Resolving Close Double Stars with Lunar and Asteroidal Occultations

David W. Dunham, IOTA and
Moscow Inst. of Electronics and Mathematics/H.S.E.

Maui Double Star Conference
Institute for Astronomy, Maui
2013 February 10

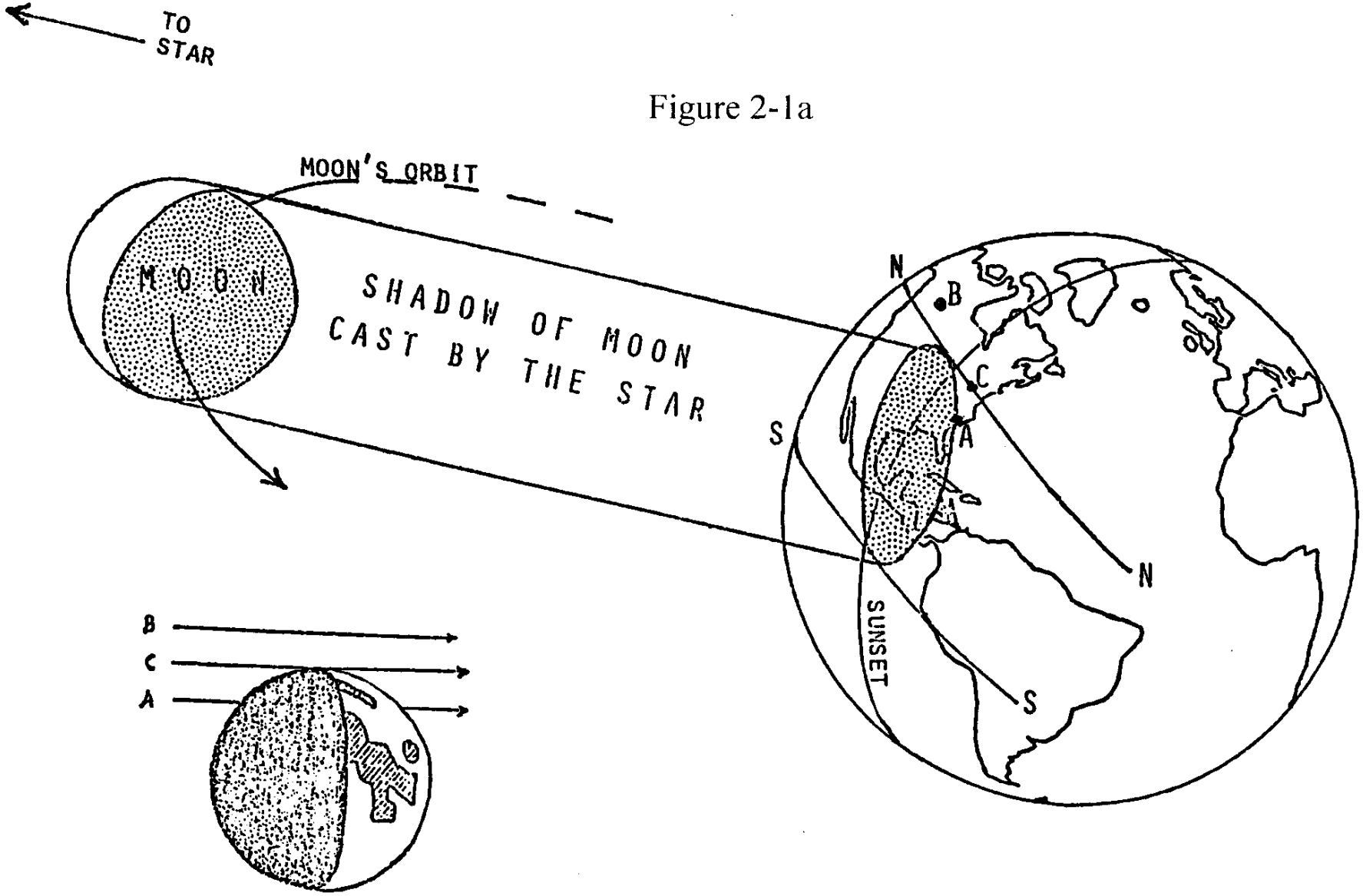
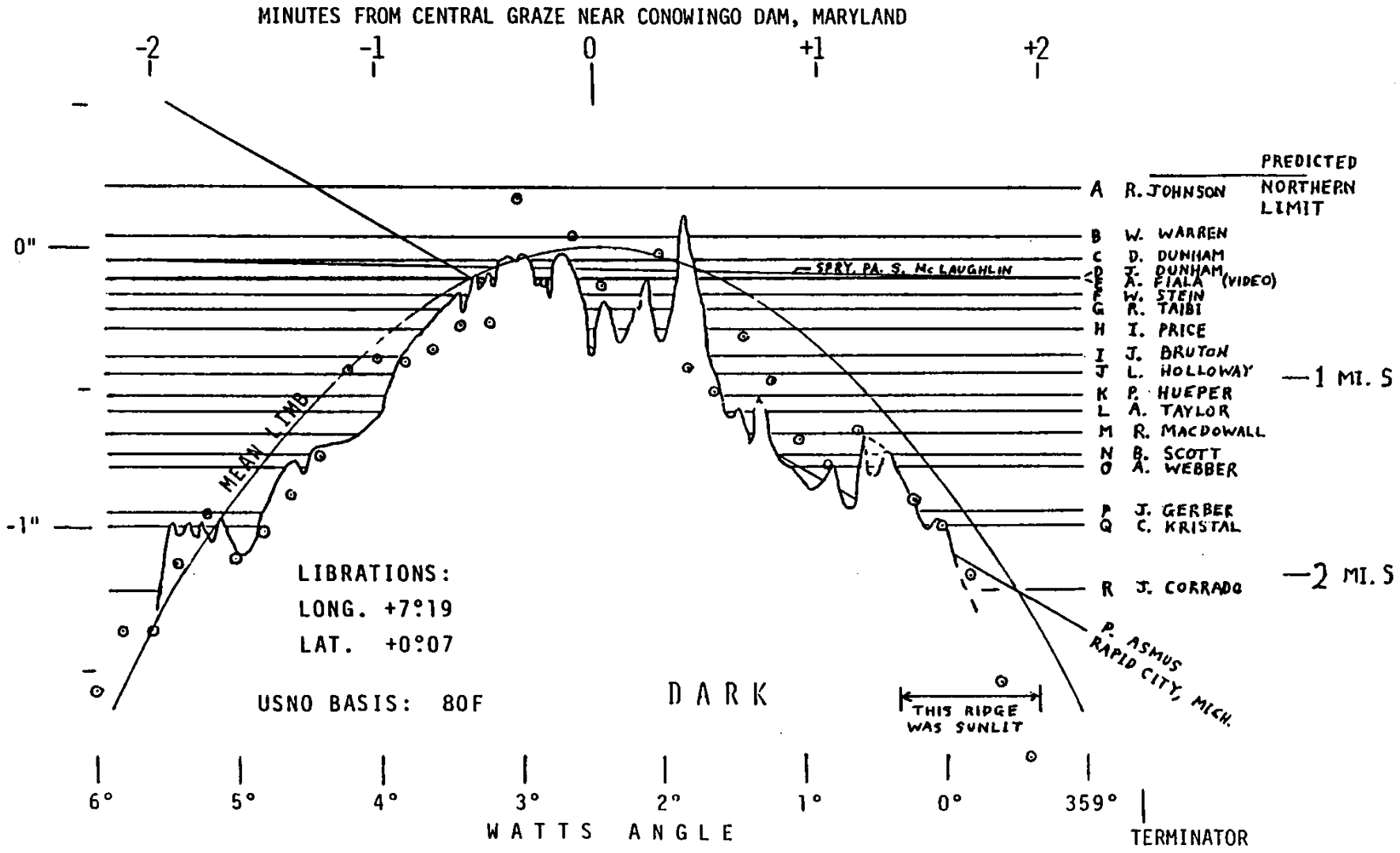


