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Baily's beads atlas in 2005-2008 eclipses

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Abstract For annular and total eclipses in 2005, 2006 and 2008 observational campaigns have been organized to record the phenomenon of Baily's beads. These campaigns were internationally coordinated through IOTA, International Occultation Timing Association, both American and European Sections. From stations in the northern and southern zone of grazing eclipse, eclipses have been videorecorded. Afterwards as many beads as possible have been identified by analyzing the video data of each observing station. In the atlas presented in this paper, the geographic positions of the observing stations and the observed time instants of disappearance or reappearance of beads, identified by an angle measured relative to the Moons axis of rotation, are given.
The atlas shall serve as a basis for determining the solar diameter. The eclipses were observed on 2005 October 3, 2006 March 29, 2006 September 22, and 2008

August 1. The atlas includes 546 data points, from 25 observers operating in 32 different observing stations.

Keywords: Baily's beads, solar eclipse, solar diameter, eclipse observation technique

1. Introduction

For more than two thousand years it has been a challenge for astronomers to measure the diameter of the Sun (Sigismondi and Oliva, 2005).

Francis Baily (1774-1844) (Hockey et al., 2007) pointed out that, if the observers' position varies by a few hundred yards from the shadow's path limit of a central eclipse, tiny points of light were visible on the lunar edge, we call this phenomenon Baily's Beads. [1]

Baily's beads occur when solar and lunar limbs are nearly parallel, both in annular and total eclipses. This situation corresponds to the instants of second and third contacts as observed from the centerline. Baily's beads can last for a significant length of time on the edges of the umbral path of the eclipse. There the eclipses are called grazing (Sigismondi and Oliva, 2006). The observation of this phenomenon provides one of the better methods to determine the angular diameter of the Sun, because the timing of such beads is not affected by atmospheric turbulence: it depends only on the space geometry along the line of sight solar limb - lunar limb - observer, moreover the light signal is ON-OFF type and even small telescopes or the naked eye are considered trustable detectors if appropriate timing is available. For these reasons that method is considered in the realm of space methods for solar diameter measurements.

Edmund Halley (Halley, 1717) steered the Royal Society's observational campaign of the total eclipse of May 3, 1715 over England, in order to determine the shadow's limits of the umbra. Similar campaigns were organized by S. Newcomb and the US Naval Observatory for the eclipse of August 7, 1869 across United States, and E. W. Brown of Yale University (Dunham, et al., 1980) for the eclipse of January 24, 1925, grazing over Manhattan Island and Providence, Rhode Island. Indipendently in Spain some military engineers, led by Lieutenant Luis Gomez de Barreda y Salvador (1905), observed form Valencia shadow bands at the limits of totality during the total solar eclipse of August 30, 1905 (Gomez, 1905), (Ruiz Castell, 2002).

The exploitation of the observations of grazing eclipses to measure the solar diameter, with the timing of Baily's beads, was first proposed by Dunham and Dunham (1973).

The idea was to use the timing of appearances or disappearances of the solar photosphere through the valleys of lunar limb profile, published by C. B. Watts (1963). For each grazing eclipses, several beads, N, are available, instead of only

[1] Mr. Baily gave a verbal account of a remarkable optical phenomenon observed by him at the late annular eclipse of the Sun, consisting of several dark ligaments apparently connecting the borders of the Sun and Moon, at the commencement and dissolution of the annulus (Baily, 1836).

the beginning and end of darkness or annularity. The departure of real lunar profile from the Watts' limb, determines a random uncertainty of $\sim \pm 0.2$" for each bead, but observing N beads the statistical accuracy on the final result improves of a factor of $\sqrt{\mathrm{N}}$.

To compare the diameters obtained in different eclipses, there are strategies used to reduce the systematical errors and to put in evidence real variations in solar diameter: eclipses separated by a Saros cycle and the analysis of polar beads. In the eclipses at whole Saros cycles of difference the beads are formed by the same valleys, because the Moon has the same libration phase (Sigismondi, 2008, a) , while the choice to analyze only polar beads (Dunham, et al., 2005), is based upon the fact that libration in latitude is always near zero during eclipses.

Observations of Baily's beads have been made for many eclipses up to now, only some of them have been analyzed to find the solar diameter (Fiala, et al., 1994), (Dunham, et al., 2005), (Sigismondi, 2008, b), and a few of them are published (Sigismondi, 2008, b) in a form suitable of being used for recalculating the solar diameter with other methods. There are various methods of analysis, based on different softwares as SOLRAD (D. W. Dunham), Occult 4 (D. Herald, 2008), Sunbeads2 (R. Büchner), and mostly observations are interpreted only by a single method. The difference between them is in the ephemerides used, while all of them are based upon Watts' atlas, and all recover the solar diameter as the one which minimizes residuals between observed and calculated heights of the solar limb above lunar valleys (Sigismondi, 2008, c).

As announced in (Kilcik, Sigismondi, Rozelot, Guhl, 2008) and based on the fact that the methods of analysis are different and continuously advancing, and the data on lunar limb are continuously updated by lunar occultations and they can be improved by new lunar satellite missions, the authors decided to publish the observed results and the details of the observers' equipment. In this way these results shall form a basis for further interpretations and recalculations. IOTA/ES and IOTA (American Section) decided to continue observing these phenomena and intend to report new results in the future. It is planned to publish observational results before 2005 as another Atlas of Baily's beads observation, as well. [2]

The present Atlas will allow the comparison between the diameter calculated upon eclipses and that one measured with groundbased experiments, like all Danjon's solar astrolabes (Laclare, et al., 1999) and DORAYSOL (Delmas, 2000), which measure transits on equal height's circles (almucantarats), or CLAVIUS (Sigismondi, et al., 2008) which will exploit the transits' timing on hourly circles, and from spacecrafts like SOHO (Kuhn, et al., 2004) and RHESSI (Fivian, et al., 2007), and incoming future missions like SDO (Drobnes and Pesnell, 2007) and PICARD (Thuillier, et al., 2006), to verify their calibrations in the instants of observed eclipses.

[2]This includes video observations, but we have visual observations of separate bead timings back to 1974. A few beads were timed before that, but almost all of the earlier observations are either still photographs (of the annular eclipses of 1966 and 1912) or timings of the 2nd and 3rd contacts only, back to nineteenth century.

2. Observation techniques and equipment

2.1. Time base

All observations were video recorded. The time base, either the radio clock DCF77 (Piester, et al., 2004) or the GPS-1PPS time signal was electronically inserted by a time inserter in the video signal, or recorded as an audio signal directly on the videotape. These video signals were stored on tape (in either analog or digital format) or directly on computers using frame grabbers. When using an observation technique without a time inserter, like web cam and computer, the system clock of the computer was synchronised before and after the observation.

