



*The observatory logo, the first image analysed from the 1990 February 9 lunar eclipse*

# Topocentric Umbra Analysis

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## Abstract

Video records of lunar eclipses have been measured by image analyst techniques to determine the geometry of the umbra. A new procedure has been developed to compute the topocentric umbral sizes for each observing site from geocentric data. The topocentric values are compared with the video umbral measures to determine change in the size of the umbra during the 1996 total lunar eclipses of September 27 and April 3-4, and the partial lunar eclipse of 1995 April 15. **Update:** Recently, still images have been measured with greater accuracy.

*Keywords: lunar eclipse, umbra, topocentric value*

## 1 INTRODUCTION

Video records of lunar eclipses have been measured by image analyst techniques to find the semi-diameters of the umbra and moon to determine the geometry of the umbra. As these images are topocentric, a procedure has been developed to compute the expected topocentric umbral semi-diameter for each observing site from geocentric data. The topocentric values of umbral size have been compared with the measurement of video images to determine change in the the umbra during both 1996 total lunar eclipses of September 27 and April 3-4 and the partial lunar eclipse of 1995 April 15. **Update:** Recently, still images of several lunar eclipses in 2007 and 2008 have been measured.

## 2 PROCEDURE

The total lunar eclipse of 1996 September 27 was observed at *Recife, Brazil by the Universidade Federal de Pernambuco* where the team lead by Jose Fernando Tepedino provided "real-time" video images of the eclipse via the Internet. The total lunar eclipse of 1996 April 3-4 was observed by two astronomers in *Portugal* and one in *Belgium*, they both used video cameras to record a series of lunar images for analysis.

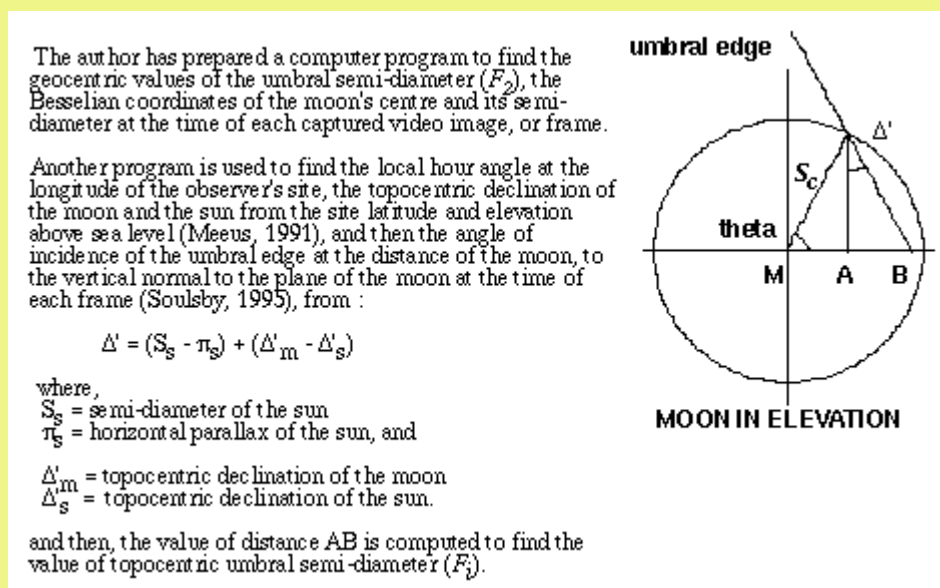
Captured frames from the real time images and video records have been digitised and measured (Soulsby, 1995) using the commercial software, *Image Analyst Version 8.0*, running on a Macintosh IIfx computer.

**Update:** I now use *Digimizer* as a measuring engine on a MacBook/Parallels/Windows XP.

A diagrammatic of the geometry of a typical lunar eclipse is shown in Figure 1, with the radius of the moon ( $S_c$ ) eclipsed by the umbra of geocentric radius ( $F_2$ ) and computed topocentric umbral radius ( $F_j$ ). A computer program (*ViaX8.exe*) has been prepared to find the topocentric semi-diameter of the umbra by applying the cosine rule to triangle *OMC*, as well as the other parameters given in Figures 1 and 2 (also described in Soulsby, 1995). The program finds the topocentric umbral radius ( $F_j$ ) for each observer's site using the following geometry and expressions at the time each measured image is captured:

**Update:** The geometry is shown [here](#).

**Figure 1:** Moon eclipsed by the umbra in plan view showing the parameters used to compute the topocentric umbral radius ( $F_j$ ).



