Solar Diameter with Eclipses

A Method of Data Reduction

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Ephemerides

- Lunar and Solar ephemerides are known with great precision (relativistic accuracy)
- Remark of IMCCE (Bureau de Longitude) on the difference between center of mass and optical center of the Moon: 0.50” in longitude and -0.25” in latitude. Empyric!
- Is it possible to allow an extra free parameter in our data analysis for this?

From www.imcce.fr P. Roché

- 1. Précision dans le calcul des prédictions d´éclipses
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- Les différents organismes nationaux producteurs d´éphémérides publient dans leurs éphémérides et dans des bulletins spécifiques les circonstances générales et locales des éclipses de Lune et de Soleil.

- Parmi ces organismes figurent entre autres :

- l´U.S. Naval Observatory, qui publie l´Astronomical Almanac,
- la Division Astronomie du Département d´Hydrographie de Tokyo, qui publie les Éphémérides Japonaises,
- le Département de Météorologie Indienne qui publie les Éphémérides Astronomiques Indiennes,
- le Bureau des longitudes qui publie la Connaissance des Temps et les Éphémérides Astronomiques,
- le Royal Greenwich Observatory qui publie le H. M. Nautical Almanac,
- la NASA qui publie et diffuse régulièrement des bulletins spécifiques aux éclipses de Soleil.
- Si on compare les prédictions de ces différentes publications, on constate des écarts, sur les instants des conjonctions en longitude, sur les limites des bandes de centralité et sur les circonstances locales des éclipses. Ces écarts proviennent des différences entre les paramètres utilisés dans les calculs de prédiction.

- Le premier choix porte sur les éphémérides et les théories utilisées dans le calcul des positions apparentes de la Lune et du Soleil. Tous les organismes cités ci-dessus, à l´exception du Bureau des longitudes, utilisent pour le calcul des éphémérides de la Lune et du Soleil les résultats de l´intégration numérique américaine DE200/LE200 du Jet Propulsion Laboratory. Au Bureau des longitudes nous utilisons, pour la Lune, la théorie analytique ELP2000 élaborée par M. Chapront-Touzé et J. Chapront, et pour le Soleil, la théorie analytique VSOP82 élaborée par P. Bretagnon. Ces deux théories et les éphémérides américaines sont suffisamment proches pour ne pas entraîner des écarts dans les prédictions.

- Par contre tous les organismes nationaux, à l´exception de la NASA, effectuent une correction empirique en latitude et en longitude dans le calcul des éphémérides des positions apparentes de la Lune. Cette correction a pour but de passer des coordonnées du centre de masse de la Lune aux coordonnées du centre optique de la Lune. Cette correction est de +0,50" en longitude et de -0,25" en latitude. L´absence de cette correction dans les bulletins de la NASA explique les écarts constatés sur les instants de conjonction et une partie des écarts dans la détermination des lignes de centralité (décalage de la ligne de centralité).

Watts Atlas

- It has been digitized by David Dunham in 1980s.
- It is available through David Herald's Winoccult, with and without Morrison and Appleby corrections (1981).
- The availability is possible through the Baily Beads module, fixing the location and the day of the eclipse (better if total)

Winoccult desiderata

Baily Beads is by far the better tool to investigate grazing solar eclipses

- The code is not accessible and modificable
- The help is rather odd (no complete analytic index, e.g. axis angle, C parameter seen in Baily Beads are explained only in Occultation outputs and Lunar Physical Ephemeris, no longer available in the new version 4)
- The formulae of solve module of Baily Beads are unaccessible
- The correction of lunar center of figure, present in 3.6 version (lunar occultations) was not explained and disappeared in 4 version.
- The module of quick prediction (eclipses and transits) does not show the durations of total and partial eclipse up to 1/10 s and in the new 4 version does not allow to select the location with arcsec accuracy
- The show of lunar mountains was possible (3.6) only near totality and not allowed for partial eclipses (1st and 4th contact). Some informations are retrievable using tricks.
- The version 3.6 is no longer available for download (I do not pretend software assistance, but to do output's modifications)
- The requests of modifications are subjected to the Author's disponibility and to his judgment on the utility of the request, after my last request he promised 2 months of delay
- The value of Delta T was visible and changeable in 3.6 version, and now disappeared
- The increment/decrement tool was working in 3.6 version and no more in 4.

