Alt-Az Telescope Initiative

www.altazinitiative.com

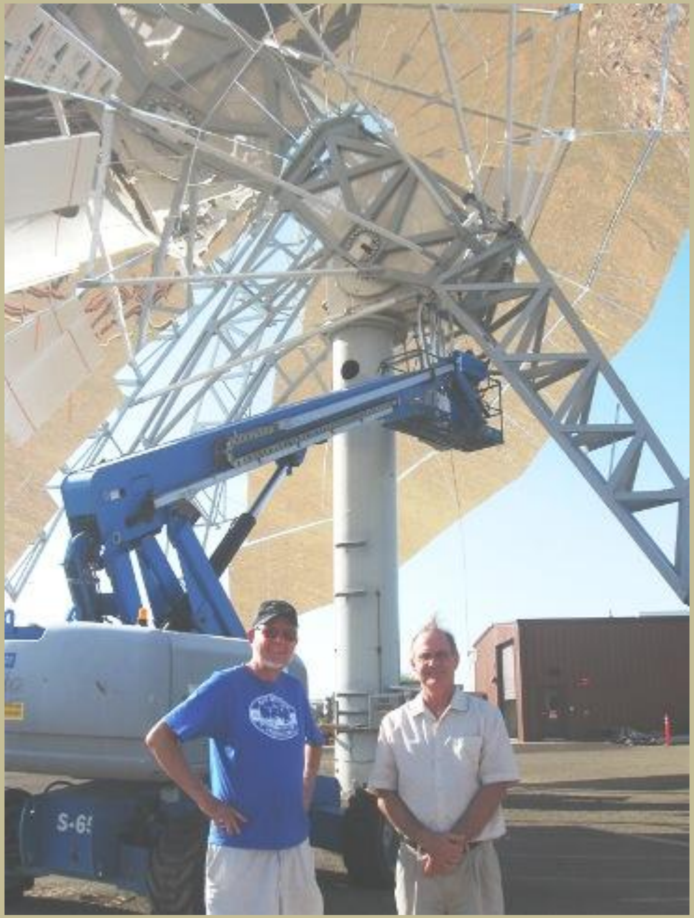
High Time Resolution Astronomy Developments

Bruce Holenstein and Russ Genet

Conference on Meter-Class Astronomy
January 20-22, 2012
Waimea, Hawaii

Overview

- **HTRA Region**
  - Variability at the second and/or sub-second time scales
  - Fine structure or precise timing
- **Fast Detectors**
  - Photometers
  - Cameras
- **Some Projects**
  - Occultations
  - Scintillation Studies
  - Stellar Intensity Interferometry
  - Speckle Interferometry
  - Future



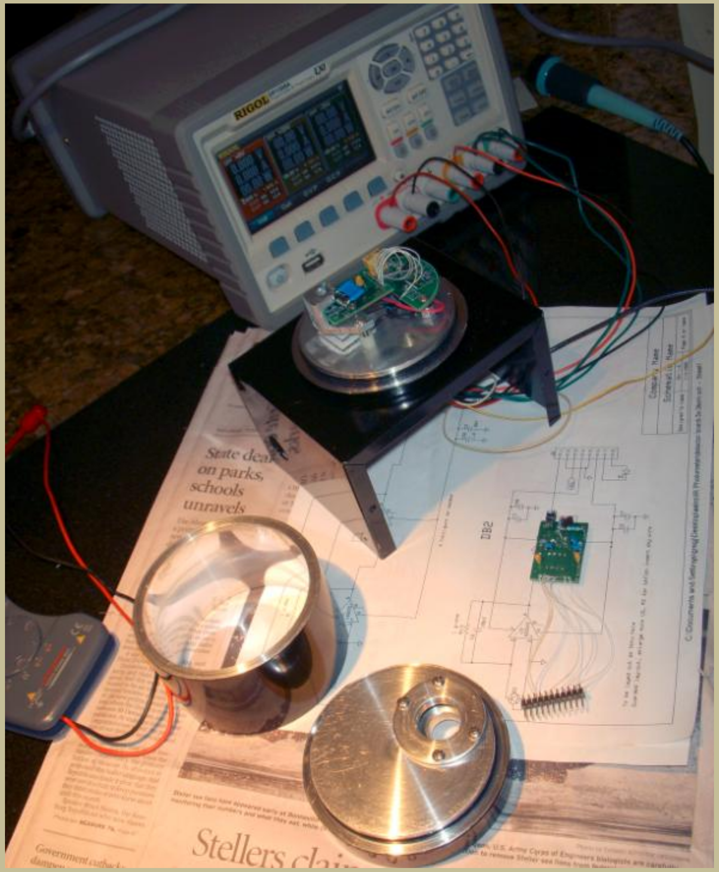
Russ Genet, Herb Hayden, and Southwest Solar Technologies' fixed-location 22 meter mirror