2.2. Telescopes

The telescopes are mostly equipped with motor driven equatorial mountings (see table chapter 5). During the eclipses 2005 and 2006 the optical equipment was different from station to station. Table 1 and Table 2 give an overview of the observation places and the techniques used. The video recording was either analog or digital (see chapter 5 table 2, column 6). On analyzing the videos from these eclipses it became obvious that a problem exists in comparing the data of different stations, due to:

- differences in scale of the different optics used
- differences in the sensitivity of the cameras used
- differences in the spectral sensitivity, and depending on the combination of optical filter and camera type

These problems have been discussed during a workshop on the "European Symposium of Occultation Projects (ESOP)" in 2007 and for future campaigns a standardized set of optical equipment has been selected. The eclipse on August 1, 2008 was the first event observed mostly with such standardized equipment. The instrumentation for each station agreed on is as follows:

- Optics: Maksutov 100mm diameter / 1000mm focal length
- Camera: Watec, Mintron or similar without an automatic brightness control
- Filter: A green filter with a reflective neutral density coating on the first surface with an average optical density of 4 (see fig.1), to reduce the influence of the chromosphere and prominences, and adjust for the brightness of the Sun.
- Timing: GPS with 1PPS or radio clock (receiving the DCF 77 time signal) based electronic time inserter.

3. Meteorological circumstances

The observations of the stations were made under perfect weather condition with exception of

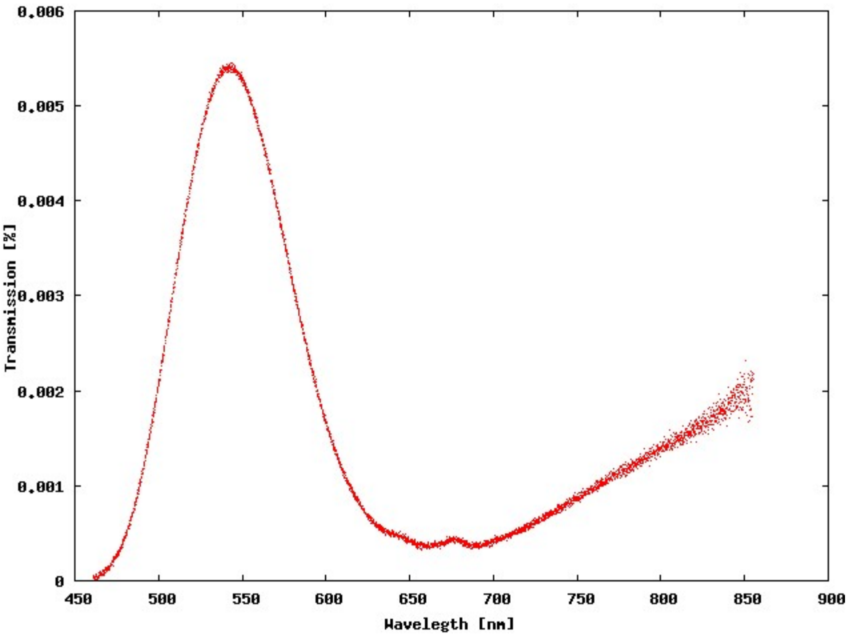

Figure 1. Transmittance of the solar filter of optical wavelenght. The ND Neutral Density coating on a green glass filter is made by Dünnschicht Technik GmbH Ing. Hans Tafelmaier, Rosenheim, Germany. Measurements of transmittance are made by Andre Knöfel.(Knöfel, 2008)

- station 2006TKN1 - moving clouds during the eclipse
- station 2008RUN2-3 and 2008RUS1-3 - strong wind caused some vibrations
- station 2005ESS1 - small clouds influences the atmospheric transparency
- station 2005ESN0abc - three stations located on a street going exactly Northward, with 500 m of separation among them, all clouded at the moment of ring formation. Only the coordinates of the Southern station in Valoria la Buena (ES) are here reported

4. Evaluation of data/accuracy of data

To identify the disappearance or reappearance it is necessary to inspect the videos visually in slow motion.

Helpful software tools are Quicktime or the video capture/processing software "VirtualDub" (Lee, 1998-2008) and "Limovie" (Miyashita, 2005-2008).

It is possible to check the videos several times and to compare the video picture with a visual simulation or the bead events. To identify the beads by watts angle (WA, an angle measured around the Moon's disk relative to its axis of rotation), a simulation with the software "Occult" (Herald, 2008) is performed on a second computer. Therefore it has been possible to compare the simulation and observation visually. "Occult" shows a simulation of the view of the lunar limb in front of the solar disk in a graphic mode. The software also allows

Figure 2. Image from videotape of station 2008RUN1.

changing the following parameters of the simulation to fit the observed video picture:

- The time of event
- The geographical position including the height above sea level
- The simulated radius of the sun.

The base for the simulation of the lunar limb is the digital version of Watts moon chart of the lunar limb profile (Watts, 1963) . It is also possible to add data points to the Watts' profile of the lunar limb. Such additional points are determined by worldwide observations of grazing or total lunar occultation in the last 50 years. Due to the limited number of observations, in some zones of the lunar limb, there are more of these observed points (that better define the profile) than others. Therefore the original Watts data are mainly used in beads identification process. In case of a major discrepancy between the simulation and observation, the additional (observed occultation) data are used instead. In such a case a remark is written in table 3.

The determined Watts angle (WA) is an output of "Occult". The cursor has to be pointed to the valley bottom, that caused the observed bead, on the drawing of the lunar limb, and the WA of that point is displayed. The cursor in the simulation program detects the Watts angle with an accuracy of $\pm 0.01^\circ$. In case of steep valleys (visible as a sudden Disappearance/Reappearance) this maximum accuracy is used. For most of the events the WA is given accurate to a tenth of degree. If this accuracy cannot be guaranteed due to a shallow shape of a valley it is given as a remark in table 3. Figure 2 shows an image from the videotape obtained at the station 2008RUN1, with some beads. In Figure 3 for the same station and time there is the simulated image. It is clear that some ranges of the simulated lunar limb give a good match with the beads shown in Figure 2. Figure 4 show the same simulation with additional observation data from occultations.

The time of disappearance (D) or reappearance (R) of beads is determined visually, based on the inserted time line from the video inserters in the video file. The time of a disappearance is the time line for the first video frame, which

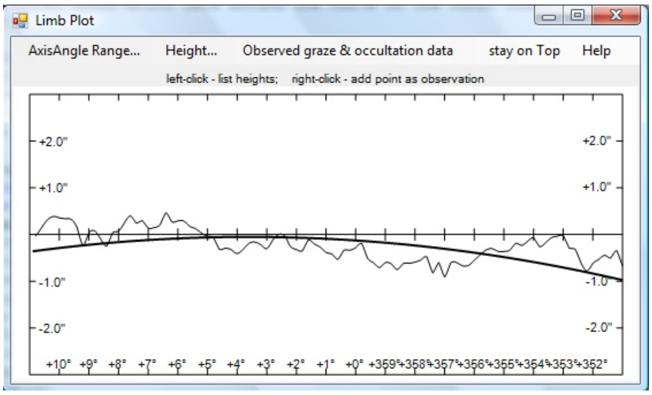

Figure 3. Lunar limb based on Watts profile, screenshot from "Occult 4".