First Step: video in avi or MPEG4

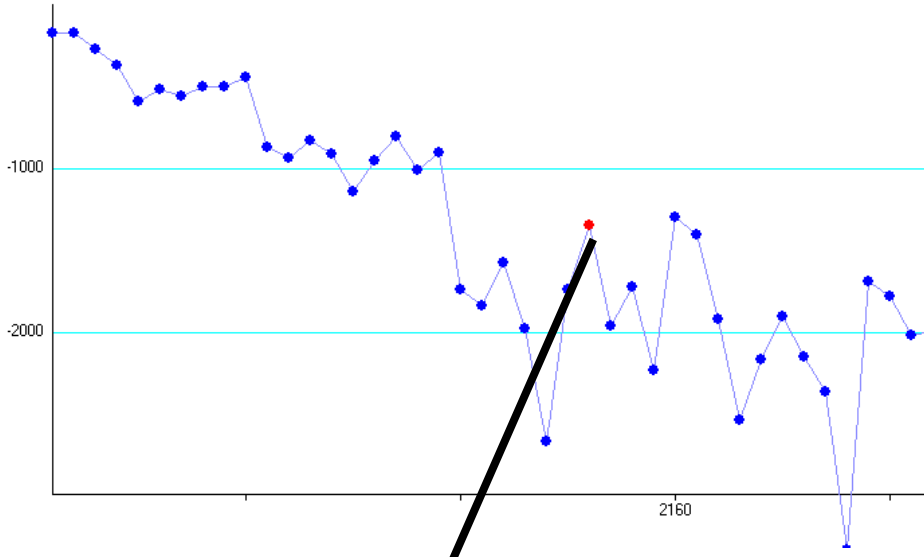
- An Older videotape of Eclipses is in NTSC (it contains 1984 annular-total; 1987; 1994; 1995 and 1998 total eclipses).
- Some of the positions were uncertain, the time was assured by WWV signals.
- The original video belongs to W.H.Warren, unfortunately my PAL copy never worked in Italy.
- An MPEG 4 version should be available on IOTA/US website for new analyses
- Same remarks on all recent eclipses observed by Paul Maley's group (R. Nugent being the most famous and skilled bead's chaser)
- Also IOTA/ES should have a reference site in those formats with eclipses data available to science community.