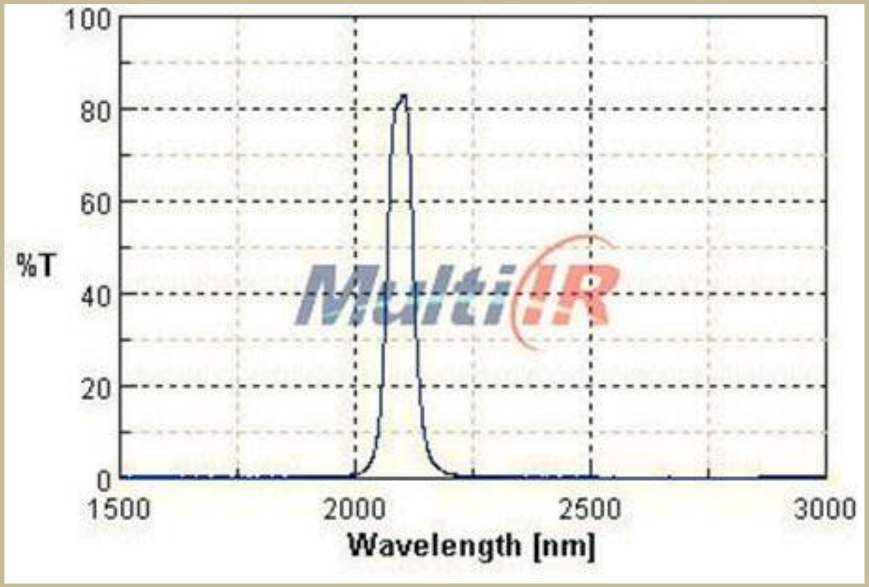
Fast Detectors

- High QE, visible and NIR (J, K &L) photometers
- Area detectors
  - CCD, emCCD evaluations
- High-speed, high gain, low noise amplifiers
- Dynamic range
  - Linearity and overload control

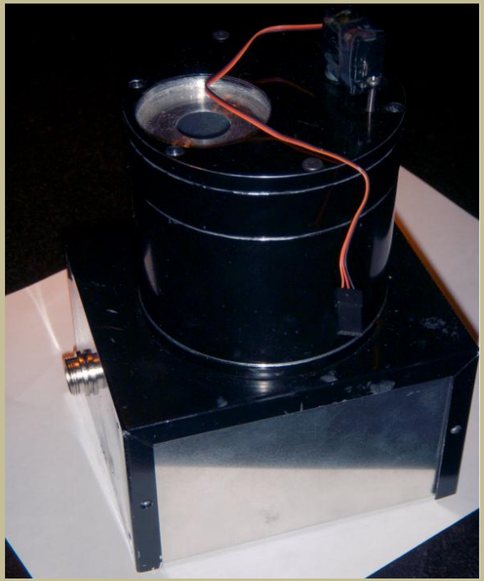
High-speed Si detector/trans impedance amp at Gravic

