every day... The most probable day of the EL was 2nd of March when Mercury, +0.5 mag. bright (acc. to Hilton's (2005) algorithm and +1.1 acc. to Mueller's) is 8° high when the Sun is -7°. This is very similar to the conditions on 5th of Sept. 2004 when Mercury (+0.7 mag. (Mueller)) rose heliacally in the east with standard AV of -7°:+8.0°.

IMPORTANT NOTE

In the end we should mention a very important fact which may be source for many errors: there is no agreement in computing the magnitude of Mercury. I know of 3 algorithms: Mueller (1891)[8], Hilton(2005)[9] and Schoch (1927)[10]. Here I have given the Mueller's values. The Hilton and Schoch values may be with 0.5 magn. brighter at some places of the heliacal cycle and especially when close to the Sun. For this reason, the data here should be used very carefully until this question is resolved.

The formulae given so far are dubious when Mercury is very close to the solar halo because then it cannot be compared with other stars.

There are noobserv ations of other planets with comparative brightness (Jupiter, Saturn) in the same relative position to the solar halo.

The formulae derived by Hilton are based on photometry which, because of the vicinity of the solar halo, is not the correct approach.

The only way to derive reliable formula for the magnitude of Mercury when close to the Sun is to amass a lot of observations of heliacal phases of Mercury, Jupiter, Saturn and stars of magnitudes +2.0 to 0.0 and analyze them.

In the end I will sum up my observations in the following table.

Seattle, USA ext~0.16					**Varna, BG** ext~0.36			
	Magnitude		**Alt. of ☿**			**Magnitude**		**Alt. of ☿**
phase	Muller	Inferred	when ☼ is -7°	***MAG.***	**phase**	Muller	Inferred	when ☼ is -7°
				-2.0	ML	-1.3	-1.9	3.5°
				-1.7	ML	-0.5	-1.7	4.5°
ML	-1.3	-1.5	4.1°	***-1.5***	EF	-1.0	-1.4	5.3°
				0.0	MF	+0.7	+0.1	8.0°
MF	+0.6	+0.4	7.2°	***+0.5***				
				+1.0				
EL	+1.4	+1.4	8.8°	***+1.5***				
				MAG				

Table 9

Explanations: The inferred magnitudes of Mercury are based on comparisons with the heliacal rise of stars and planets of similar magnitude at the same location. They are, however, not mathematically deduced, but only rough estimates. The magnitude scale in the middle follows the inferred magnitude. Observ. 8 is left out.

RELIABILITY OF C. SCHOCH'S TABLES

The famous tables of C. Schoch contain the arcus visiones (AV) of the planets in their different heliacal phases[2]. Generations of scholars have used them to compute heliacal phenomena and draw critical conclusions on age, provenance and exactness of ancient texts.

In table 10 is given the difference between the observed heliacal phases of Mercury and the predicted ones using the AV values of C. Schoch. +2 means that the observed phase is 2 days later. -3 means that the observed phase is 3 days earlier. The EL phase shows the biggest deviation.

Table 10

Schoch's AV		Seattle Δ	Varna Δ
13.0°	MF	0	+2
9.5°	ML	-1	-1, -4
10.2°	EF		+2
11.0°	EL	-4	-3

Explanations: The AV of C. Schoch are on the far left. Observation 8, EL from Varna is also included. As expected, the deviations of the Seattle's data are smaller because the extinction there (~0.16) approaches that one in Mesopotamia (estimated at around 0.12)[11].

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Notes and References

1: Ptolemaeus, 'Handbuch der Astronomie', K.Manitius, Teubner, Leipzig, 1963

2: Carl Schoch, the 1924 version: 'The Arcus Visionis of the Planets in the Babylonian Observations', 'Monthly Notices of the Royal Astronomical Society' 84, No.9, 1924. the 1927 version: 'Planeten-Tafeln fuer Jedermann', 1927, Linser Verlag, Berlin-Pankow

3: The simple AV method takes as a factor only the altitude of the Sun when the planet is exactly on the horizon. The different speed of the planet (or the star) and the Sun in gaining altitude is not considered and consequently this becomes a source for many errors. There are many more shortcomings of this method which will be discussed in a different article.

4: In the 'Monthly Notices of the Royal Astronomical Society' (look at the note above) Schoch writes that he used ancient babylonian observations to compile his AV tables. These observations were translated and published in works by Kugler and Epping, namely:
F. X. Kugler, 'Sternkunde und Sterndienst in Babel', 1907, Muenster.
F. Epping, Zeitschrift fur Assyriologie, vols. 5-8, 1890-1893

5: With the exception of few sightings mainly of Sirius.

6: The heliacal theories of S.O.Kastner (1976), B. Schaefer (1987) and F. Inklaar (1989) are not based on empirical data (or use insufficient one).

7: The extinction measures how 'transparent' is the atmosphere to the star's light.

8: J. Meeus, 'Astronomical Algorithms', Willmann-Bell, 1991

$$\text{Mag.} = +1.16 + 5 * \log (r * d) + 0.02838 * (i-50) + 0.0001023 * (i-50)^2$$

r = distance to Sun in astron.units; d = distance to Earth; i = Phase angle in degrees.

9: The Astronomical Journal, 129, 2902-2906, 2005

10: 'Planeten-Tafeln fuer Jedermann', 1927, Linser Verlag, Berlin-Pankow
In cases when the phase angle of Mercury is between 0° and 40°, Schoch uses:
Mag. = -3 + 0.0385*Phase-angle.

11: This is in contrast with the 0.27 evaluation of the atmospheric extinction at Babylon done on theoretical grounds by the Dutch scholar Teije de Jong in his article 'Early Babylonian Observations of Saturn' in the volume 'Under One Sky', 2002, Muenster. My preliminary evaluation of 0.12 is based on practical observations.