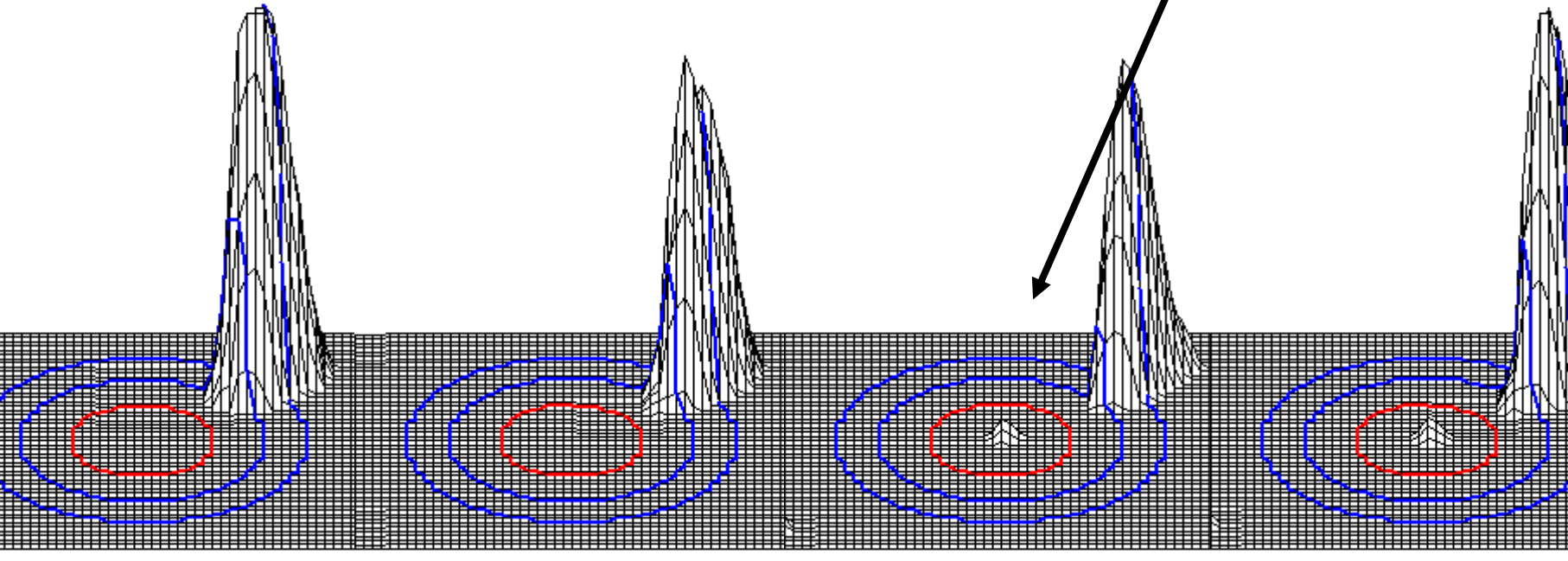
Second Step: frame by frame

- The best way to do this analysis is using Quicktime (on avi and mpeg4 files)
- IOTA/US use Limovie
- Using arrows (left for backward and right for forward) during play it goes frame by frame and a control window shows the time passed from the beginning of the video

XAMPLE OF LIMOVIE ANALYSIS Bead #3 by R. Nugent IOTA/US Aug 1, 2008

tudy of light curve and limiting magnitude





1.184 1.217 1.250 1.284

Third Step: residuals

- Baily beads events are to be selected: only D and A, to avoid “black drop effects”
- They are labelled with their UTC and with the help of Winoccult Baily Bead module also their Axis Angles are identified (here there can be some source of uncertainty)
- With right-hand click the height of lunar and solar limbs appear for a given Angle
- Their values AA and residual (Sun-Moon) are plotted on an Excel worksheet in both cases of MA (Morrison and Appleby corrections) and no MA.

Fourth Step: free parameters

- Even with the better intentions, the Baily Bead module works with a value of DeltaT which is not exactly the daily value for a given eclipse (≤ ± 0.7 s).
- We have to allow the Moon to cover an extra (±) gap on its orbit, and it corresponds to a motion of the lunar profile at different speed for different Position Angles.
- The equations of this motion are analytical, the data are retrievable from ephemeris programs
- I recommend very basic programs like ephemvga, and www.calsky.com interactive website which yields hourly motion in declination and right ascension for Sun and Moon.