Figure 2-1a

Figure 2-1b

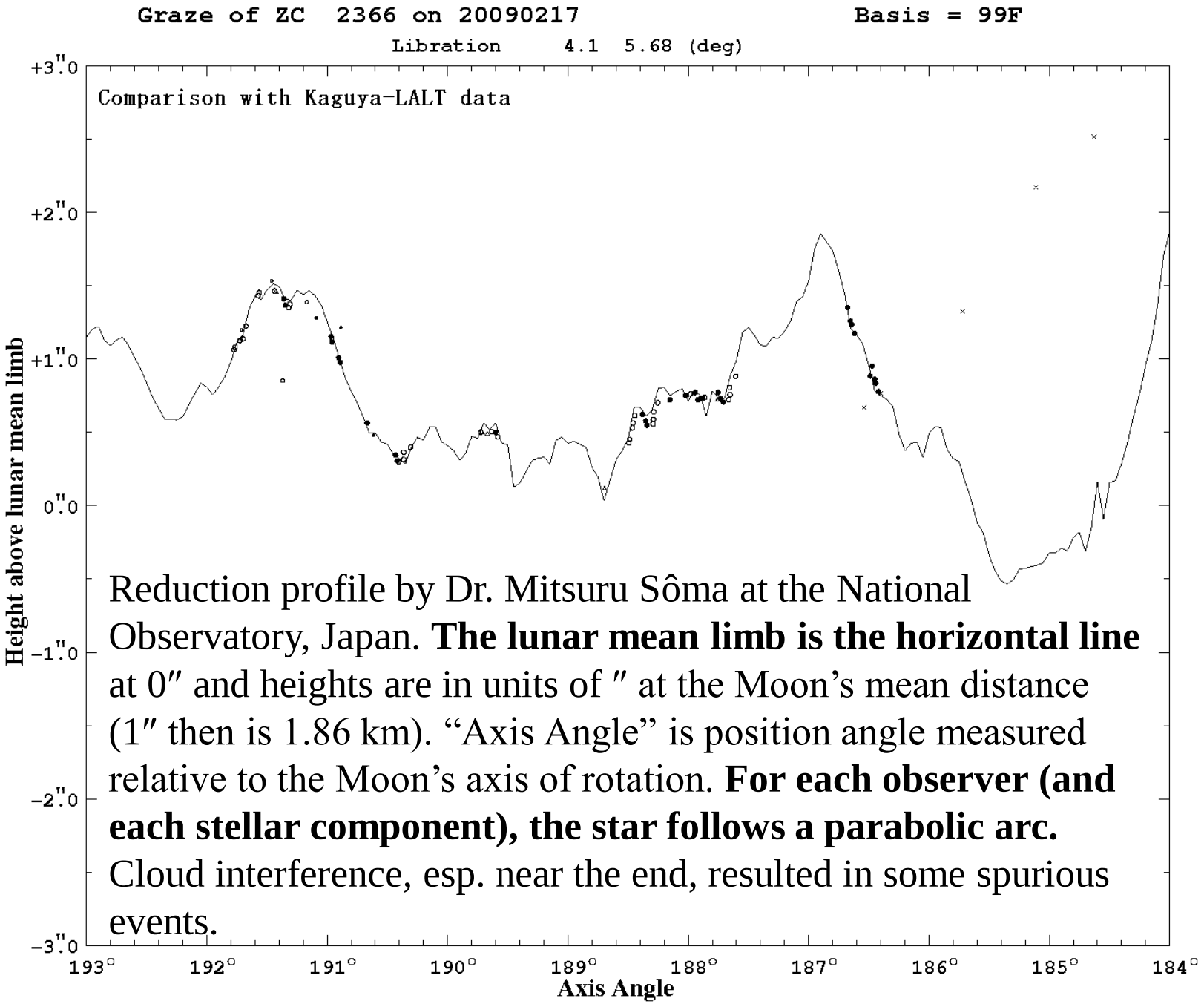
Lunar Profile from Graze of delta Cancri – 1981 May 9-10



Circled dots are Watts' predicted limb corrections

Long History of Double Star Discoveries from Lunar Occultations; Antares was 1st

- Duplicity of Antares discovered during a lunar occultation observed at Vienna by Johann Tobias Bürg on 1819 April 13. I observed a graze of Antares by the thin crescent Moon on 1969 January 25
- Contrast of the red giant star and its 5^{th}-mag. blue companion was striking
- I recorded an Antares graze with a color video camera and 12cm SCT from Western Australia on 2009 Feb. 17
- Show events of both components, 19:44:10 to 19:44:25 and
- 19:47:00 to 19:47:30



Reduction profile by Dr. Mitsuru Sôma at the National Observatory, Japan. **The lunar mean limb is the horizontal line** at 0″ and heights are in units of ″ at the Moon's mean distance (1″ then is 1.86 km). "Axis Angle" is position angle measured relative to the Moon's axis of rotation. **For each observer (and each stellar component), the star follows a parabolic arc.** Cloud interference, esp. near the end, resulted in some spurious events.

IOTA's Efforts to Catalog Possible Double Star Discoveries from Lunar Occultations

- In the **early 1970's**, I worked with David Evans' group at the Univ. of Texas to analyze hundreds of **photoelectric lunar occultation observations**
- I worked with a student, Don Stockbauer, to create a **list of possible doubles from lunar occultations using:**
  - Photoelectric occultations, Univ. of Texas and other published obs.
  - Grazing occultations observed since 1962
  - Total occultations, both current and from published obs.
  - **Spectroscopic binaries** (including 1-line) were included to **encourage observation** of their occultations.
- **Too many dubious events** were included; especially visual observers often reported **"gradual" events more likely due to Fresnel diffraction**, and sometimes stellar angular diameter
- **Codes** that indicated "certain, events in clear steps", "probable", and "possible" **were lost** when transferred to **currently-used lists**, for occultation predictions but also even the Washington interferometric catalog

IOTA's Recent Double Star Efforts

- We now strongly encourage observation with relatively **inexpensive video** equipment to better quantify the observations, and obtain at least **approximate photometric information** using specially-developed software for analyzing video records, esp. Limovie from Japan and Tangra from Australia
- We encourage observation of stars with a **past claim of duplicity**;
- **Over 90%** of those show **no evidence of duplicity with the new video obs.**
- We encourage observations of the same occultation of a suspected double from widely-separated locations with real-time coordination using "Occult Watcher" Web software.
- If the **same lunar occultation is observed from widely-separated locations** (with the contacts at different position angles), the **separation and position angle (P.A.) can be uniquely determined**; otherwise,
- **Only a "vector separation" in the P.A. of the occultation** is found
- If orbital motion slow, "vector separations" from events a few months apart can give approximate double star separation and P.A.
- Results are **published in JDSO** periodically, including lists where the new observations indicate "probably single" for previous occ'n duplicity claims

Lunar Occultation Observations of Known Double Stars – Report #1

Brian Loader, Darfield, New Zealand (BL)
Royal Astronomical Society of New Zealand (RASNZ)
International Occultation Timing Association

Y. Asada, Otsu, Kyoto, Japan (YA)
D. Breit, Morgan Hill, California, USA (DB)
J. Bradshaw, Yugar, Queensland, Australia (JB)
D. Gault, Hawkesbury Heights, NSW, Australia (DG)
D. Herald, Kambah, Canberra, Australia (DH)
E. Iverson, Lufkin, Texas, USA (EI)
M. Ishida, Matusaka, Mie, Japan (MI)
H. Karasaki, Nerima, Tokyo, Japan (HK)
M. Kashiwagura, Oe, Yamagata, Japan (MK)
K. Miyashita, Azumino, Nagano, Japan (KM)
S. Messner, Minneaplois, Minnesota, USA (SM)
T. Oono, Kurashiki, Okayama, Japan (TO)
S. Russell, North Parramatta, Sydney, NSW, Australia (SR)
G. Smith, Black Town, Sydney, NSW, Australia (GS)
J. Talbot, Waikanae, New Zealand (JT)

Email: palbrl@clear.net.nz

Abstract: Reports are presented of lunar occultations of close double stars observed using video including cases where a determination of the position angle and separation of the pair can be made and other cases where no duplicity has been observed.

This report is the first of a continuing series of double star measurements made during lunar occultations. The observations are contributed from observers around the world who observe lunar occultations. Unless noted otherwise, the observations were made using video at 30 fps (observers located in North America and Japan) or 25 fps (observers located in Europe and Australasia). Loader, in New Zealand, normally uses a 30 fps video.

timing of such events of close double stars, in general limited to those with separations less than 2 arcseconds. When the occultation of a double star is timed from two or more well spread locations an accurate determination of the PA and separation of the pair can be made. Results for a few such events are presented in Table 1. When only one observation is made of a double star occultation a complete solution is not possible, but a vector (minimum) separation of