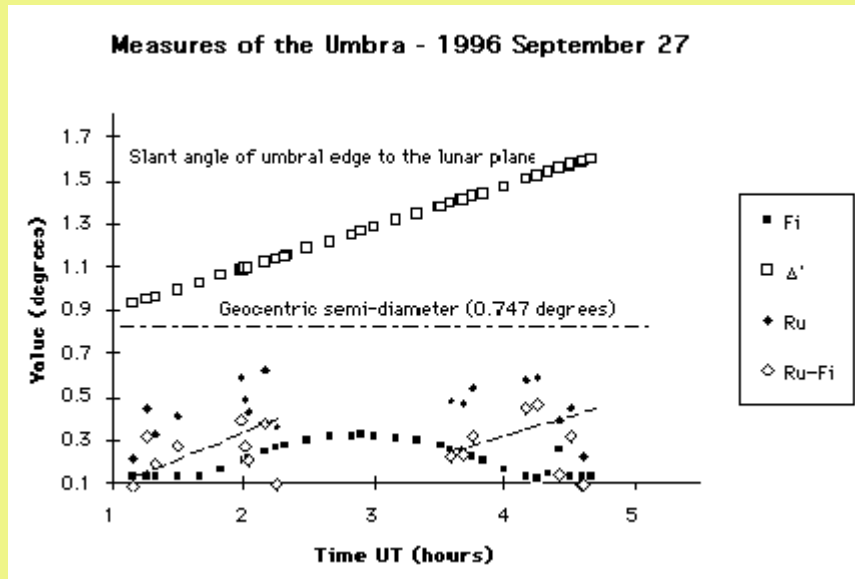
**Figure 2:** Moon eclipsed at the umbral edge in an elevation view. The topocentric declination of the moon ( $\Delta'_m$ ) and the sun ( $\Delta'_s$ ) are also given in (Meeus, 1991). The distance AB is used to compute the topocentric umbral semi-diameter ( $F_j$ ). This geometry is also described in (Soulsby, 1995 on pages 45-46).

### 3 MEASUREMENT COMPARISON

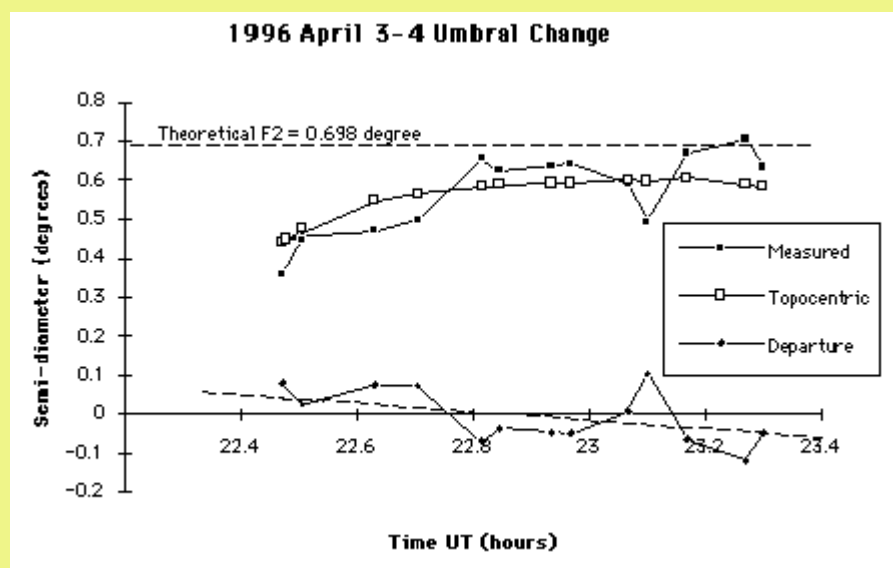
The analysis of the measurements of captured frames before and after totality from the Internet images provided by the Universidade Federal de Pernambuco, in Brazil are shown in Figure 3 below. The analysis of the measurements of captured frames before and after totality from the video record by the astronomer Marques, in Portugal are shown in Figures 4 and 5.