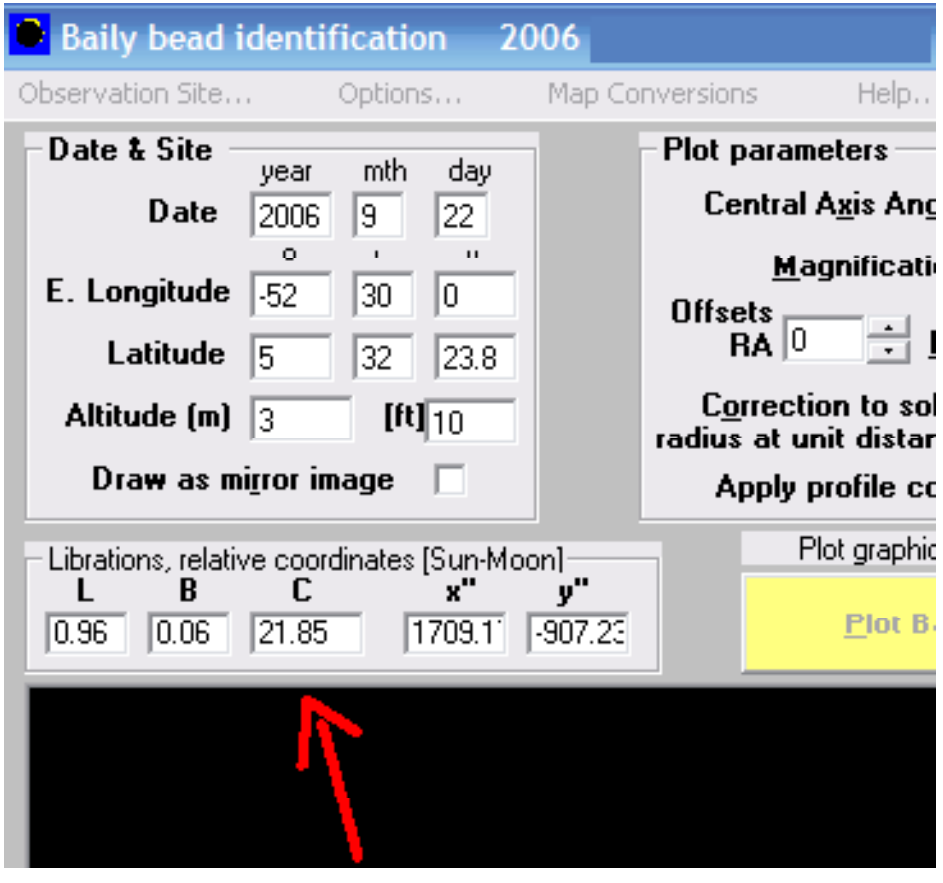
Fifth step: lunar parallax

- It is the effect of Earth rotation: its magnitude depends on the distance D of the Moon from the observing Location (topocentric) and from the angular distance A from East cardinal point:
- Arctan(0.465 · cos(lat)/D[km]) · Cos(A) [°/s]
- Cos(A)=cos(h)· cos(Az-90°)
- Where h is the height above the horizon and Az the azimut of the Sun/Moon center
- This effect can change in few minutes depending on geometry

Example: Annular Eclipse 2006

- Data (longitude, latitude), C (conversion Axis Angle-Position Angles) and equations
- Original Table of Recorded Beads
- Residuals computation

C-parameter


Baily bead identification 2006
Observation Site...
Options...
Map Conversions
Help...
Date & Site
year
mth
day
Date
2006
9
22
E. Longitude
-52
30
0
Latitude
5
32
23.8
Altitude (m)
3
[ft]
10
Draw as mirror image
Plot parameters
Central Axis Ang
Magnificati
Offsets
RA
0
Correction to sol
radius at unit distar
Apply profile co
Librations, relative coordinates [Sun-Moon]
L
B
C
x"
y"
0.96
0.06
21.85
1709.1
-907.23
Plot graphic
Plot B

Example: Guyana annular eclipse,Table of Residuals and comparison with ΔT minimization