SAO 97883 - A New Double Star

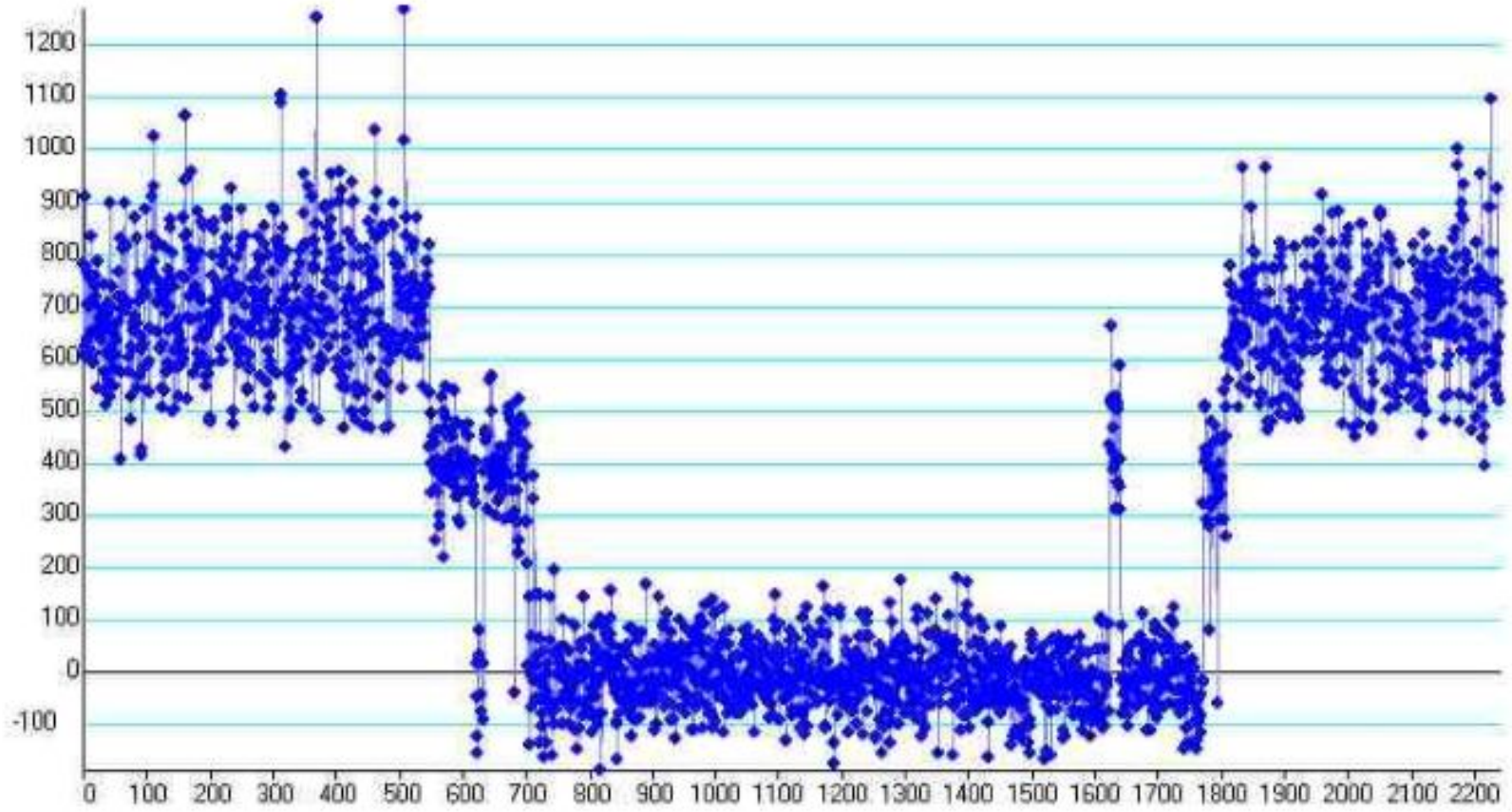


Figure 1: Light curve of the lunar grazing occultation of SAO 97883, extending for 90 seconds. The horizontal axis is the frame number in the video recording. The vertical axis is the intensity, in arbitrary units.

Table 1: PA and separation measured

WDS name	XZ	RA Dec	PA	+/-	Sep	+/-	Mag. diff	Date	Observers
HO 345AB	10979	07227+2205	304	4	1.84	0.17	1.4	2009.851	HK, MI, MK
AG 140	101356	07260+2205	165	4	1.38	0.15	0.8	2009.851	HK, MK
A 2768	16040	10426+0335	241	4	0.41	0.08	1.3	2009.413	DB, EI, SM
CHR 78	25788	18448-2501	8	+21 -35	0.016	+0.006 -0.002	2.5	2009.214	DG, BL
FIN 327	26957	19253-2431	275	17	0.095	0.005	1.5	2008.693	DG,DH,GS,JB
CHR 184Aa,Ab	28441	20273-1813	50	7	0.071	0.015	2.6	2009.668	DH,BL
SHJ 323AB	28475	20289-1749	214.8	1.2	1.44	0.02	1.7	2009.668	DH,BL
HDS3054	29697	21274-1335	357	6	0.113	0.013	1.5	2009.747	EI,DB

Lunar Occultation Observations of Known Double Stars – Report #1

Table 2: Vector separation measured

WDS name	XZ	RA Dec	Vector Angle	Vector Sepn.	Mag. Diff	Date	Observer
CHR 127AB	6268	04536+2522	265.910	0.34″	1.75	2009.845	SM
CHR 203	7200	05365+2556	334.873	0.06″	0.98	2009.856	MK
COU 914	9119	06283+2441	280.129	0.20″	0.86	2009.700	SM
HDS 910	9439	06375+2435	273.696	0.45″	2.56	2009.867	SM
HO 247	11655	07461+2107	274.531	0.49″	0.51	2009.770	MI
COU 773	13520	08539+1958	79.721	0.135″	0.52	2008.134	DG
HDS1323	13821	09062+1552	323.032	0.17″	2.55	2009.407	DH
HO 253	14778	09478+1004	348.300	0.77″	2.3	2009.410	EI
BU 932AB	19503	13347-1313	133.397	0.11″	1.6	2007.179	BL
HDS2008	20149	14171-1835	359.764	0.014″	3.5	2009.199	BL
BU 125AB	23196	17122-2703	73.543	1.81″	1.7	2008.611	DH
I 1031	26024	18531-2745	25.709	0.24″	0.97	2005.774	DG

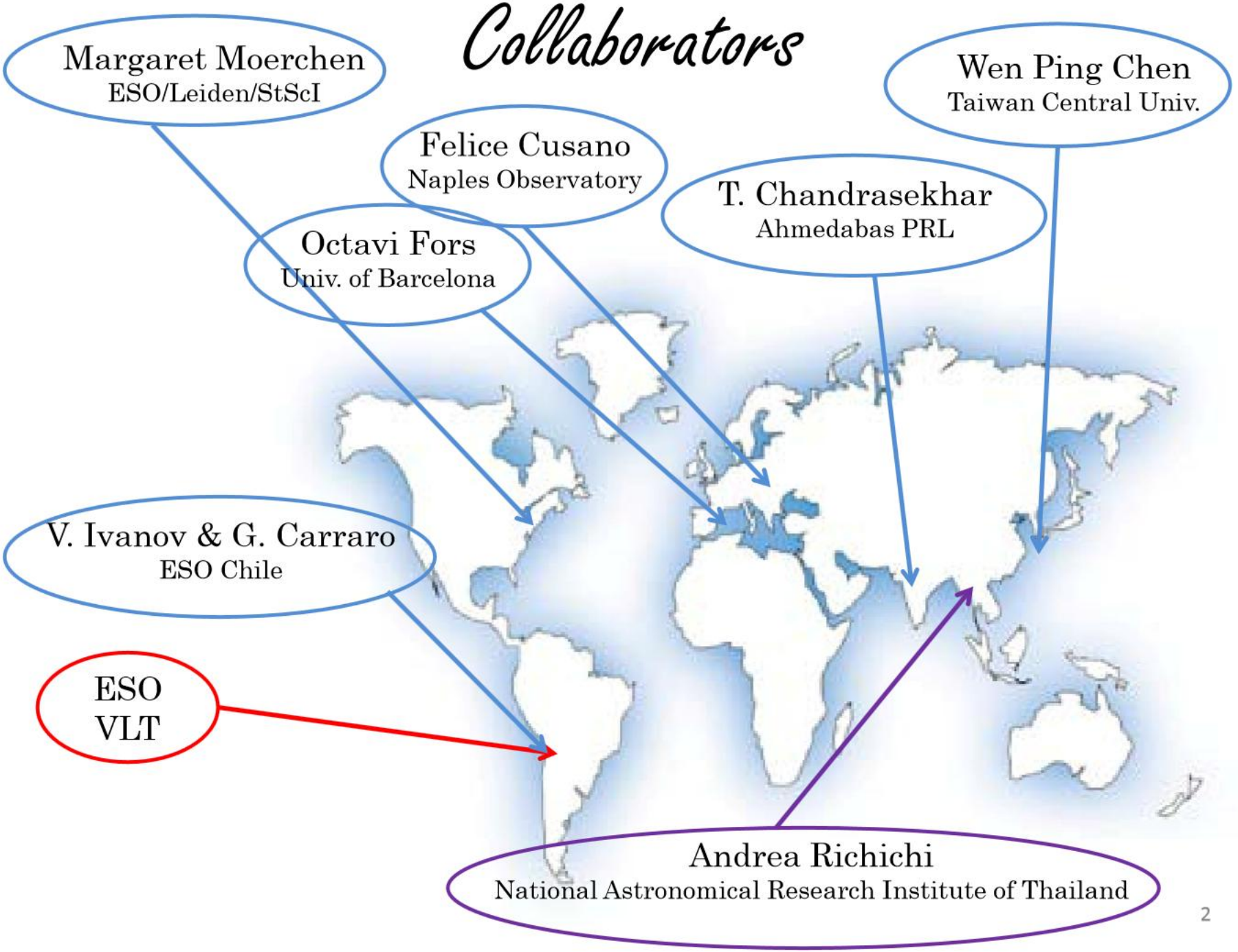
Table 3: Companion not observed (definite double star)