Greg Jones's H/K NIR Photometer





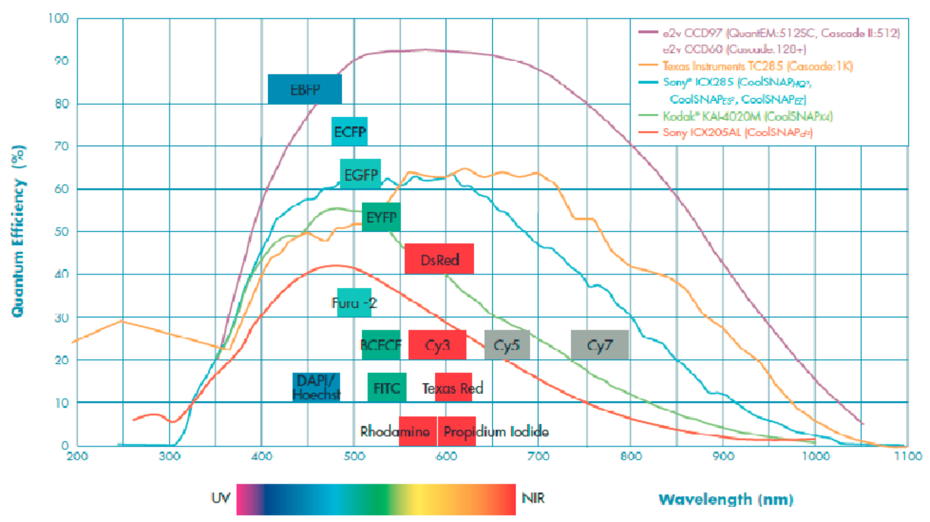
Parts - Bit-whacker controller, VCO, vacuum chamber, custom detector boards



Fast Cameras

- **Area detectors**
  - Fast CCD, sCMOS, and emCCD
- **Evaluation of scientific and industrial units**
- **Software**
  - WinFlour, RSImage, MicroManager, …
  - Custom

Top row from left: Photometrics Cascade 512B emCCD, 512B emCCD w/UV enhanced, 1k emCCD, CoolSNAP K4
Bottom row: Supercircuits 164CEX-2, Andor Luca-S emCCD, Watec 902H2-Ultimate, two 902H2's (PAL), Two JAI 6740GE GigEthernet