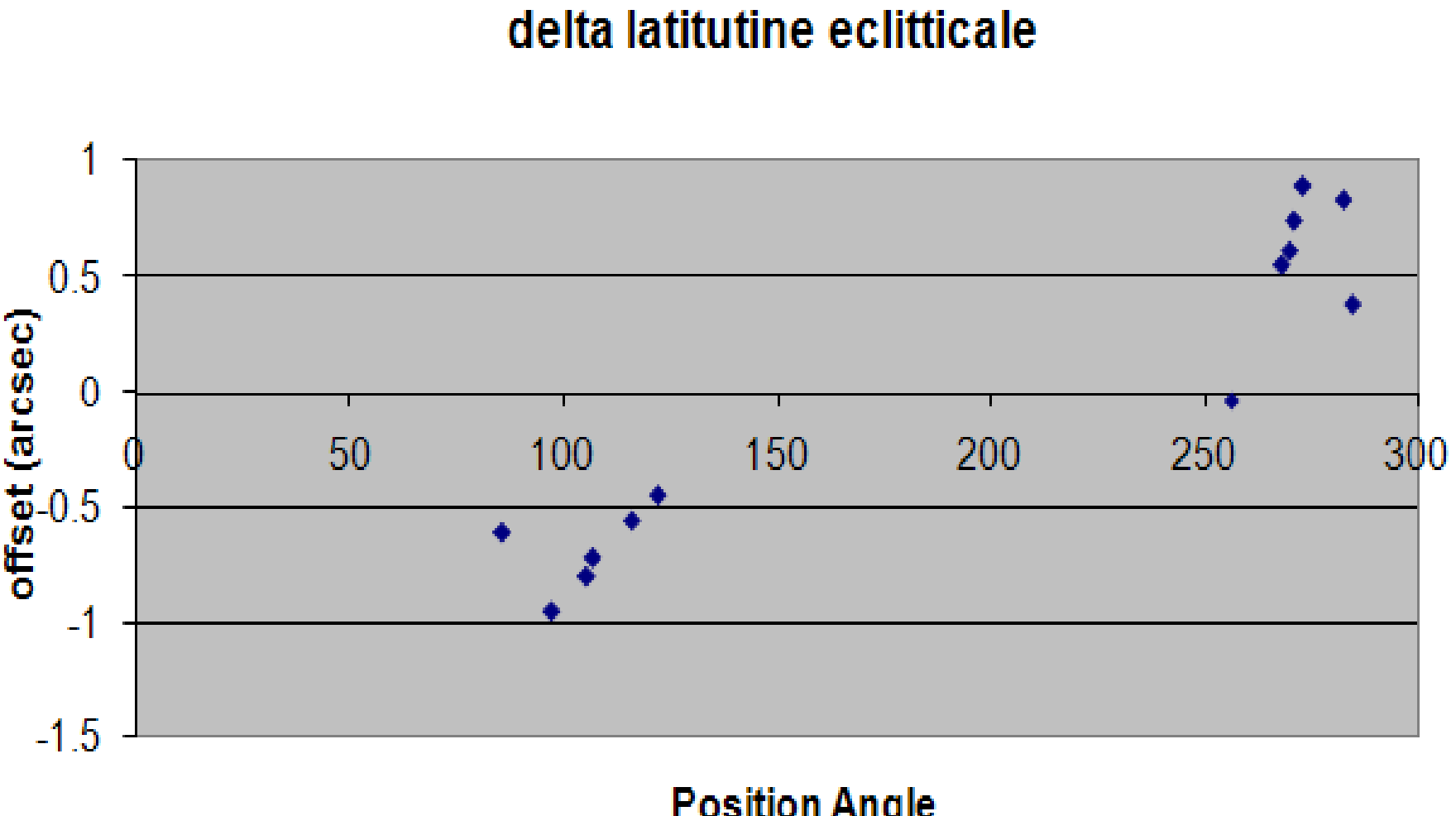
	A	B	C	D	E	F	G	H	I	J	K
1	ORA UTC	evento	P.A.	residuo (sole-luna)	no MA	derivata	delta T	residui corretti MA	somma q	res cor NM	som nMA
2	30.9	a	256	-0.04	0.19	0.36	-1.52	-0.5872	0.61104	-0.3572	0.56855
3	34.9	a	268	0.55	0.71	0.38		-0.0276		0.1324	
4	35	a	270	0.61	0.76	0.41		-0.0132		0.1368	
5	35.5	a	271	0.74	0.88	0.45		0.056		0.196	
6	35.8	a	273	0.89	1.02	0.45		0.206		0.336	
7	35.8	a	282	0.83	0.87	0.45		0.146		0.186	
8	36	a	285	0.38	0.42	0.45		-0.304		-0.264	
9	19.7	d	97.4	-0.95	-0.84	-0.45		-0.266		-0.156	
10	20.5	d	106	-0.8	-0.69	-0.45		-0.116		-0.006	
11	20.5	d	107	-0.72	-0.6	-0.45		-0.036		0.084	
12	21.6	d	116	-0.56	-0.44	-0.4		0.048		0.168	
13	25	d	85.8	-0.61	-0.52	-0.43		0.0436		0.1336	
14	26.4	d	122	-0.45	-0.31	-0.38		0.1276		0.2676	
15								-0.0556		0.065938	
16								0.218107558		0.206565	
17											