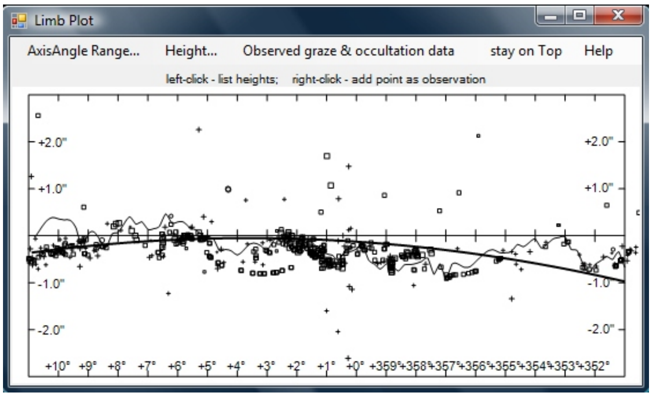

Figure 4. Lunar Watts' limb with observation data points, screenshot from "Occult 4".

doesn't show the bead, while the time of reappearance is the time of the first video frame, which shows the bead. The time point is rounded mathematically and given with an accuracy of ± 0.1s. For some special cases a disappearance or reappearance of a bead is not a sudden event. In such a case and under bad signal-noise ratio a worse accuracy of timing is possible. A remark is then given in table 3.

For the station 2008CNS1, Richard Nugent made an analysis of the video tape by measuring the brightness of the beads image. The software tool used is Limovie (Miyashita, 2005-2008). Figure 5-7 show the video frame with some beads, the 3D light curve simulation created by "Limovie" and the light level versus the time to calculate the time of disappearance. This style of analysis guaranteed a higher accuracy. The data from this station are given to a hundredth of second.

4.1. Other beads events

We have selected the disappearance and reappearance of beads. Their times are determined by the valleys' bottoms of the lunar limb. Mountain tops on the

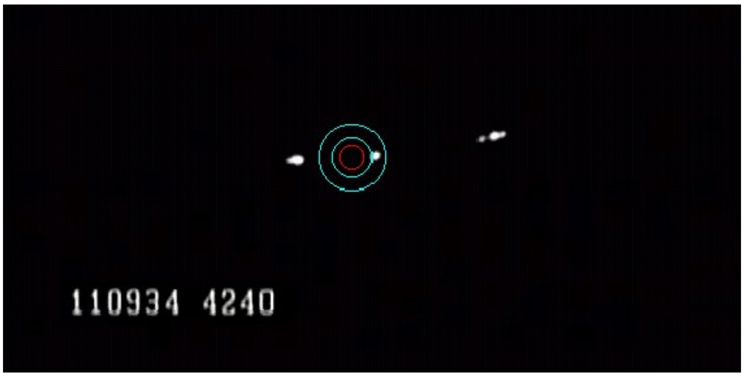

Figure 5. Image from videotape station 2008CNS1, the bead under investigation is marked.

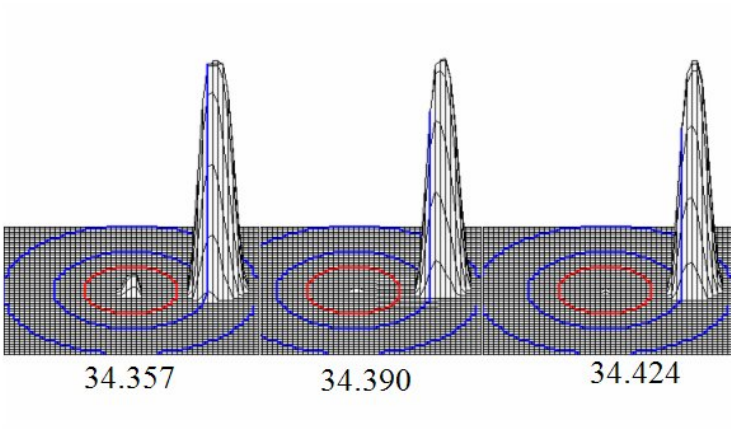

Figure 6. 3D diagram of light intensity: a small bead is visible up to 34.390 s, while at 34.424 is disappeared.

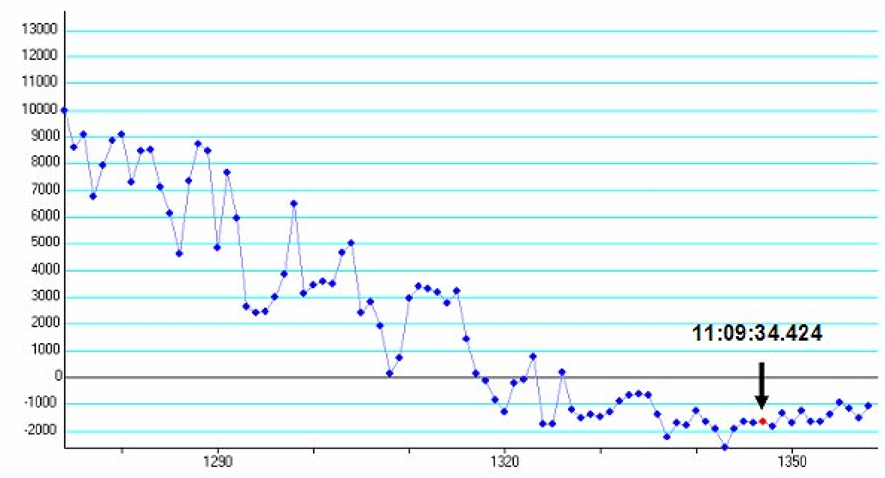

Figure 7. Lightcurve of a selected bead obtained with Limovie.

lunar limb cause two other events: beads form or beads merge. Bead form (F) means the mountaintop breaks the tip of the shrinking crescent to form a bead and bead merge (M) means the bead merges with expanding crescent (Sun's limb moves above a mountain top). Such events are analysed for observations from the stations 2006TKS2 and 2006TKS6. The data are given in table 4, new beads event in the same style as the disappearance and reappearance in table 3. The evaluation of data is analogous to the method described for disappearances and reappearances. Such events can be more affected by optical characteristics of the observing instruments as in the "Black Drop" effect (Schneider, et al., 2004).

5. Final data

5.1. Observers and positions

All coordinates are given in the WGS84 system and are measured by GPS-Receivers. For the different observation positions a station code is created. The station code used is constructed as follows
YYYYCCEn:

- YYYY - year
- CC - country:
  - EG Egypt
  - ES Spain
  - RU Russia
  - TN Tunisia
  - TK Turkey
  - FG French Guyana
  - CN China
- E - edge as
  - N (north)
  - S (south)
- 'n' for the number of the station, consecutively numbered, starting with the station closest to the central line.