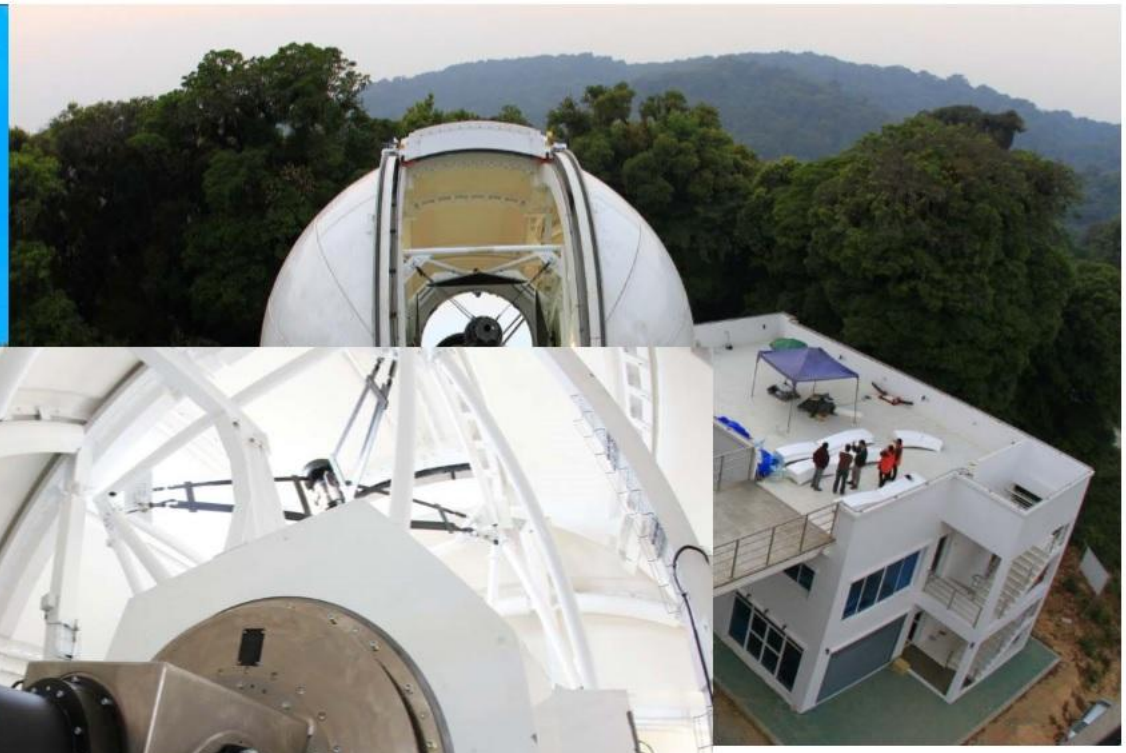
WDS name	XZ	RA Dec	Vector angle	Resolution limit	Limiting Mag. diff	Date	Observer
CHR 184Aa,Ab	4888	03470+2431	222°	0.034″	---	2007.672	SM

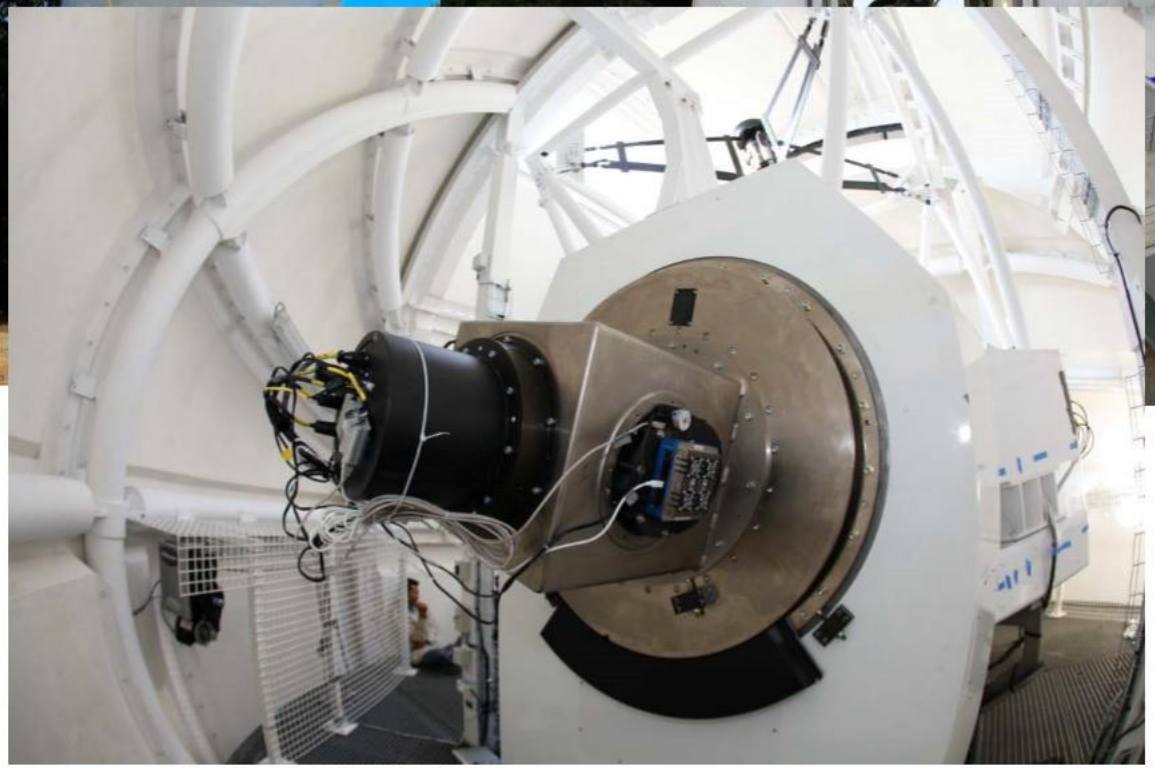
Professional Work

- Is mainly coordinated now by **Andrea Richichi** at the National Astronomical Research Institute of Thailand, andrea@narit.or.th
- He worked before for a long time at the **European Southern Observatory,** where he still makes most of his observations
- Most observations are recorded in the **infrared, allowing higher S/N** and even some daytime observations
- Observations are concentrated on times when the Moon traverses the **Galactic center region**, an area of obvious high interest; a hundred occultations might be recorded in a single night
- Passages over the **Pleiades and other interesting clusters** are also observed
- The equipment is set up so that it can be used during “dead times” between other astronomical observations

Collaborators

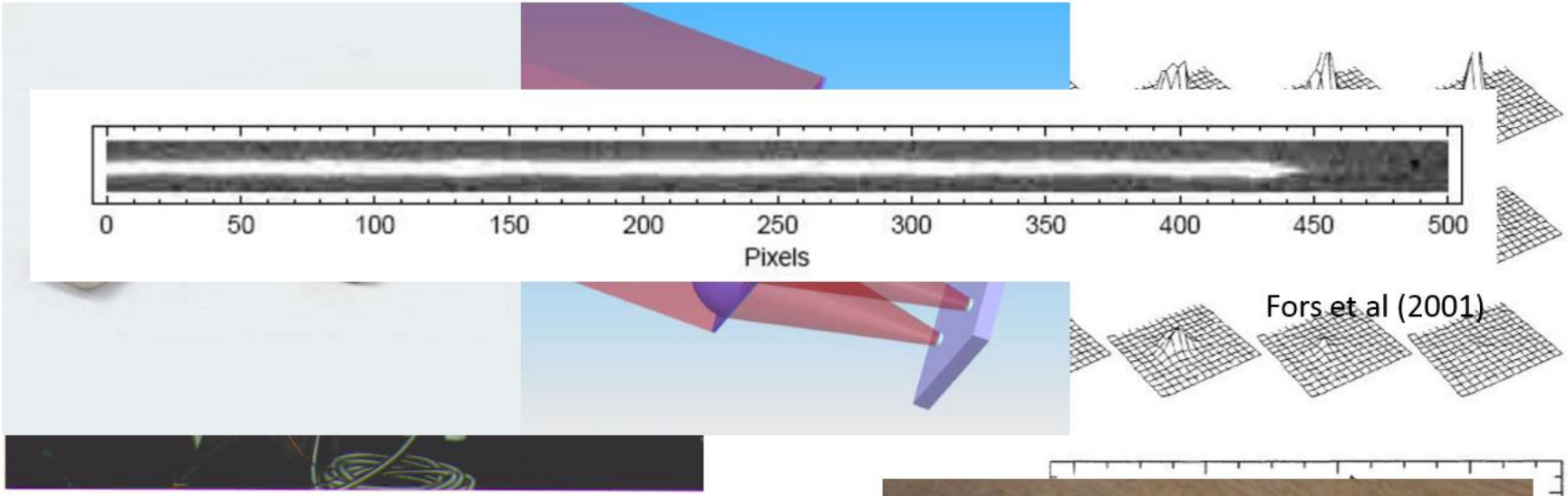






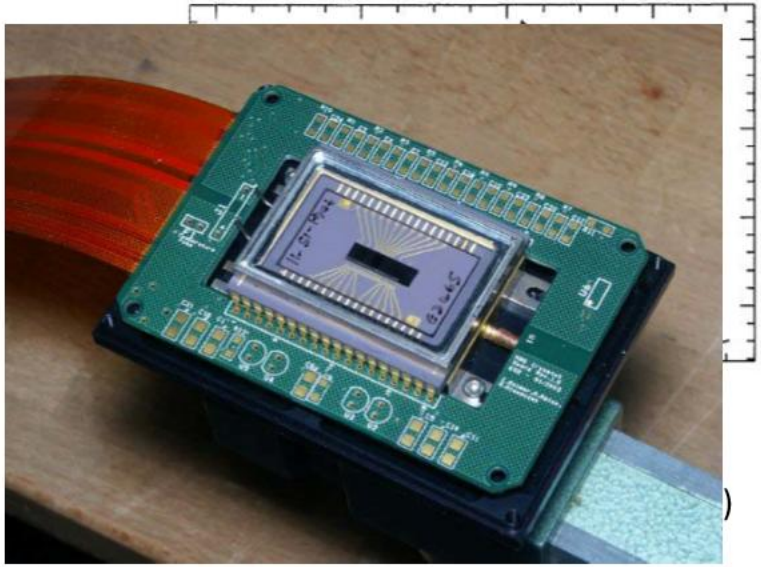
2.4m f/10 TNT
Doi Inthanon
2400m site
First light 03/12