Sixth step: minimization of residuals

- Using a single parameter Δt we can include effects of
- Delta T (UT1-UTC) even if this can be updated daily and inserted in winoccult from IERS site
- Offset in lunar longitude of optical Center with respect to ephemerides
- Systematic offset of the reference clock (always in need of being tested)

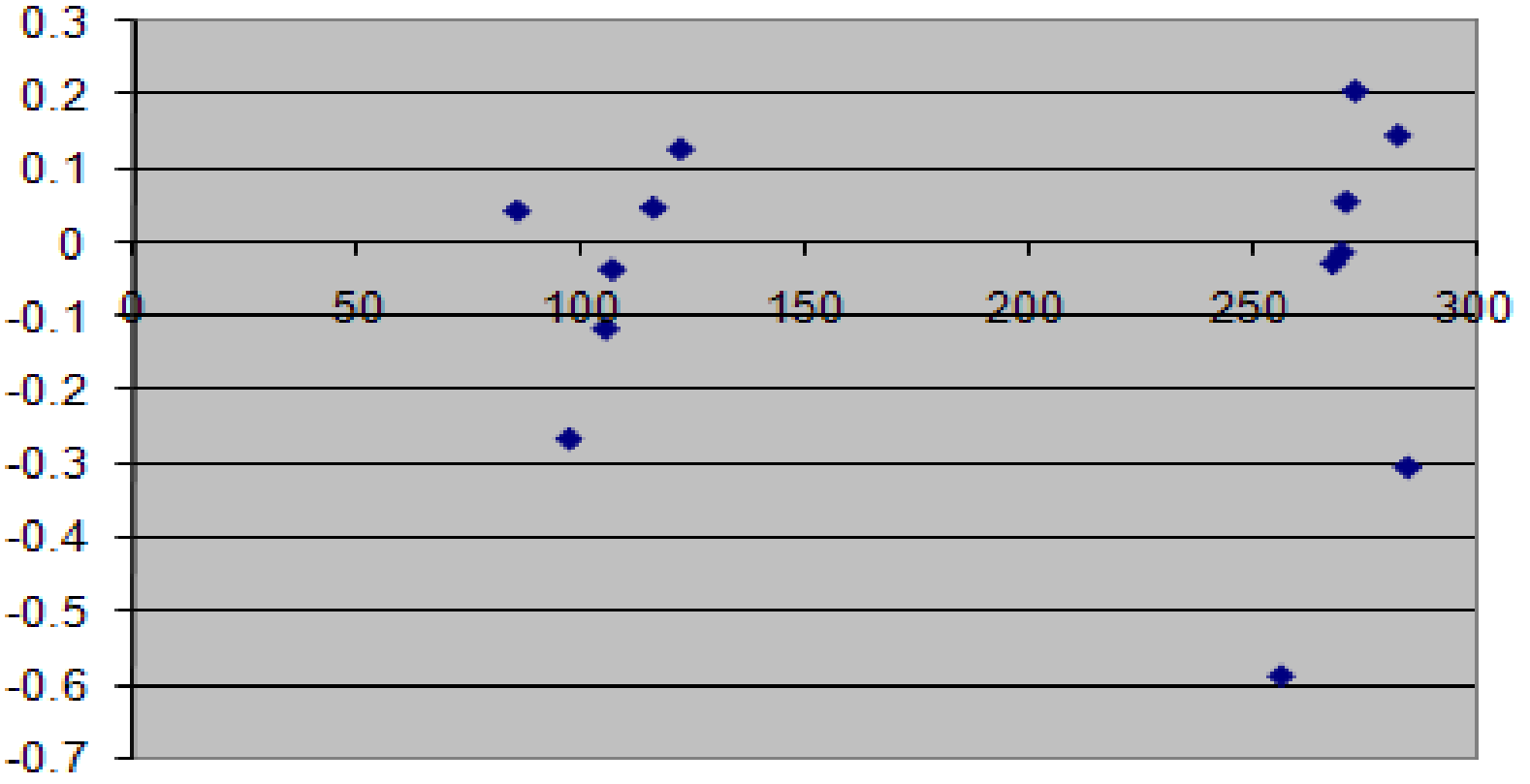
Example: Guyana 2006

- Raw data



Eclipse in Guyana 2006

- After ΔT minimization



Seventh Step: comparison between North and South limits

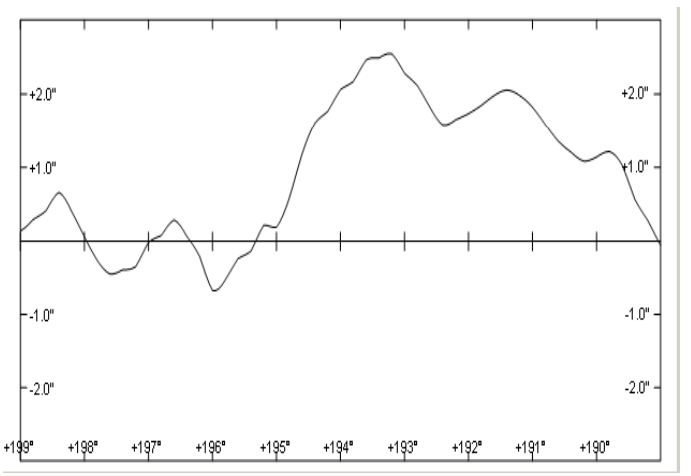
- When possible this allows to consider a lunar latitude uncertainty (?) in the optical center
- The latitude offset is rather unefficient at centerline, while it produces different radius corrections ΔR at each shadow limit.