In these figures the presumed static theoretical geocentric semi-diameter of the umbra ( $F_2$ ) is shown with the measured umbral radii ( $R_u$ ) and the computed topocentric semi-diameter of the umbra. The topocentric values are compared with each measurement of the apparent umbral semi-diameter taken from the video frames. The computed slant angle ( $\Delta'$ ) of the umbral edge to the lunar plane, also defined in Figure 2, is included for each image time in Figure 3. The departure of each measured diameter from the computed topocentric value shows the change throughout the eclipse. This is also shown as a smoothed (dashed) line

in the figures as an estimate of the change in umbral size.

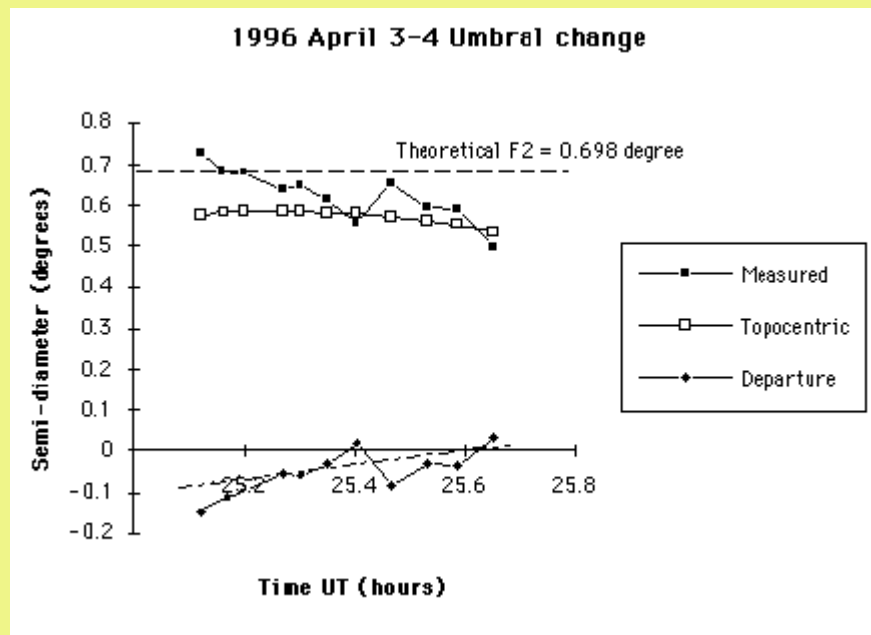


**Figure 3:** Comparison of geocentric semi-diameter of the umbra, computed topocentric ( $F_i$ ) and umbral measurements ( $R_u$ ) from first to fourth contact after the live Internet video images from Jose Tepedino at the Universidade Federal de Pernambuco, in Brazil. There is a large spread between the image measurements and the computed topocentric semi-diameter. However, the departure of the measured semi-diameter from the expected topocentric umbral semi-diameter, shown as a smoothed (dashed) line, has a general **increase** during the eclipse of around 0.2 of a degree for each phase.



**Figure 4:** Comparison of geocentric, computed topocentric and umbral semi-diameter measurements from first to second contact after the video record by Marques, Portugal. There is a slight spread in the image measurements, however, the departure of the measured semi-diameter from the computed topocentric umbral semi-diameter, shown as a smoothed (dashed) line, has a general **decrease** in size during the eclipse,

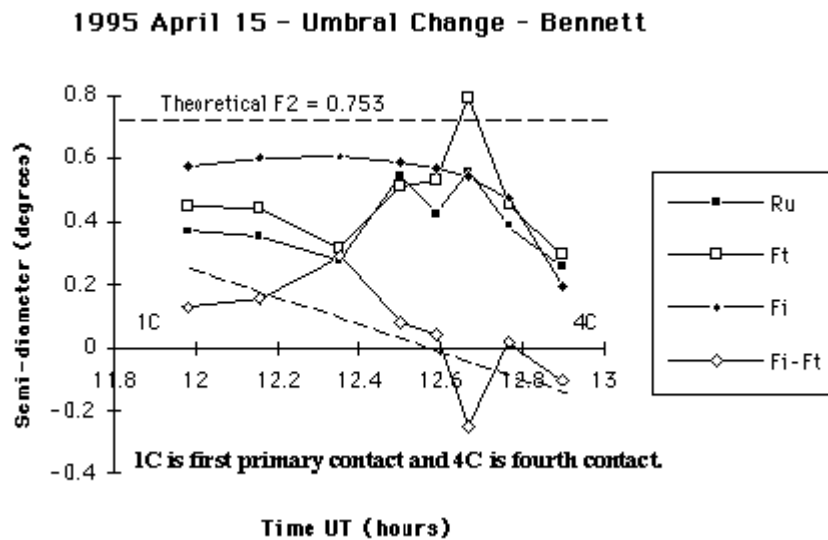
of around 0.1 of a degree.