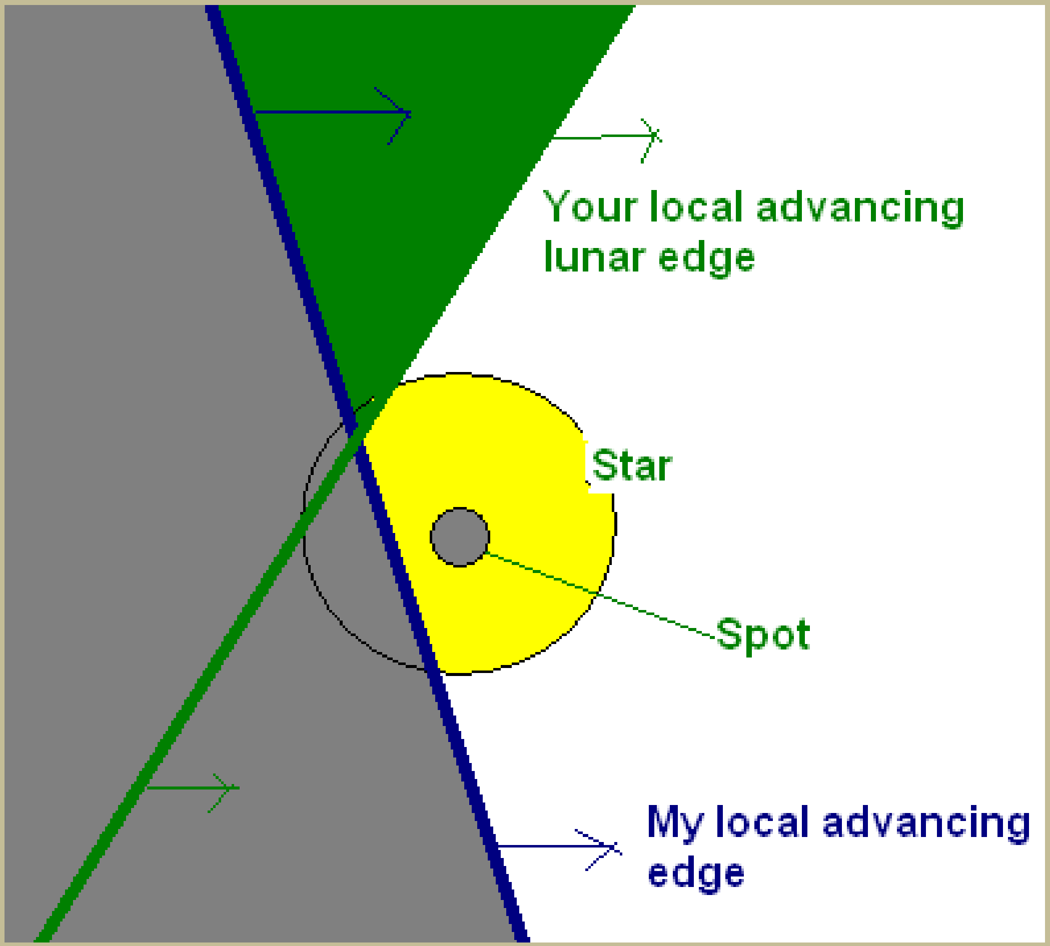
Source: Photometrics

Some camera specs

Make/model	Type	Inter-face	Pixel size	Pixel well/ bits	Read Noise	Max frame rate	Peak QE	Cooling	Price new
Low-End									
Supercircuits 164CEX-2	Sony EXview CCD 510x 492	Video	NA – 1/3" sensor	NA	NA	30	~50%	None	$130
Watec 902H2 Ultimate	Sony EXview CCD 768x 494	Video	NA – 1/2" sensor	NA	NA	30	~50%	None	$250
Medium-End									
JAI TM-6740GE	KAI-0240 CCD 696x 492	Gigabit Ethernet	7.4µm 1/3" sensor	20k 10 bits	14e-	3205ROI and bin	54%	None	$2500
Lumenera SKYnyx2-0	CCD Sony ICX424 659x 494	USB2 Interlaced?	7.4µm 1/3" sensor	8-and 12-bit	10e-	>200fps w/ROI binning		None	$1000
High-End									
Andor Luca-S DL-658M	TI TC247SPD emCCD 658x496	USB2	10µm	26k 14bits	<1e-	>300 w/ROI and binning	52%	-20°C regulated	$11k
Photometrics Cascade 512B	e2v emCCD 512x 512	PCI card	16µm 1/2" sensor	200k 16bits	<1e-	>300 w/ROI and binning	93%	-30°C regulated	$30k