Table 1.: Observers and positions

Date	Event	Observer	Beads	Longitude	Latitude	Height	Code
03.10.2005	annular	C.Sigismondi, P.Colona, P.Oliva	0	W04°31′52.0″	N41°48′03.0″	729m	2005ESN0abc
03.10.2005	annular	A.Selva	29	W0°09′43.3″	N39°45′28.0″	5m	2005ESN1
03.10.2005	annular	O.Canales	22	W0°08′18.6″	N39°48′01.8″	3m	2005ESN2
03.10.2005	annular	C.Perello	23	W0°07′52.3″	N39°48′31.2″	3m	2005ESN3
03.10.2005	annular	J.Rovira	14	W0°07′28.8″	N39°48′57.7″	10m	2005ESN4
03.10.2005	annular	M.Fernández-Ocaña, C. Schnabel	7	W0°06′28.4″	N39°50′0.7″	3m	2005ESN5
03.10.2005	annular	W.Strickling	8	W01°19′47.8″	N38°30′14.4″	561m	2005ESS1
03.10.2005	annular	S.Andersson	22	E11°0′15.6″	N33°02′15.6″	67m	2005TNN1
03.10.2005	annular	W.Rothe	33	E11°01′27.9″	N33°03′18.1″	29m	2005TNN2
03.10.2005	annular	T.Schaefer	33	E07°46′26.4″	N33°21′30.4″	42m	2005TNS1
03.10.2005	annular	K.Guhl	9	E07°46′45.42″	N33°20′53.64″	40m	2005TNS2
29.03.2006	total	K.Guhl	4	E30°46′51.618″	N37°23′40.158″	600m	2006TKN1
29.03.2006	total	B.Thome	2	E32°11′11.4″	N36°23′23.7″	42m	2006TKS1
29.03.2006	total	D.Dunham	47	E32°11′24.2″	N36°23′9.4″	5m	2006TKS2
29.03.2006	total	W.Warren	31	E32°11′24.15″	N36°23′9.36″	5m	2006TKS3
29.03.2006	total	A.Tegtmeier	2	E32°15′37.4″	N36°26′32.9″	367m	2006TKS4
29.03.2006	total	C.Tegtmeier	7	E32°15′37.4″	N36°26′32.9″	367m	2006TKS5
29.03.2006	total	O.Farago	35	E32°15′49.6″	N36°26′32.0″	409m	2006TKS6
29.03.2006	total	C.Sigismondi	16	E26°11′32.3″	N31°32′17.6″	27m	2006EGS1
29.03.2006	total	P.Colona	13	E26°11′24″	N31°32′27.4″	27m	2006EGS2
22.09.2006	annular	C.Sigismondi	13	W52°37′41.5″	N5°9′42.6″	3m	2006FG1
01.08.2008	total	S.Andersson	27	E84°17′18.9″	N55°37′55.7″	224m	2008RUN1
01.08.2008	total	M.Haupt	27	E84°17′25.4″	N55°38′03.2″	224m	2008RUN2
01.08.2008	total	K.Guhl	29	E84°17′35.2″	N55°38′12.3″	224m	2008RUN3
01.08.2008	total	W.Rothe	21	E81°02′55.3″	N54°22′08.1″	197m	2008RUS1
01.08.2008	total	A.Selva	26	E81°02′20.5″	N54°22′18.5″	194m	2008RUS2
01.08.2008	total	A.Massalle, M.Fernández-Ocaña, C.Schnabel	20	E81°01′45″	N54°22′13″	191m	2008RUS3
01.08.2008	total	R.Nugent	7	E93°35′13.6″	N42°52′54.6″	817m	2008CNS1
01.08.2008	total	C.Herold	20	E93°36′19.4″	N42°53′38.8″	839m	2008CNS2

5.2. Observation techniques

Table 2. Oberservation techniques

code	Telescope	Optical Corrector	Camera	Filter	Recording
2005ESN1	R150/750		Webcam		Computer
2005ESN2	R80/600		Mintron		miniDV
2005ESN3	M125/1900	0.5 f/red.	Webcam		Computer
2005ESN4	R180/2160		Webcam		Computer
2005ESN5	R60/700		Webcam		Computer
2005ESS1	M62/500		Sony PC100	B	Mini-DV
2005TNN1	R50/540		Mintron/C	B	Digital8
2005TNN2	R50/540		Mintron/BW	C	Digital8
2005TNS1	M70/840	reducer	Webcam		Computer
2005TNS2	R50/540		Watec120N	B	VHS
2006TKN1	R50/540		Mintron/C	B	VHS
2006TKS1	R70/350	2x Barlow	Webcam		Digital
2006TKS2	SCT125/1250		PC23C	ND5	Analog8
2006TKS2B	SCT100/1000		PC164C	B	Analog8
2006TKS3	SCT125/1250		PC23C	ND5	Digital8
2006TKS4	R70/740		Watec 120N	B	VHS
2006TKS5	R64/180	2x Barlow	JVC GX-N7e	B	VHS
2006TKS6	M100/1000		Mintron/C	B	VHS
2006EGS1	R70/350	Projection	SONY DCR-TRV9E	Y	miniDV
2006EGS2	R70/350	Projection	JVC GR-DF540E	Y	miniDV
2006FG1	R70/350	Projection	SONY DCR-TRV9E	Y	miniDV
2008RUN1	M100/1000		Mintron/BW	I	Digital8
2008RUN2	M100/1000		Mintron/C	I	Digital8
2008RUN3	M100/1000		Watec 120N	I	Computer
2008RUS1	M100/1000		Mintron/BW	I	Digital8
2008RUS2	M100/1000		Mintron/BW	I	miniDV
2008RUS3	M100/1000		Mintron/BW	I	miniDV
2008CNS1	M90/1400		Watec902H	C1	Digital
2008CNS2	SCT125/1000		PC164C	C1	Digital

Remarks:
Telescopes: R Refractor, M Maksutov, SCT Schmidt Cassegrain Telescope
Filter: B Baader astro solar,
Filter: I IOTA/ES green glass based neutral filter ND4 (cp. figure 1),
C chrome filter (Zeiss),C1 - chrome filter,Y YA2 Tamron
Others: Station 2005ESN3 Perello alt-azimuth mounting,
2008RUS3 Schnabel manually driven,
2006TKS2 used two telescopes, B was manually driven. The
recordings with both of these telescopes were analog, on 8mm tape.
2006EGS1, 2 and FG1: a 12 cm image is obtained by projection
on a white screen and videorecorded.