Instruments & Detectors

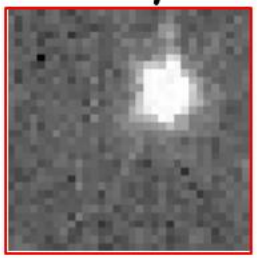


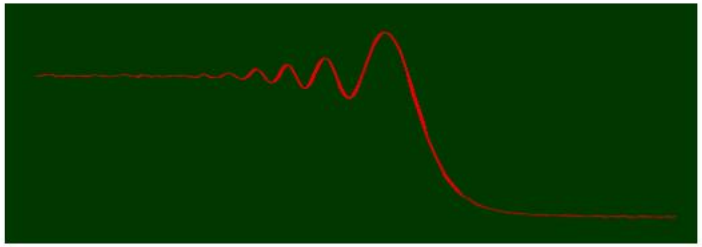
Fors et al (2001)

- Photometers, photomultipliers, InSb diodes
- APD, SPAD
- CCD (drift scanning)
- NIR Arrays (subwindow)
- Specialized small format arrays (AO)

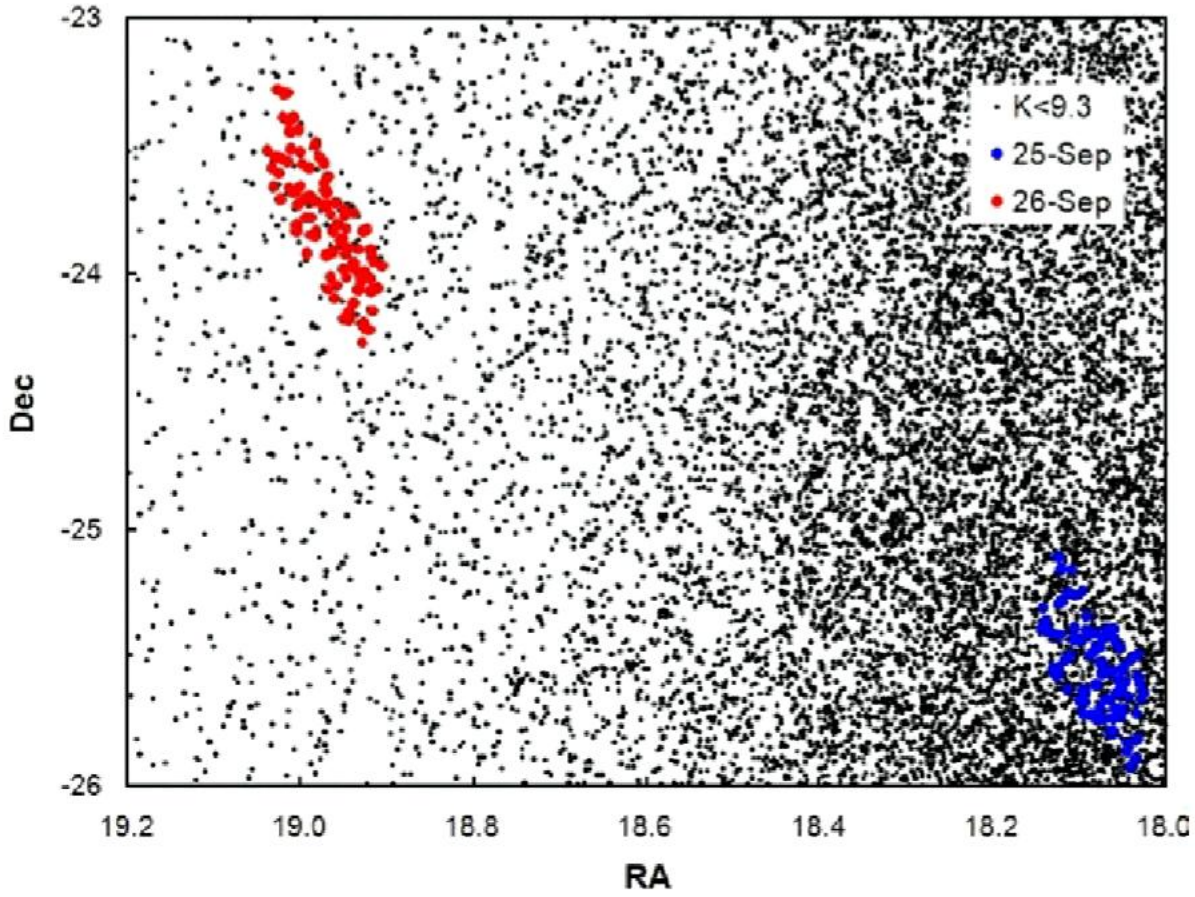


LO @ VLT in September 2009

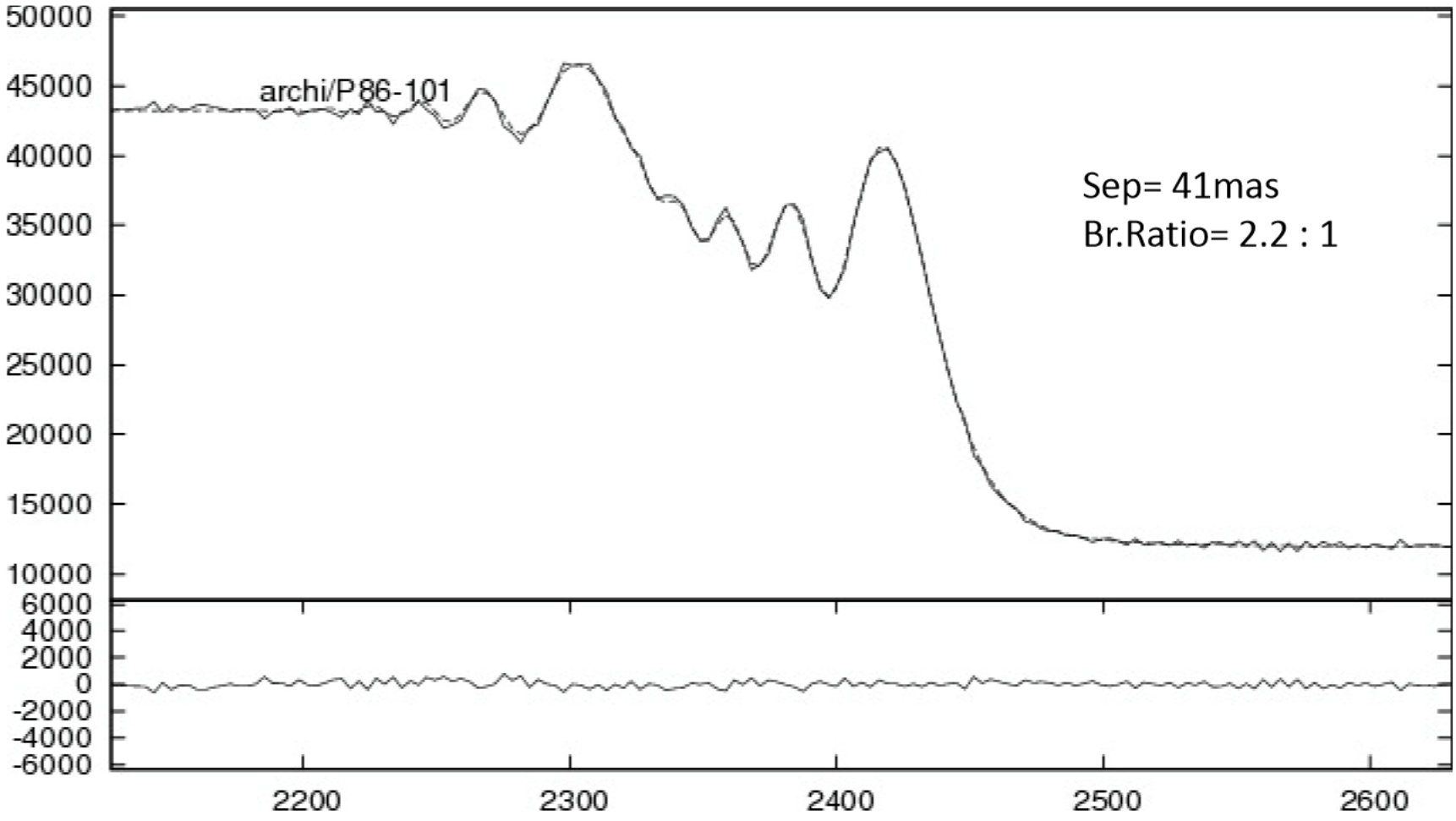




- ISAAC in burst mode, 3.2ms with 32x32
- ~200 events recorded over 2 half-nights
- 184 confirmed LO
- 22 binaries, 5 triples
- 2 ang. diameters
- several extended or complex sources