- For the eclipse in Guyana it was not possible (antumbral limits in the forest and in the ocean)

Example: Spanish annular eclipse 2005 (IOTA/ES and Sabadell+WS)

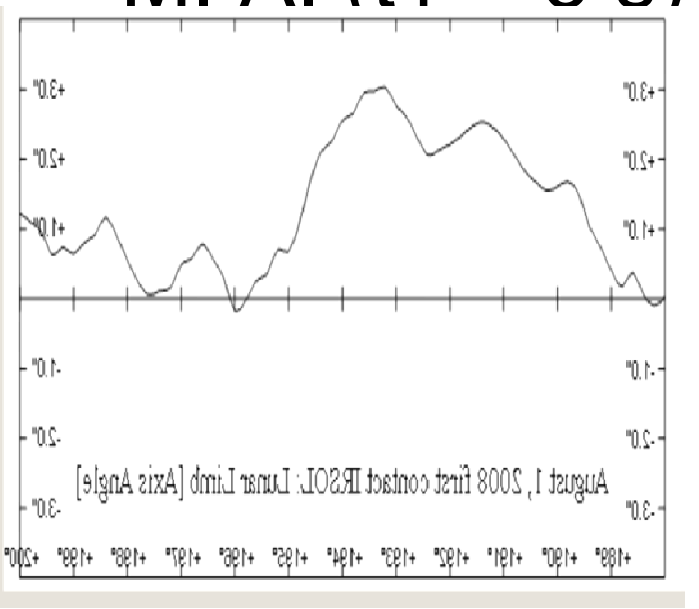
- For Northern limit $\Delta R=0.21” \pm 0.04”$ stat. err
- For Southern limit $\Delta R=-0.01” \pm 0.06”$
- The difference is a systematic effect, attribuable to the aforesaid difference between optical and mass centers
- The radius correction is $\Delta R=0.10” \pm 0.07”$
- It is the average (not weighted), and it corresponds to the shift of +0.11” North of optical center (eclipse on descendant node). The corresponding error is in quadrature

And what about Morrison & Appleby?

- 3.6 and 4 versions of Baily Beads allow to compare the Watts profiles with lunar occultations
- NO M. A.