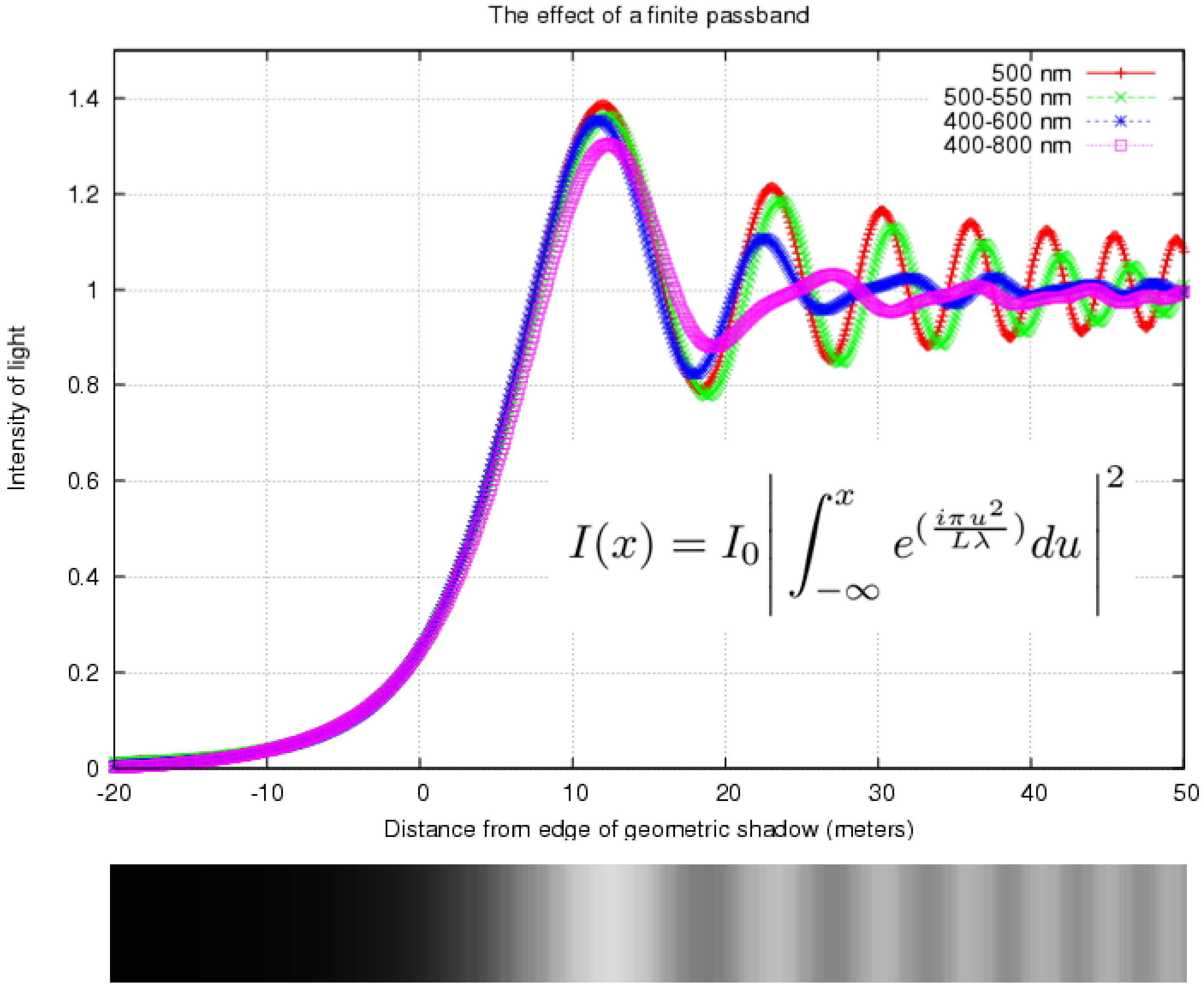
Occulted Object Science Potentials with a Sufficient SNR

- Presence/absence of stellar companions
  - Separations, PA, relative luminosity
- Stellar sizes
- Limb darkening laws
- Presence of plages and spots
- Circumstellar disks
- Detection of hot Jupiters