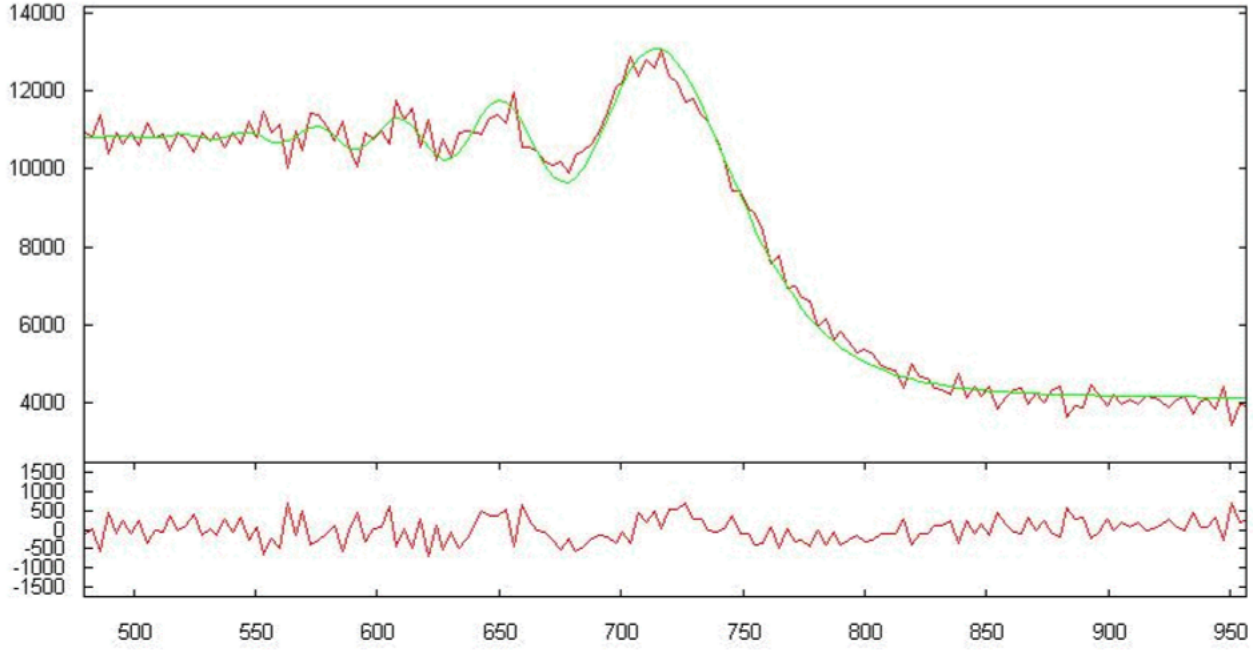


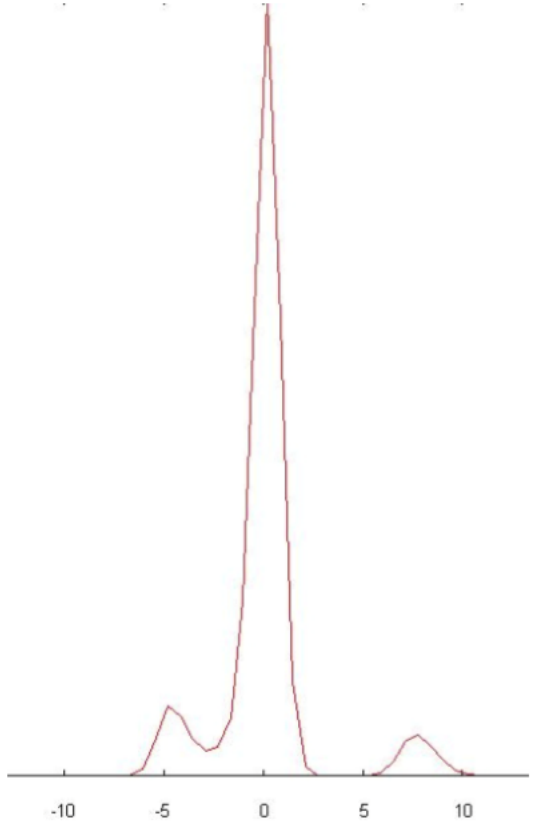
Example of a binary star (easy)



Example of a triple star

P83-23 Field star no refs, V=9.3 K=7.8





Pair A-B: Sep=4.1±0.2 mas Pair A-C: Sep=8.4±0.2 mas

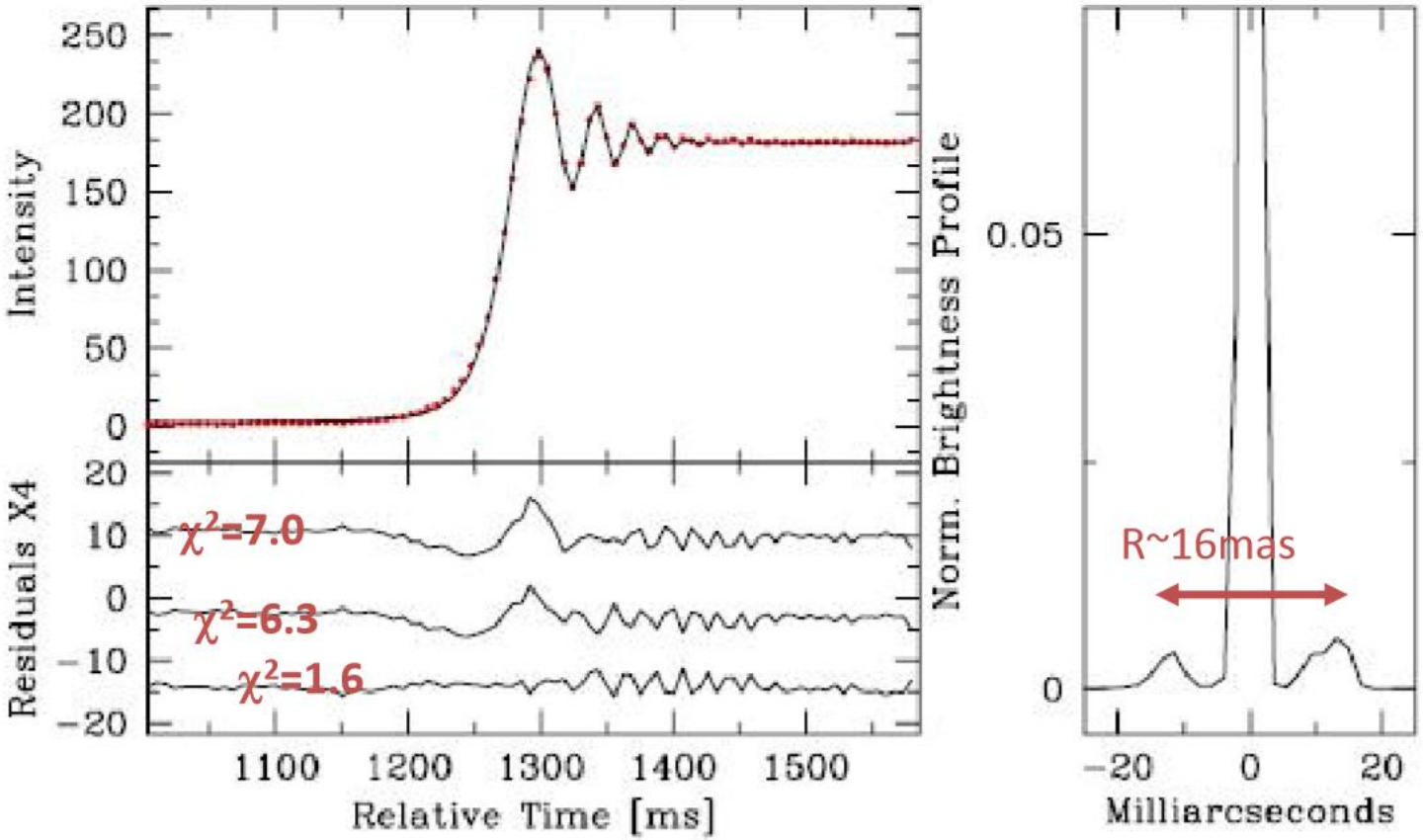
K=8.03, 10.09, 10.41 (±0.02)

Example of a circumstellar shell

2MASS 17453224-2833429 = ISOGAL-P J174532.3-283338

IR source K=5.3, J-K=3.7; no optical cross-ID; SiO Maser

probably fore-GC star ("low" A_K=1.1mag) 1kpc-> shell ~20AU



Double Stars from Asteroidal Occultations

- The diffraction scale for lunar occultations is about 10m at the Moon's distance, or about 10 mas (milliarcseconds).
- The diffraction scale for asteroidal occultations is about 300m at their distance of around 2 – 3 A.U., or about 0.5 mas.
- Asteroids move much farther from the ecliptic than the Moon but
- Asteroids subtend a much smaller (than the Moon) area of the sky, so opportunities with specific stars are rare.
- A good example of an occultation of a binary star by an asteroid is the one by (160) Una by Dennis DiCicco at

http://www.asteroidoccultation.com/observations/YouTubeVideos.htm

Mighty Mini complete portable occultation timing setup (air carryon)