M. A. (t1>+3 s)



- Advance not observed…

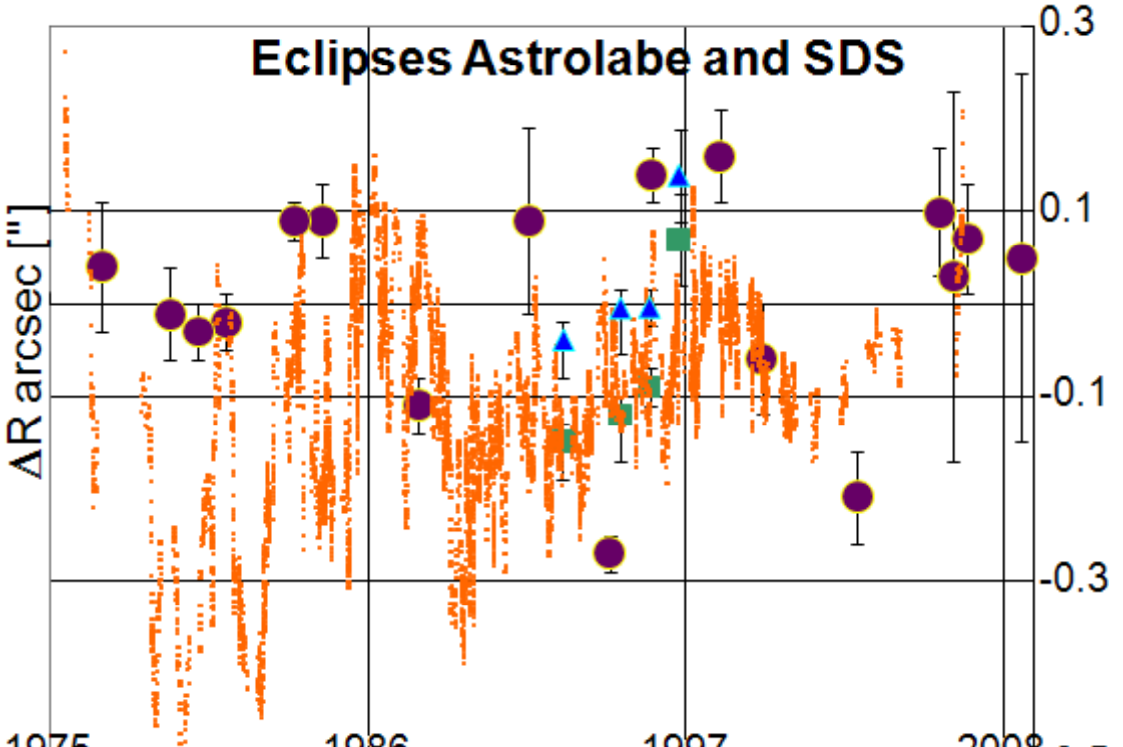
Data reduction thanks to Michele Bianda:IRSOL, CH Gregory-Coudé Solar Telescope

Conclusions

- In 2008 case Morrison Appleby are ruled out.
- In general I am skeptical with Statistical changes, even with a large dataset in support
- Same criticism with ancient eclipse and transits analyses, where the average is done among very accurate observations and data obtained with unadeguate instruements

Application of same methood to past eclipses

Here 2008 eclipse is calculated upon 3 news (one from the web: Frank Edison at Alert, Nunavut, Canada…)



Historical eclipses and transits: the question remains open

TABLE 1. Corrections to average solar radius at uniy distance (959.63") from Fiala et al. (1994) and from Sigismondi et al. *(2008, this volume).

Date	Type of Eclipse	Correction to solar radius
May 3 1715	*Total 3 obs.*	$\Delta R=(+0.48\pm0.20)$
May 5 1832*	*Mercury tr.*	$\Delta R=(+0.77\pm0.10)$
Aug 7 1869*	*Total 3 obs*	$\Delta R=(+0.23\pm0.20)$
Jan 24 1925	*Total 8 obs.*	$\Delta R=(+0.51\pm0.08)$
Feb 26 1979	*Total 47 obs*	$\Delta R=(-0.11\pm0.05)$

Revival of the centerline

- After Guyana's eclipse Video on centerline are also very useful to check the N and S limit results.
- They are also useful to measure the oblateness.
- Oblateness is the ultimate precision of eclipse method.
- 7.8 mas is the expected and observed (RHESSI) oblateness at solar surface due to rotation