5.3. Beads observations

Table 3.: Beads events: D disappearance, R reappearance

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
2005ESN1	9h00m44.6	R	243.2	
	9h00m45.1	R	235.68	
	9h00m47.3	R	231.44	
	9h00m47.8	R	218.48	
	9h00m48.6	R	215.44	
	9h00m50.6	R	221.02	
	9h00m51.6	R	221.63	
	9h00m51.9	R	224.63	
	9h00m54.4	R	222.73	
	9h02m35.6	D	158.42	
	9h02m39.3	D	165.98	
	9h02m42.0	D	173.46	
	9h02m42.2	D	154.26	
	9h02m43.4	D	163.97	
	9h02m43.8	D	151.71	
	9h02m43.8	D	155.93	
	9h02m45.8	D	177.68	
	9h02m45.9	D	175.02	
	9h02m46.9	D	190.31	
	9h02m47.7	D	176.82	
	9h02m47.8	D	181.4	
	9h02m48.6	D	162.72	
	9h02m48.7	D	161.7	
	9h02m49.3	D	170.65	
	9h02m51.2	D	189.0	
	9h02m51.6	D	148.62	
	9h02m55.6	D	186.17	
	9h02m56.7	D	146.6	
	9h03m04.8	D	192.35	
2005ESN2	9h00m42.0	R	204.0	
	9h00m54.1	R	236.0	
	9h01m05.8	R	210.6	
	9h01m06.2	R	224.5	
	9h01m07.5	R	218.6	
	9h01m08.6	R	221.7	
	9h01m09.1	R	212.6	
	9h01m11.6	R	215.6	
	9h02m13.8	D	192.2	
	9h02m18.7	D	188.8	
	9h02m28.2	D	181.5	
	9h02m29.2	D	186.0	
	9h02m29.8	D	173.6	
	9h02m33.0	D	177.0	
	9h02m33.9	D	174.8	
	9h02m38.8	D	156.0	
	9h02m39.4	D	170.6	
	9h02m41.8	D	161.6	
	9h03m04.3	D	140.2	
	9h03m06.3	D	137.6	
	9h03m11.8	D	129.5	
	9h03m26.1	D	121.6	

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
2005ESN3	8h59m42.9	R	198.2	[3]
	9h00m05.5	R	199.8	
	9h00m48.1	R	204.9	
	9h00m50.8	R	203.7	
	9h00m58.4	R	206.3	
	9h01m00.0	R	202.5	
	9h01m09.4	R	218.4	
	9h01m09.6	R	210.5	
	9h01m10.1	R	212.7	
	9h01m15.0	R	215.5	
	9h01m53.4	D	190.2	
	9h02m03.0	D	192.2	
	9h02m09.4	D	188.1	
	9h02m22.0	D	181.2	
	9h02m22.4	D	186.6	
	9h02m28.1	D	174.9	
	9h02m28.1	D	176.9	
	9h02m35.4	D	170.5	
	9h02m36.7	D	155.8	
	9h02m39.0	D	161.4	
	9h02m51.0	D	194.2	
	9h03m04.1	D	196.1	
	9h03m36.7	D	198.9	
2005ESN4	9h02m18.4	D	181.2	
	9h02m19.7	D	177.6	
	9h02m21.8	D	172.0	
	9h02m23.2	D	167.8	
	9h02m23.8	D	173.5	
	9h02m23.8	D	176.9	
	9h02m26.3	D	168.9	
	9h02m26.4	D	175.0	
	9h02m26.6	D	166.0	
	9h02m30.9	D	169.5	
	9h02m32.0	D	164.1	
	9h02m33.8	D	170.5	
	9h02m37.1	D	162.7	
	9h02m37.7	D	161.5	
2005ESN5	9h01m08.5	D	192.2	
	9h01m13.4	R	228.6	
	9h01m18.8	D	195.9	
	9h04m06.2	R	102.5	
	9h04m13.1	R	100.0	
	9h04m22.4	R	95.3	
	9h04m27.1	R	92.8	
2005ESS1	8h59m48.9	D	319.1	
	8h59m53.5	D	325.6	
	9h01m38.8	R	47.6	
	9h01m46.7	R	54.2	
	9h01m51.2	R	58.3	
	9h02m00.6	R	66.2	
	9h02m05.3	R	72.6	
	9h02m11.4	R	76.6	
2005TNN1	9h19m26.0	R	273.6	
	9h19m26.7	R	274.5	
	9h19m55.6	R	258.9	
	9h19m56.9	R	256.1	

[3] No valley found in Watts' profile

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	9h20m02.1	R	205.4	
	9h20m06.1	R	250.1	
	9h20m14.7	R	243.1	
	9h20m17.7	R	241.0	Watts angle ±0.5°
	9h20m17.9	R	235.8	
	9h20m24.8	R	231.5	
	9h20m36.2	R	224.4	
	9h20m36.9	R	225.7	
	9h20m39.1	R	215.0	
	9h20m42.8	R	221.3	
	9h20m44.5	R	210.5	
	9h21m29.7	D	181.4	
	9h21m37.1	D	173.6	
	9h21m39.1	D	177.0	
	9h21m39.8	D	174.9	
	9h21m47.9	D	170.6	
	9h21m54.6	D	161.6	
	9h21m53.5	D	151.7	
2005TNN2	9h20m10.6	R	250.1	
	9h20m18.9	R	243.1	
	9h20m22.0	R	235.9	
	9h20m24.1	R	231.5	
	9h20m31.4	R	228.5	
	9h20m38.6	D	192.3	
	9h20m44.2	R	225.7	
	9h20m44.2	R	224.5	
	9h20m48.1	D	196.0	
	9h20m49.9	R	221.7	
	9h20m51.9	R	222.7	
	9h20m52.1	R	218.5	
	9h20m53.2	R	219.5	
	9h20m58.4	D	188.1	
	9h20m58.4	D	194.4	
	9h21m05.1	R	215.5	
	9h21m05.1	R	213.5	
	9h21m13.1	R	212.7	
	9h21m13.1	R	210.6	
	9h21m14.7	D	185.7	
	9h21m21.7	D	181.3	
	9h21m31.5	R	205.5	[4]
	9h21m32.7	D	177.0	
	9h21m33.1	D	173.6	
	9h21m34.5	D	174.9	
	9h21m44.0	D	170.4	
	9h21m44.5	D	164.1	
	9h21m49.8	D	154.3	
	9h21m50.9	D	155.9	
	9h21m51.1	D	161.5	
	9h21m52.5	D	151.7	
	9h22m02.4	D	149.1	
	9h22m08.8	D	146.5	
2005TNS1	9h14m35.1	R	311.9	
	9h14m41.0	R	319.1	
	9h14m41.9	R	316.1	
	9h14m42.7	R	317.4	
	9h14m43.1	R	321.2	

[4] No valley found in Watts profile.