Uses half of a $36 50mm pair of binoculars, system designed by Scotty Degenhardt. It can record occultations of stars to mag. 9.5, even mag. 10.0 under good conditions with a 3° FOV (with low-light-level PC164CEX2 security camera and Knight Owl 0.5 focal reducing lens)

Remote 50mm Mighty Mini (to mag. 9.5), 120mm Maxi (to mag. 12.5), and 80mm Midi (to mag. 11.3) Video Systems

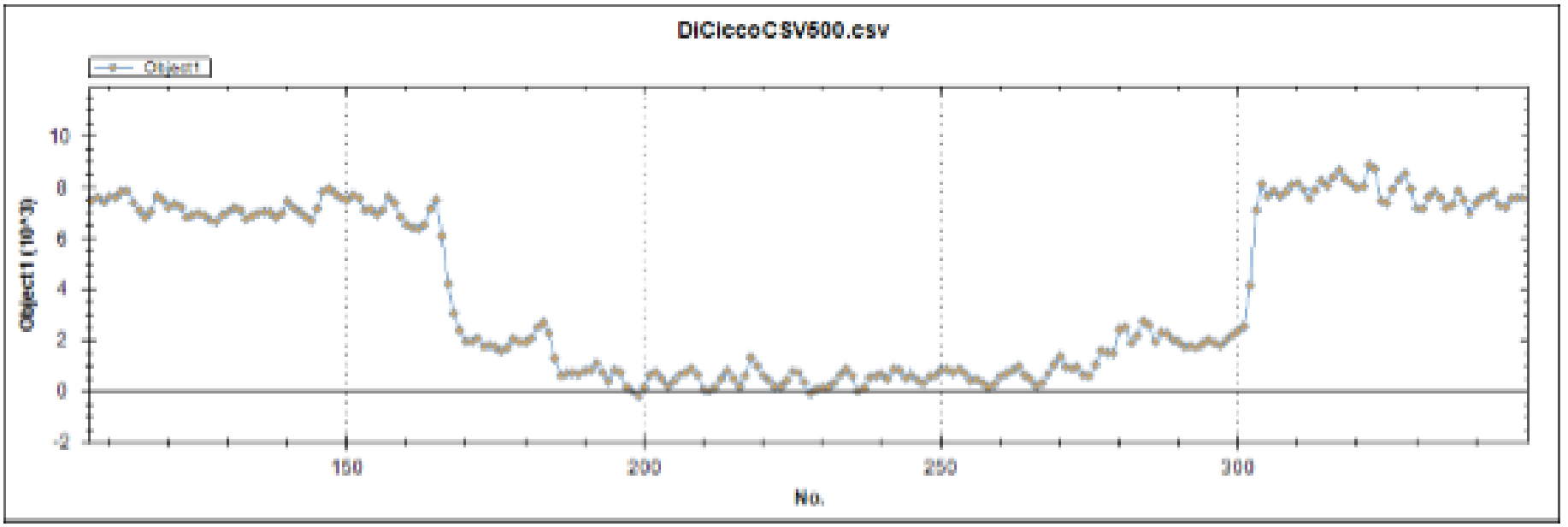
Scotty's Maxi Mount

- Solid as a rock
- All sky accessible
- Air portable @ < 12 lbs.
- (<20 including scope)
- 2 axis slow motion control
- Stealthy black for multi-station deployment
- Stands only 24" tall
- Costs ~$100
- Mag limit with PC164EX-2 = **12.5**

Lightcurve of occultation of SAO 80827 by (160) Una recorded by Dennis DiCicco at his observatory in Sudbury, Mass., 2011 January 24