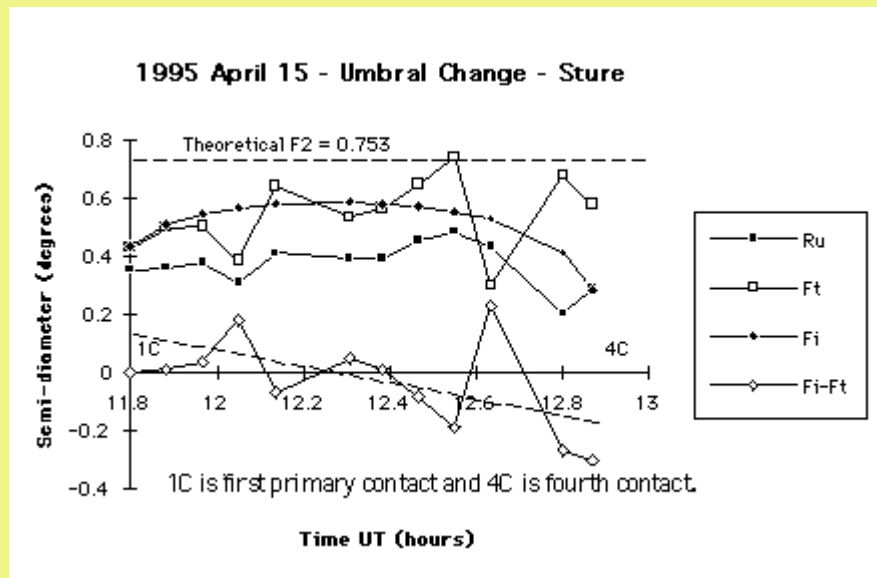
**Figure 5:** Comparison of geocentric, computed topocentric and semi-diameter umbral measurements from third to fourth contact after the video record by Marques, Portugal. There is a slight spread in the image measurements. The departure of the measured semi-diameter from the expected umbral semi-diameter, shown as a smoothed (dashed) line, has a general **increase** in size during the eclipse, of around 0.1 of a degree.

#### 4 PARTIAL LUNAR ECLIPSE OF 1995 APRIL 15

Several observers in Australia provided video records of the partial lunar eclipse of 1995 April 15 (Soulsby, 1995). These are re-analysed in a similar manner using the measured image umbral radii ( $R_u$ ) for comparison with the topocentric corrected values ( $F_p$ ). These are compared with the assumed static geocentric theoretical value ( $F_2$ ) and the computed topocentric values ( $F_p$ ). The results from Bennett and Sture for this eclipse are shown in Figures 6 and 7 below:



**Figure 6:** Comparison of geocentric, topocentric and semi-diameter umbral measurements ( $Ru$ ) which are corrected to topocentric ( $F_t$ ) (Soulsby, 1995), for first to fourth contact from the video record by John Bennett. The scattered measured values, when corrected to topocentric ( $F_t$ ) are near to the computed topocentric semi-diameter ( $F_i$ ). There is a general **decrease** in umbral size ( $F_i - F_t$ ) shown as a smoothed (dashed) line, of around 0.25 of a degree.



**Figure 7:** Comparison of geocentric, topocentric and semi-diameter umbral measurements ( $Ru$ ) corrected to topocentric ( $F_t$ ), for first to fourth contact from the video record by Brian Sture and Harry Moller. The scattered measured values, when corrected to topocentric ( $F_t$ ) are near to the computed topocentric semi-diameter ( $F_i$ ). Again there is a **decrease** in umbral size ( $F_i - F_t$ ) shown as a smoothed (dashed) line, of 0.2 of a degree.