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	9h14m43.1	R	320.2	
	9h14m45.8	R	325.6	
	9h14m46.3	R	326.4	
	9h14m50.1	R	328.8	
	9h14m55.4	R	331.8	
	9h15m01.2	R	333.9	
	9h15m05.6	R	336.4	
	9h15m09.6	R	338.7	
	9h15m09.7	R	21.7	
	9h15m11.6	R	343.1	
	9h15m16.8	R	346.1	
	9h15m18.5	R	347.7	
	9h15m25.0	R	352.0	
	9h15m26.9	R	356.6	
	9h15m30.7	R	0.1	
	9h15m30.8	R	0.5	
	9h15m31.9	R	3.9	
	9h15m35.3	R	6.9	
	9h15m37.5	R	11.3	
	9h15m37.3	R	18.7	
	9h15m38.9	R	9.4	
	9h15m39.0	R	14.7	
	9h16m16.3	D	31.4	
	9h16m27.2	D	18.4	
	9h16m33.7	D	47.5	
	9h16m41.5	D	55.8	
	9h16m42.4	D	54.1	
	9h16m46.2	D	58.5	
2005TNS2	9h14m45.0	R	319.2	
	9h14m50.4	R	325.0	
	9h15m09.2	R	335.7	
	9h15m15.4	R	343.0	
	9h15m18.9	R	346.0	
	9h16m31.4	D	47.5	
	9h17m27.5	D	54.0	
	9h17m43.6	D	100.2	
	9h18m19.2	D	118.3	
2006TKN1	10h55m56.5	D	18.5	
	10h56m03.5	D	6.7	
	10h56m09.5	D	347.3	
	10h57m06.8	R	325.6	
2006TKS1	10h56m36.6	D	150.45	
	10h56m37.3	D	149.3	
2006TKS2	10h56m39.9	D	109.1	
	10h56m46.6	D	111.3	
	10h56m49.8	D	114.6	
	10h56m56.1	D	122.3	
	10h56m53.7	D	123.8	
	10h57m04.2	D	133.4	
	10h57m15.4	D	141.6	
	10h57m15.8	D	145.0	
	10h58m35.5	R	211.6	
	10h58m39.1	R	214.0	
	10h58m45.9	R	219.7	
	10h56m58.5	D	122.3	
	10h57m03.8	D	132.59	
	10h57m04.9	D	133.4	
	10h57m04.3	D	134.0	
	10h57m04.0	D	134.95	

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	10h57m11.8	D	138.36	
	10h57m07.7	D	162.86	
	10h57m19.5	D	151.4	
	10h57m57.5	R	161.05	
	10h57m43.1	R	162.83	
	10h57m54.8	R	165.97	
	10h57m56.2	R	166.77	
	10h57m39.9	R	170.79	
	10h57m44.8	R	173.4	
	10h57m44.8	R	175.29	
	10h57m44.8	R	177.06	
	10h57m58.8	R	181.44	
	10h58m01.5	R	184.77	
	10h58m01.5	R	186.11	
	10h58m09.4	R	188.0	
	10h58m18.8	R	192.38	
	10h58m14.4	R	195.71	
	10h59m04.1	R	236.97	
	10h59m25.3	R	244.85	
	10h59m27.9	R	246.62	
2006TKS2B	10h56m39.9	D	109.1	2^{nd} telescope
	10h56m46.6	D	111.3	2^{nd} telescope
	10h56m49.8	D	114.6	2^{nd} telescope
	10h56m56.1	D	122.3	2^{nd} telescope
	10h56m53.7	D	123.8	2^{nd} telescope
	10h57m04.2	D	133.4	2^{nd} telescope
	10h57m15.4	D	141.6	2^{nd} telescope
	10h57m15.8	D	145.0	2^{nd} telescope
	10h58m35.5	R	211.6	2^{nd} telescope
	10h58m39.1	R	214.0	2^{nd} telescope
	10h58m45.9	R	219.7	2^{nd} telescope
2006TKS3	10h56m20.9	D	154.1	
	10h56m39.7	D	150.5	
	10h56m47.0	D	111.4	
	10h56m49.3	D	114.6	
	10h56m49.7	D	115.6	
	10h56m56.1	D	122.4	
	10h56m54.3	D	123.8	
	10h56m53.7	D	125.4	
	10h56m53.0	D	127.9	
	10h56m53.7	D	129.8	
	10h57m04.2	D	133.4	
	10h57m03.5	D	136.7	
	10h57m06.0	D	147.5	
	10h57m10.9	D	140.0	
	10h57m15.1	D	140.6	
	10h57m15.8	D	141.6	
	10h57m16.3	D	144.3	
	10h58m13.7	R	162.9	
	10h58m14.0	R	188.0	
	10h58m16.0	R	195.8	
	10h58m18.1	R	166.8	
	10h58m21.4	R	192.4	
	10h59m47.1	R	254.6	
	10h59m48.6	R	256.4	
	11h00m05.3	R	261.2	
	11h00m06.2	R	262.2	
	11h00m07.4	R	264.2	
	11h00m07.2	R	263.3	

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	11h00m15.9	R	267.0	
	11h00m17.5	R	268.0	
	11h00m22.8	R	269.6	
2006TKS4	10h56m54.2	D	111.4	
	10h56m57.1	D	114.5	
2006TKS5	10h56m56.4	D	114.64	
	10h57m02.9	D	122.24	
	10h57m11.1	D	133.84	
	10h57m22.9	D	141.65	
	10h57m57.8	R	170.71	
	10h58m18.2	R	184.72	
	10h58m30.9	R	197.31	
2006TKS6	10h56m28.3	D	92.0	
	10h56m32.1	D	94.01	
	10h56m38.0	D	100.11	
	10h56m50.6	D	107.32	
	10h56m52.3	D	109.13	
	10h56m56.0	D	111.38	
	10h56m56.1	D	113.55	
	10h56m58.4	D	114.66	
	10h57m04.2	D	122.25	
	10h57m02.9	D	123.78	
	10h57m01.7	D	125.41	
	10h57m11.1	D	133.39	
	10h57m21.0	D	139.91	
	10h57m21.3	D	141.61	
	10h57m20.6	D	144.3	
	10h58m27.9	R	162.84	
	10h58m56.1	R	164.07	
	10h58m57.0	R	165.94	
	10h58m47.4	R	166.78	
	10h57m53.0	R	171.06	
	10h58m18.0	R	173.39	
	10h58m10.3	R	175.24	
	10h58m09.8	R	177.0	
	10h58m18.2	R	181.46	
	10h58m19.9	R	184.79	
	10h58m27.8	R	187.97	
	10h58m36.0	R	192.38	
	10h58m29.5	R	195.78	
	10h58m37.0	R	199.11	
	10h58m38.6	R	199.87	
	10h58m39.3	R	201.38	
	10h58m39.6	R	205.4	
	10h58m48.1	R	211.45	
	10h58m51.2	R	214.01	
	10h58m58.4	R	216.86	
2006EGS1	10h40m27.10	D	94.0	[5]
	10h40m33.46	D	100.1	
	10h40m49.90	D	109.2	
	10h40m53.58	D	111.4	
	10h40m57.18	D	114.6	
	10h41m04.66	D	122.4	
	10h41m14.22	D	133.4	
	10h41m29.58	D	141.6	
	10h41m33.18	D	147.0	