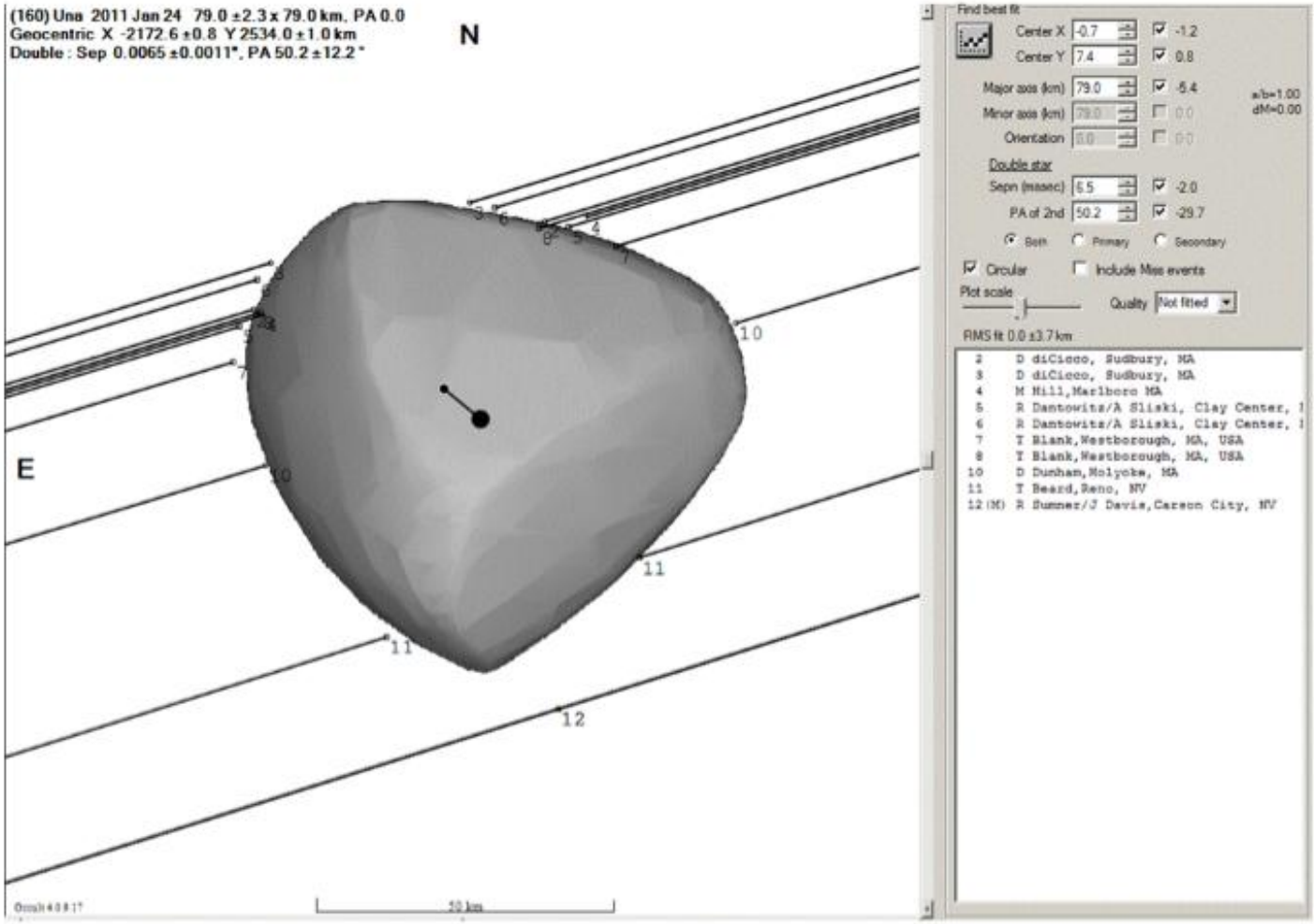
Video at

http://www.asteroidoccultation.com/observations/YouTubeVideos.htm



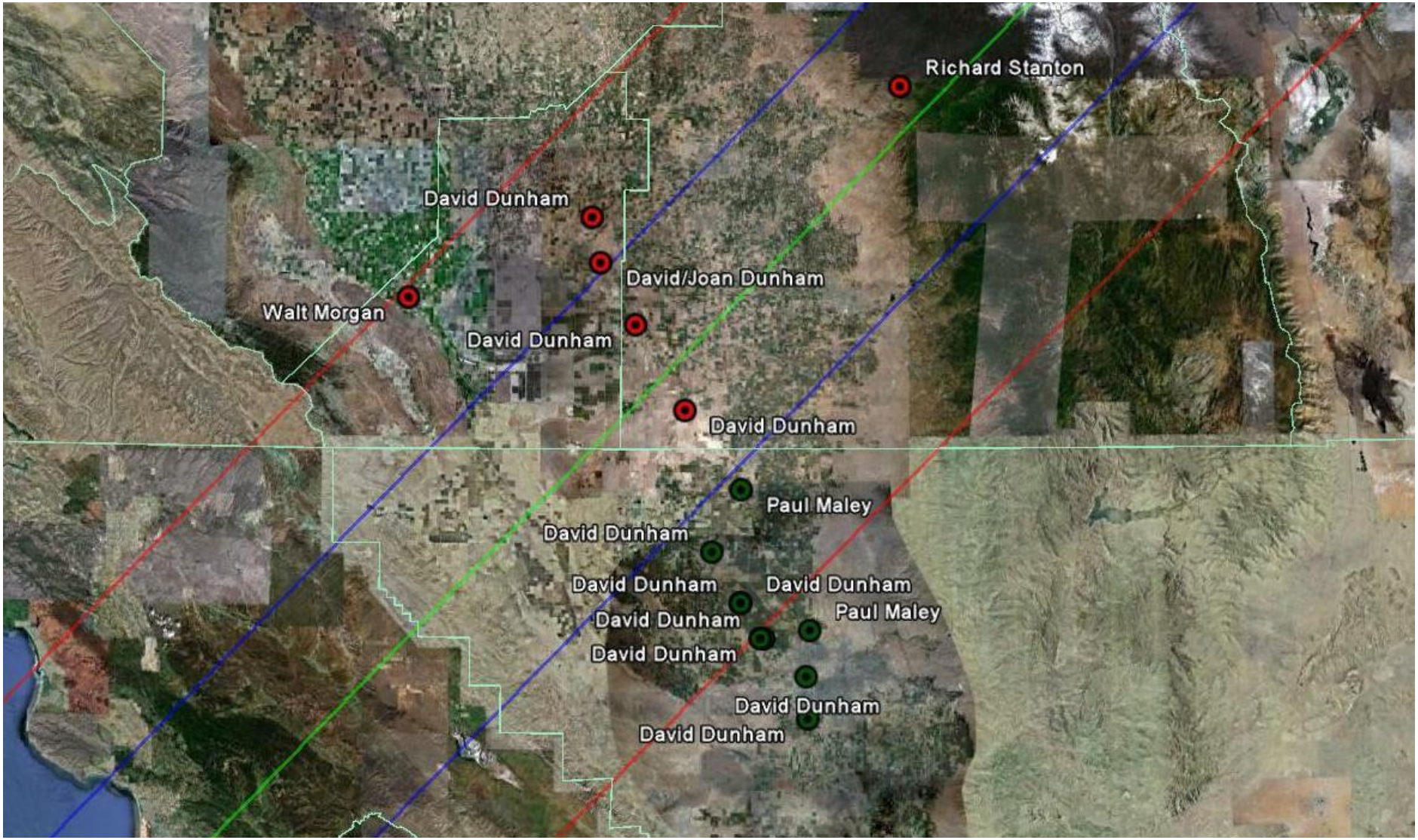
Di Cicco light curve showing distinct two-step event on D and R

Sky-plane profile from occultation of SAO 80827 by (160) Una observed in Massachusetts, 2011 January 24
Separation 6.5 ±1.1 mas, PA 50° ±12°

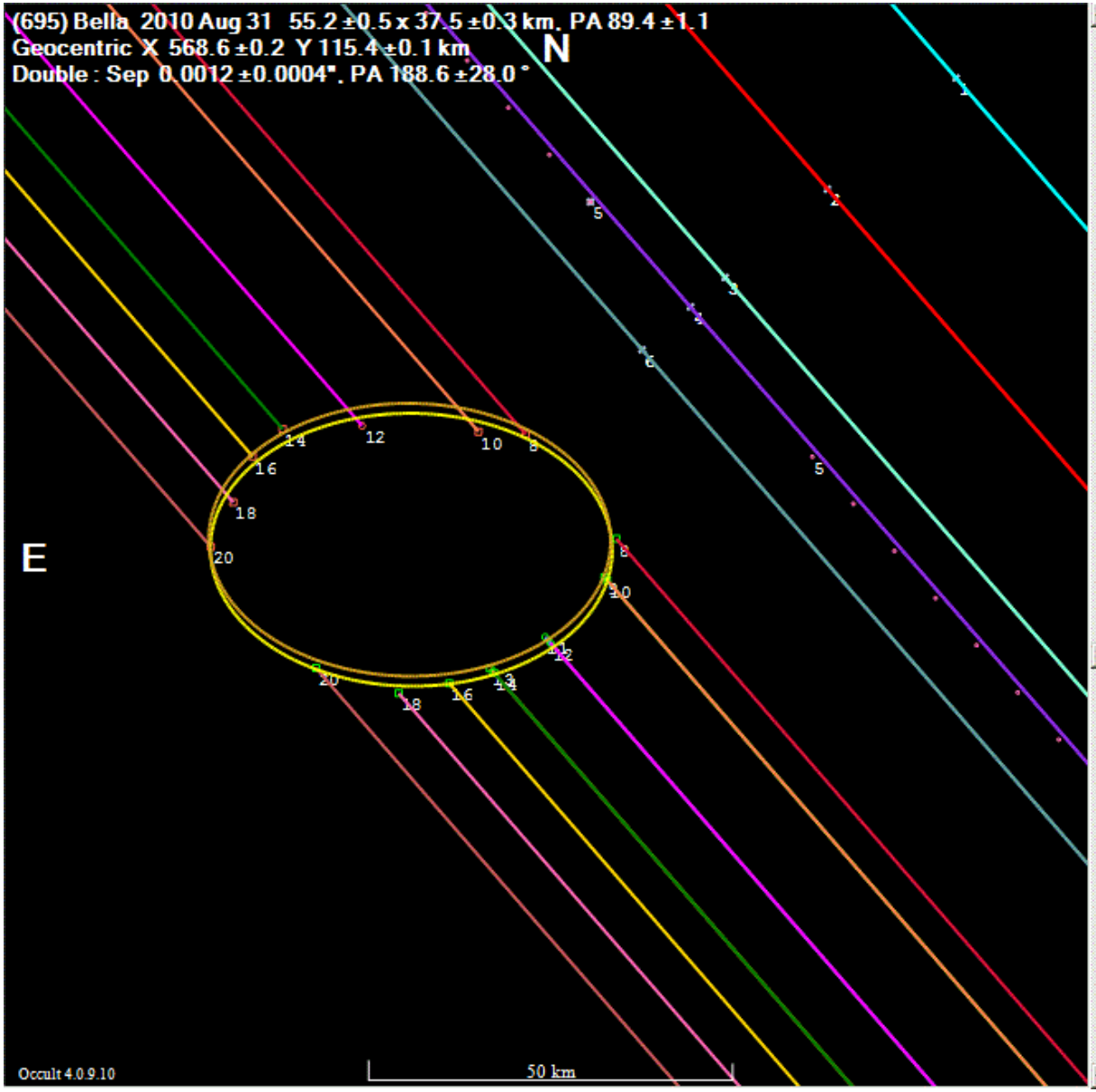


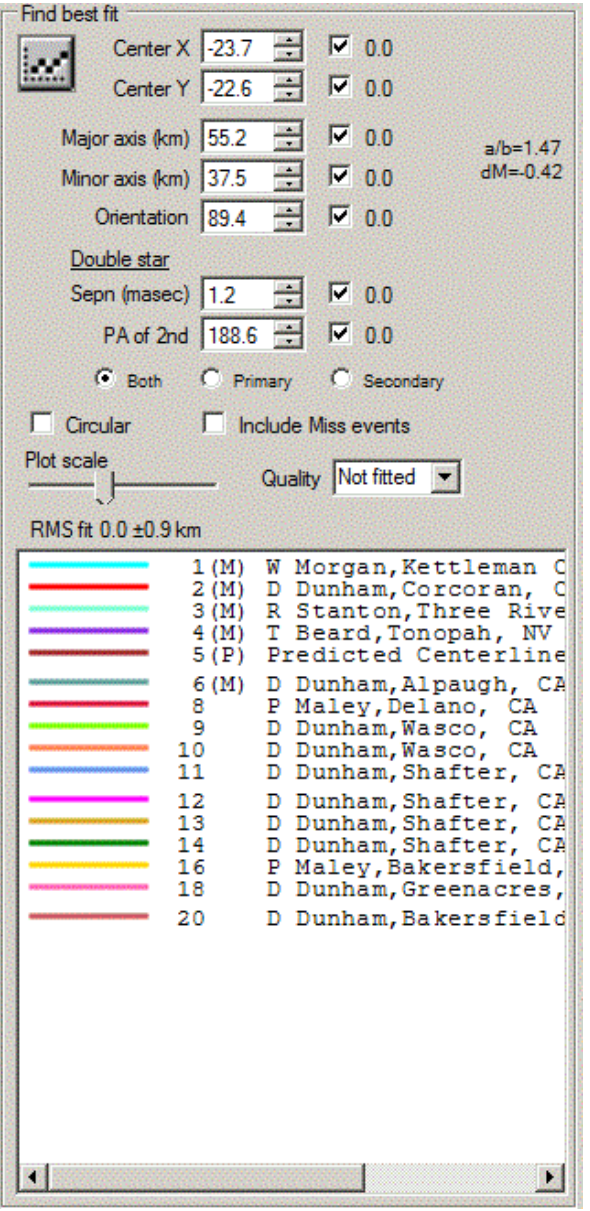
(160) Una occultation of HIP 46249 and DAMIT inversion model plot. Note that Chord 1 (a miss) was left off the plot to avoid conflict with other plot text. The direction of travel of the asteroid in the diagram is from upper right to lower left.

Remote Station Deployment for Occultation of 7.7-mag. SAO 55659 by (695) Bella, 2010 August 31, central Calif.



Possible Close Double, Step R at 3 stations





For More Information about IOTA and observing occultations:

- **http://www.occultations.org – main IOTA site with links to the others**
- http://iota.jhuapl.edu - my web site.
- Updates by e-mail – dunham@starpower.net
- http://www.lunar-occultations.com/iota – the main lunar occultations web site
- http://www.asteroidoccultations.com - asteroidal occultation updates
- For high-speed recording of lunar occultations, contact Andrea Richichi, andrea@narit.or.th