Fresnel Diffraction

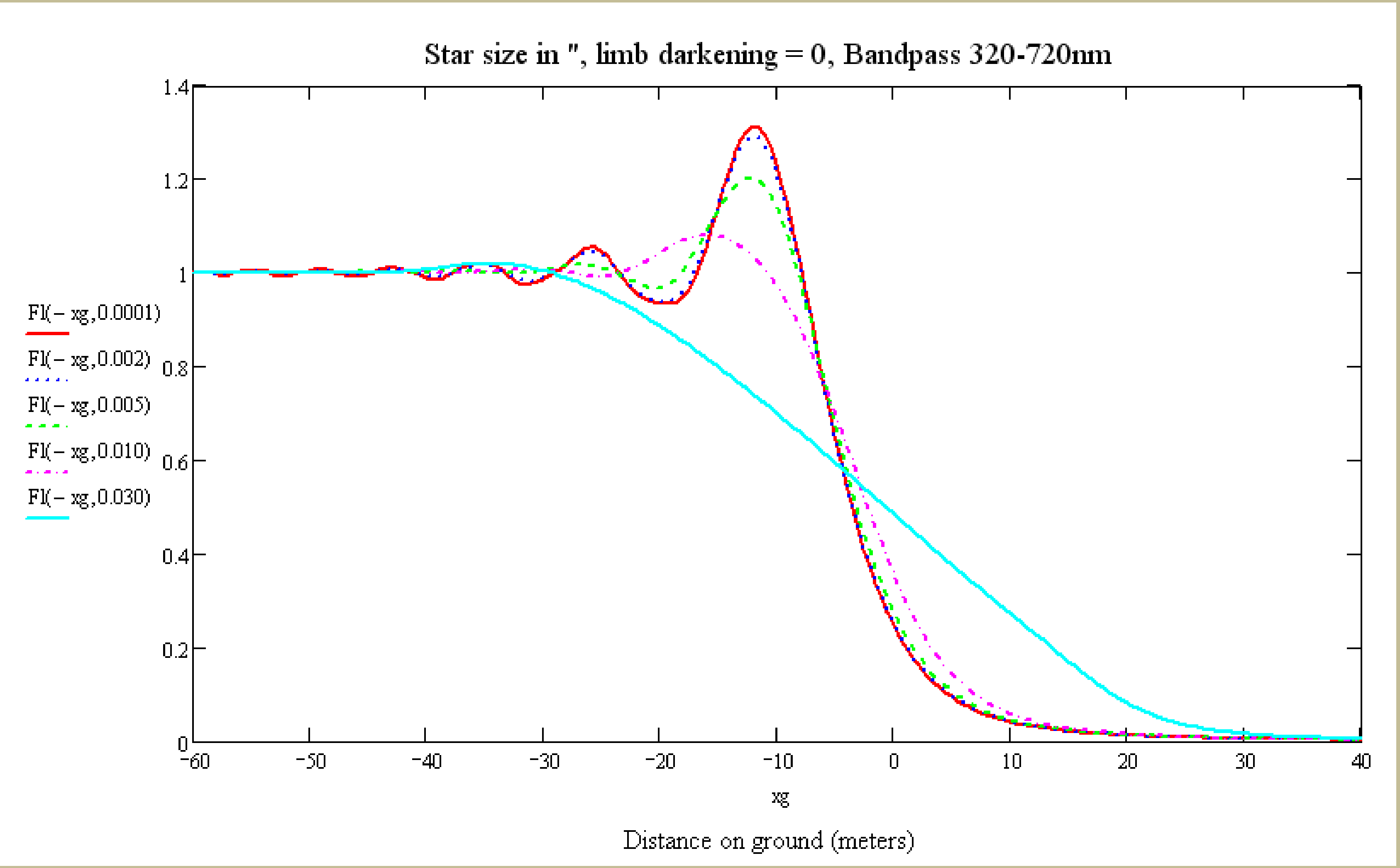
Dependencies on bandpass and geometry



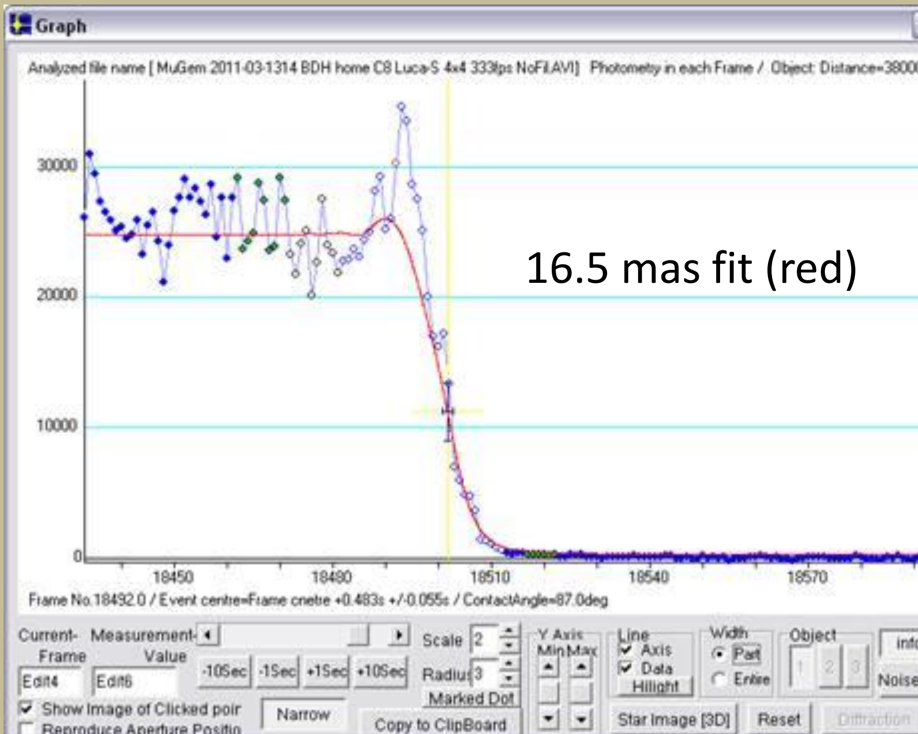
Adapted from: Michael Richmond, 2005, http://spiff.rit.edu/richmond/occult/bessel/bessel.html