[5]to all this station's data apply $\Delta T = +0.06$ s

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	10h41m29.06	R	162.8	
	10h41m39.18	R	170.8	
	10h41m53.94	R	175.2	
	10h41m55.26	R	177.0	
	10h42m06.62	R	181.4	
	10h42m09.54	R	184.7	
	10h42m22.94	R	195.8	
2006EGS2	10h40m56.86	D	114.61	[6]
	10h41m14.34	D	133.4	
	10h41m27.22	D	141.2	
	10h41m27.46	D	141.69	
	10h41m27.46	D	145.40	
	10h41m39.02	R	162.9	
	10h41m41.26	R	170.7	
	10h41m54.78	R	177.0	
	10h41m57.34	R	175.2	
	10h42m06.94	R	181.4	
	10h42m10.46	R	184.7	
	10h42m19.34	R	188.0	
	10h42m24.06	R	195.8	
2006FG1	9h49m30.9	R	256.3	[7]
	9h49m34.9	R	267.9	
	9h49m35.0	R	269.8	
	9h49m35.5	R	270.8	
	9h49m35.8	R	272.8	
	9h49m35.8	R	282.4	
	9h49m36.0	R	284.5	
	9h55m19.7	D	97.4	
	9h55m20.5	D	105.5	
	9h55m20.5	D	107.0	
	9h55m21.6	D	116.2	
	9h55m25.0	D	85.8	
	9h55m26.4	D	122.3	
2008RUN1	10h44m18.9	D	35.5	
	10h44m22.2	D	32.5	
	10h44m26.9	D	18.7	
	10h44m26.9	D	19.8	
	10h44m27.4	R	11.19	[8]
	10h44m33.6	R	8.4	
	10h44m34.6	R	9.19	
	10h44m35.9	R	3.9	
	10h44m40.4	R	357.0	
	10h44m40.6	R	0.5	
	10h44m42.0	R	352.2	
	10h44m43.8	R	350.8	
	10h44m46.4	R	348.4	
	10h44m46.4	R	347.9	
	10h44m49.2	R	343.0	
	10h44m49.6	R	344.3	

[6] to all this station's data apply $\Delta T = +0.06$ s

[7] Watts angle of this Bead remains uncertain: Watts' profile there does not show significant valleys.

[8] This clearly identified valley is not included in Watts profile. Additional observations of lunar occultations show the valley with a number of data-points. This valley at 11.19° has been called "Kislevka valley", because it was discovered at Kislevka station (Russia), as a typical example where Watts limb departs significantly from the observed one.

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	10h44m50.7	R	339.7	
	10h44m51.0	R	340.7	
	10h44m51.0	R	338.2	
	10h44m54.8	R	337.0	
	10h44m55.9	R	336.0	
	10h44m56.6	R	334.0	
	10h44m57.0	R	333.4	
	10h44m58.4	R	333.0	
	10h44m58.6	R	332.6	
	10h44m59.1	R	332.0	
	10h45m05.1	R	325.6	
2008RUN2	10h44m08.7	D	48.0	
	10h44m12.7	D	42.2	
	10h44m16.2	D	34.7	
	10h44m17.2	D	35.5	
	10h44m19.5	D	32.5	
	10h44m27.1	D	18.7	
	10h44m27.1	D	19.8	
	10h44m28.7	R	11.19	[9]
	10h44m34.0	R	8.4	
	10h44m35.2	R	9.19	
	10h44m35.5	R	3.9	
	10h44m40.1	R	0.5	
	10h44m42.2	R	357.0	
	10h44m42.4	R	352.2	
	10h44m43.9	R	350.8	
	10h44m46.6	R	348.4	
	10h44m46.6	R	347.9	
	10h44m49.0	R	343	
	10h44m49.5	R	344.3	
	10h44m50.7	R	339.7	
	10h44m50.9	R	340.7	
	10h44m51.0	R	338.2	
	10h44m54.8	R	337.0	
	10h44m56.6	R	334.0	
	10h44m57.0	R	333.4	
	10h44m58.6	R	333.0	
	10h44m58.6	R	332.6	
2008RUN3	10h44m09.1	D	48.0	
	10h44m13.7	D	42.2	[10]
	10h44m17.3	D	34.7	
	10h44m18.4	D	35.5	
	10h44m21.1	D	32.5	
	10h44m23.4	R	11.19	[11]
	10h44m23.8	D	29.4	
	10h44m29.4	D	18.7	
	10h44m29.4	D	19.8	
	10h44m31.9	R	8.4	
	10h44m32.5	R	9.19	
	10h44m34.5	R	3.9	
	10h44m38.9	R	0.5	
	10h44m39.4	R	357.0	

[9] No valley found in Watts profile.

[10] No valley found in Watts profile.

[11] This clearly identified valley, the "Kislevka valley", is not included in Watts profile. Additional observations of lunar occultations show the valley with a number of data-points.

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	10h44m41.3	R	352.2	
	10h44m42.8	R	350.8	
	10h44m45.6	R	348.4	
	10h44m45.6	R	347.9	
	10h44m48.4	R	343.0	
	10h44m48.5	R	344.3	
	10h44m50.1	R	339.7	
	10h44m50.2	R	340.7	
	10h44m50.4	R	338.2	
	10h44m54.1	R	337.0	
	10h44m55.9	R	334.0	
	10h44m56.3	R	333.4	
	10h44m57.9	R	333.0	
	10h44m57.9	R	332.6	
	10h45m04.2	R	326.0	
2008RUS1	10h45m18.4	D	156.1	Time ±0.3s
	10h45m27.1	D	168.0	
	10h45m31.1	D	163.01	
	10h45m34.9	D	174.46	
	10h45m38.1	D	184.6	Time ±0.3s
	10h45m41.7	D	171.2	
	10h45m42.0	D	188.8	Time ±0.3s
	10h45m44.7	D	177.01	
	10h45m45.3	D	188.1	Time ±0.3s
	10h45m52.7	R	196.0	
	10h45m57.7	R	195.0	
	10h46m02.2	R	205.2	
	10h46m02.7	R	204.3	
	10h46m04.4	R	207.2	
	10h46m04.4	R	208.0	
	10h46m06.7	R	211.5	
	10h46m09.1	R	214.8	
	10h46m09.1	R	217.0	
	10h46m11.8	R	226.2	
	10h46m12.5	R	220.1	
	10h46m12.8	R	227.0	
2008RUS2	10h45m14.3	D	143.0	
	10h45m17.2	D	153.8	
	10h45m17.5	D	147.6	
	10h45m17.5	D	145.5	
	10h45m18.3	D	156.2	
	10h45m19.0	D	157.8	
	10h45m21.0	R	196.0	Time ±1s
	10h45m27.0	D	165.8	
	10h45m27.9	D	167.0	
	10h45m32.1	D	163.0	
	10h45m35.7	D	173.5	
	10h45m36.3	D	178.0	Time ±0.3s
	10h45m36.2	D	179.0	Time ±0.3s
	10h45m37.0	R	197.2	Time ±0.5s
	10h45m42.6	D	175.3	
	10h45m43.1	D	188.1	
	10h45m44.0	D	171.2	Time ±0.2s
	10h45m44.5	D	181.4	
	10h45m45.4	D	177.0	
	10h45m49.1	R	205.2	Time ±0.5s
	10h45m55.5	D	186.0	Time ±0.5s
	10h46m00.1	R	211.5	Time ±0.5s
	10h46m02.0	R	210.0	Time ±0.3s