#### 4 CHANGE IN UMBRAL SIZE

By comparing the measured semi-diameters of umbral images with the computed topocentric values,

dynamic change in umbral geometry is detected. For observations of the eclipse of 1996 September 27 made in Brazil, the departures show a large spread due to the small image size and low quality, but give a general umbral increase both before and after totality.

For the eclipse of 1996 April 3-4 observed in Portugal, a decrease in umbral size was determined before totality and an increase after totality, each around 0.1 of a degree. A similar departure between the umbral measurements and topocentric umbral semi-diameters was found from the video record by Garcia, whom also observed in Portugal. There is considerable spread, but the nominal increase before totality is near that found for the other Portuguese observations.

The 1996 data suggests that change in umbral geometry occurred during both lunar eclipses, probably due to variation in transparency and/or cloud cover in the Earth's atmosphere.

Two other sets of scattered data for the partial lunar eclipse of 1995 April 15 from the observers Bennett and Sture, Australia gave a general decrease in umbral semi-diameter of around 0.2 of a degree.

**Update:** A recent lunar eclipse of **2008 February 21** provided results for a comparison of computed topocentric umbral size and image measurement. In this comparison it can be seen that the image measurements and the computed topocentric values are very close. A comparison of the measured umbral semi-diameter and computed topocentric umbra size for Bernard Durand's images can be seen [here](#).

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## 5 CONCLUSIONS

In work reported earlier (Soulsby, 1995, 1994) the puzzling result of consistently low values of measured umbral semi-diameters taken from video records near first and fourth contact has now been resolved by considering computed topocentric values of umbral semi-diameter at the time of each image frame. Most umbral measurements, and those corrected to topocentric values by other techniques (Soulsby, 1995) are now much closer to the computed topocentric semi-diameters. The previously large difference between the measured umbral semi-diameter and the static geocentric values has been resolved.

Even though there is some large scatter for the 1995 April 15 partial lunar eclipse measurements and the corrected topocentric values, these now compare well with the computed topocentric values.

There appears to be a measurable, but slow dynamic change in umbral semi-diameter during these three lunar eclipses, although the scatter suggests that improved image quality and accuracy in their measurement should be pursued. **Update:** Recent measurements of the 2008 February 21 total lunar eclipse show good comparison with the computed topocentric umbral data.

## 6 COMMENTS

One problem with the image analysis technique is associated with the high magnification used by most observers. A preferred value (around 84 X) is that which provides a complete image of the moon during all stages of the eclipse, as this greatly assists image calibration and measurement. Most video images tend to be overexposed, due in part to both high magnification and large telescope aperture. An improvement in image contrast (by reducing the effective aperture, but not by filtering) would also assist measurement analysis of future lunar eclipses.

The video imaging and measurement technique requires improvement, but it is the only known technique where change in the upper atmosphere of the Earth can be detected during lunar eclipses. By improved refinement, it may also be possible to measure dynamic change in umbral oblateness in addition to the change in size presented here.

The exciting prospect of obtaining live video images from lunar eclipses not visible in Australia has been achieved for the first time for the 1996 September 27 total lunar eclipse, thanks to the team in Brazil. They provided me with my "first" day time lunar eclipse.

**Update:** The images of the 2008 February 21 eclipse provided the best results so far in this project, and images from Bernard Durand and Jay Pasachoff have provided important data.

## 7 ACKNOWLEDGMENTS

The author would like to express his thanks to the astronomers whom have contributed to this research by providing video records. In particularly to those overseas observers who have provided video records and real-time Internet images of the moon in eclipse when such lunar eclipses are not visible in Australia.

## 8 REFERENCES

Update: see <http://www.netspeed.com.au/minnah/2008/LE2008-1.html>

Soulsby, B.W., 1995, Analysis of the 1995 April 15 partial lunar eclipse, *Aust. J. Astr.*, (6)2: 33-52.

Soulsby, B.W., 1994, Change during lunar eclipses, *Proc. 16th Natn. Aust. Conv. amat. Astrer., Canberra*, pp 101-114.

Meeus, J., 1991. *Astronomical Algorithms*, pp 263-4. Willmann-Bell Inc. 429 pp.

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