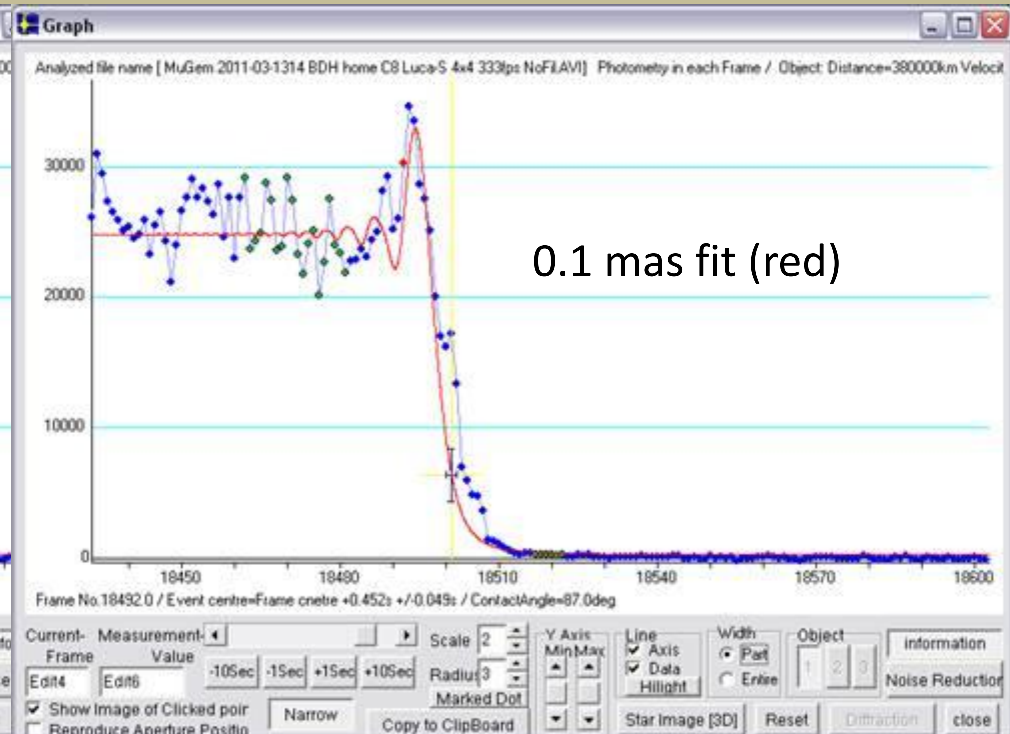
Lunar Occultations Examples

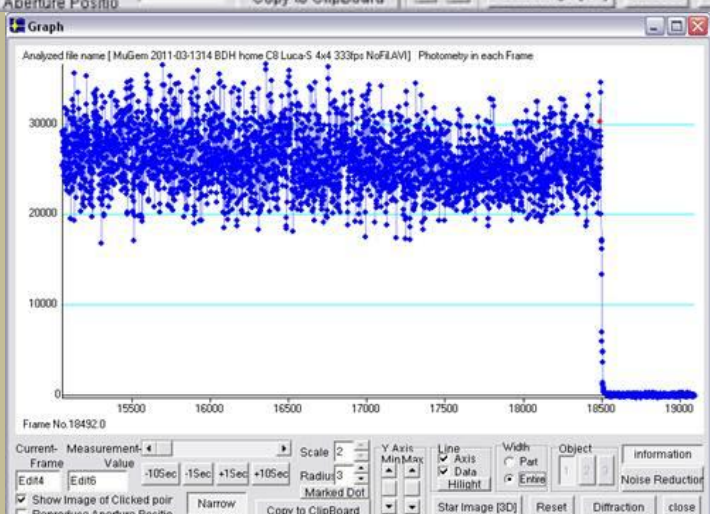
Theoretical diffraction light curves for different sized stars (0.1 to 30-mas)