Station	Time/hms (UTC)	D/R	Watts angle[°]	Remarks
	10h46m02.2	R	214.8	Time ±0.2*s*
	10h46m02.8	R	217.0	Time ±0.2*s*
	10h46m03.4	R	199.4	
2008RUS3	10h45m10.9	D	139.9	
	10h45m12.9	D	142.0	
	10h45m16.1	D	147.6	
	10h45m17.5	D	156.1	
	10h45m25.7	D	165.8	
	10h45m27.0	D	167.0	
	10h45m30.8	D	163.0	
	10h45m32.8	R	196.0	Time ±0.3s
	10h45m38.5	D	188.1	
	10h45m40.7	D	175.3	Time ±0.2s
	10h45m41.4	D	181.4	Time ±0.2s
	10h45m41.5	D	171.3	Time ±0.2s
	10h45m44.1	D	177.0	Time ±0.2s
	10h45m44.1	R	197.3	Time ±0.4s
	10h45m52.1	D	184.5	Time ±0.2s
	10h46m08.0	R	199.4	[12]
	10h46m08.5	R	226.2	Time ±1s
	10h46m11.0	R	230.0	Time ±1s
	10h46m13.5	R	234.4	
	10h46m24.1	R	146.2	[13]
2008CNS1	11h09m34.42	D	175.3	
	11h09m36.36	D	171.2	
	11h09m36.63	D	177.0	
	11h09m38.19	D	184.7	
	11h09m53.51	R	205.2	
	11h09m59.98	R	211.6	
	11h10m01.35	R	210.0	
2008CNS2	11h08m47.42	D	108.69	
	11h08m53	D	114.91	[14]
	11h08m57.13	D	121.86	
	11h08m58.84	D	127.34	
	11h09m11.55	D	141.85	
	11h09m12.62	D	145.55	
	11h09m12.75	D	153.79	
	11h09m12.75	D	156.31	
	11h09m23.99	D	163.02	
	11h09m26.8	D	175.26	
	11h09m28.87	D	177.09	
	11h09m29.23	D	170.8	
	11h09m31.27	D	171.61	
	11h09m31.77	D	168.01	
	11h09m55.89	R	205.37	
	11h10m15.45	R	246.3	
	11h10m19.9	R	251.9	
	11h10m23.45	R	258.12	
	11h10m23.45	R	256.35	
	11h10m23.45	R	255.01	

[12] No valley found in Watts' profile

[13] No valley found in Watts' profile

[14] There is a systematic shift in all timings, avoidable in data analysis (Sigismondi, 2008c).

Table 4.: Beads F/M

Station	Time/hms (UTC)	F/M	Watts angle[°]
2006TKS2	10h56m39.9	F	109.97
	10h56m43.6	F	112.43
	10h56m44.3	F	117.0
	10h56m50.9	F	125.0
	10h56m51.3	F	122.97
	10h57m00.3	F	135.58
	10h57m09.9	F	143.17
	10h58m36.7	M	210.43
	10h58m40.5	M	213.64
	10h58m47.1	M	219.18
	10h57m02.5	F	132.85
	10h57m02.9	F	133.67
	10h57m02.2	F	134.41
	10h57m01.1	F	135.56
	10h57m08.2	F	139.04
	10h57m03.0	F	150.07
	10h58m28.0	M	165.37
	10h58m23.9	M	166.4
	10h58m19.8	M	167.35
	10h57m59.1	M	172.9
	10h58m05.6	M	174.0
	10h58m04.4	M	175.8
	10h58m05.0	M	179.83
	10h58m13.0	M	183.0
	10h58m04.5	M	185.46
	10h58m17.1	M	187.06
	10h59m08.1	M	236.67
	10h59m26.1	M	244.56
	10h59m28.5	M	246.24
2006TKS2B	10h56m39.9	F	109.97
	10h56m43.6	F	112.43
	10h56m44.3	F	117.0
	10h56m50.9	F	125.0
	10h56m51.3	F	122.97
	10h57m00.3	F	135.58
	10h57m09.9	F	143.17
	10h58m36.7	M	210.43
	10h58m40.5	M	213.64
	10h58m47.1	M	219.18
2006TKS6	10h56m27.0	F	92.64
	10h56m29.8	F	95.41
	10h56m35.4	F	100.58
	10h56m48.2	F	107.63
	10h56m47.7	F	109.95
	10h56m52.3	F	112.4
	10h56m51.6	F	114.1
	10h56m52.7	F	117.0
	10h56m59.9	F	122.98
	10h56m59.2	F	124.97
	10h56m59.9	F	126.8
	10h57m08.6	F	135.56
	10h57m18.4	F	140.26
	10h57m12.9	F	143.19
	10h59m25.0	M	163.68
	10h59m21.4	M	165.36
	10h59m06.9	M	166.36
	10h58m53.2	M	167.35

Station	Time/hms (UTC)	F/M	Watts angle[°]
	10h58m20.9	M	172.94
	10h58m36.7	M	174.0
	10h58m25.6	M	175.87
	10h58m21.8	M	179.81
	10h58m31.1	M	183.03
	10h58m34.5	M	187.03
	10h58m39.5	M	191.56
	10h58m40.8	M	193.42
	10h58m38.4	M	198.25
	10h58m41.0	M	199.51
	10h58m41.1	M	200.94
	10h58m40.1	M	203.84
	10h58m49.1	M	210.42
	10h58m52.1	M	213.58
	10h58m59.2	M	216.49

6. Summary and outlook

This article is the result of expeditions to various regions of the World. The positions of the observers were chosen depending on the number of available observers and the width of the observation zone, the zone of grazing eclipse. Due to higher mountains and deeper valleys along the lunar south pole in comparison with the north pole, the northern grazing zone is always smaller. The experiences made during the observations in 2005 and 2006 resulted in stipulating standardized optical equipment (cf. Chapter 2). The focal length used, which is 1000mm, is a good compromise between the error of the automatic drive, the tolerance in focusing and the scale of the image. The results achieved with this standardised optical equipment can be evaluated with higher accuracy due to the comparability of the stations. IOTA and IOTA/ES is planning to continue Bailys beads observations during solar eclipses in the future, especially on the 22^{th} of July 2009. For further videotapes' analyses, the method of light curves to determine the start or end of beads (reappearance and disapearance) by Limovie will be investigated. The previously-described form and merge bead events will be investigated for their possible value for determination of the solar diameter.

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