mu Gem Lunar Occ. 1314Mar11



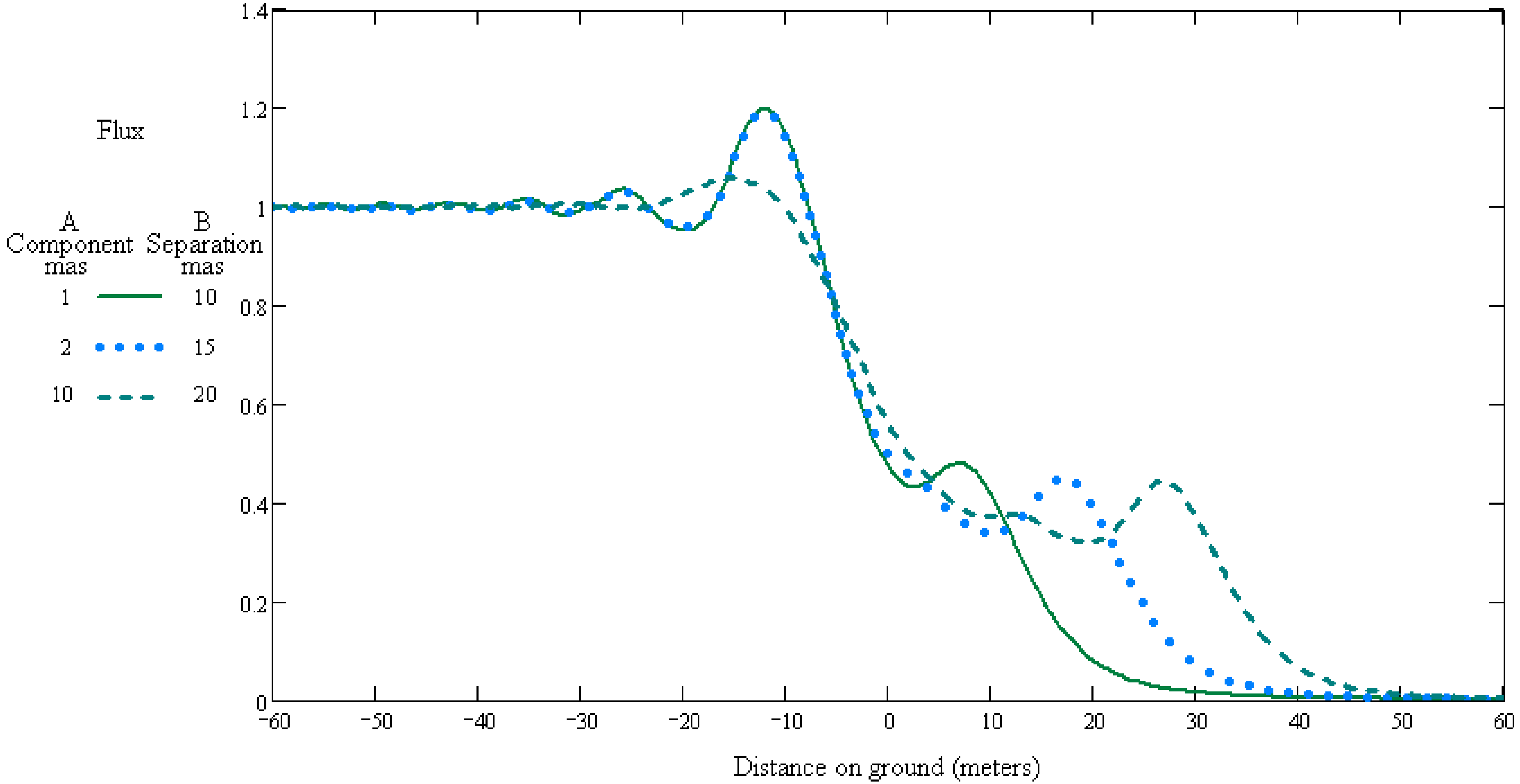




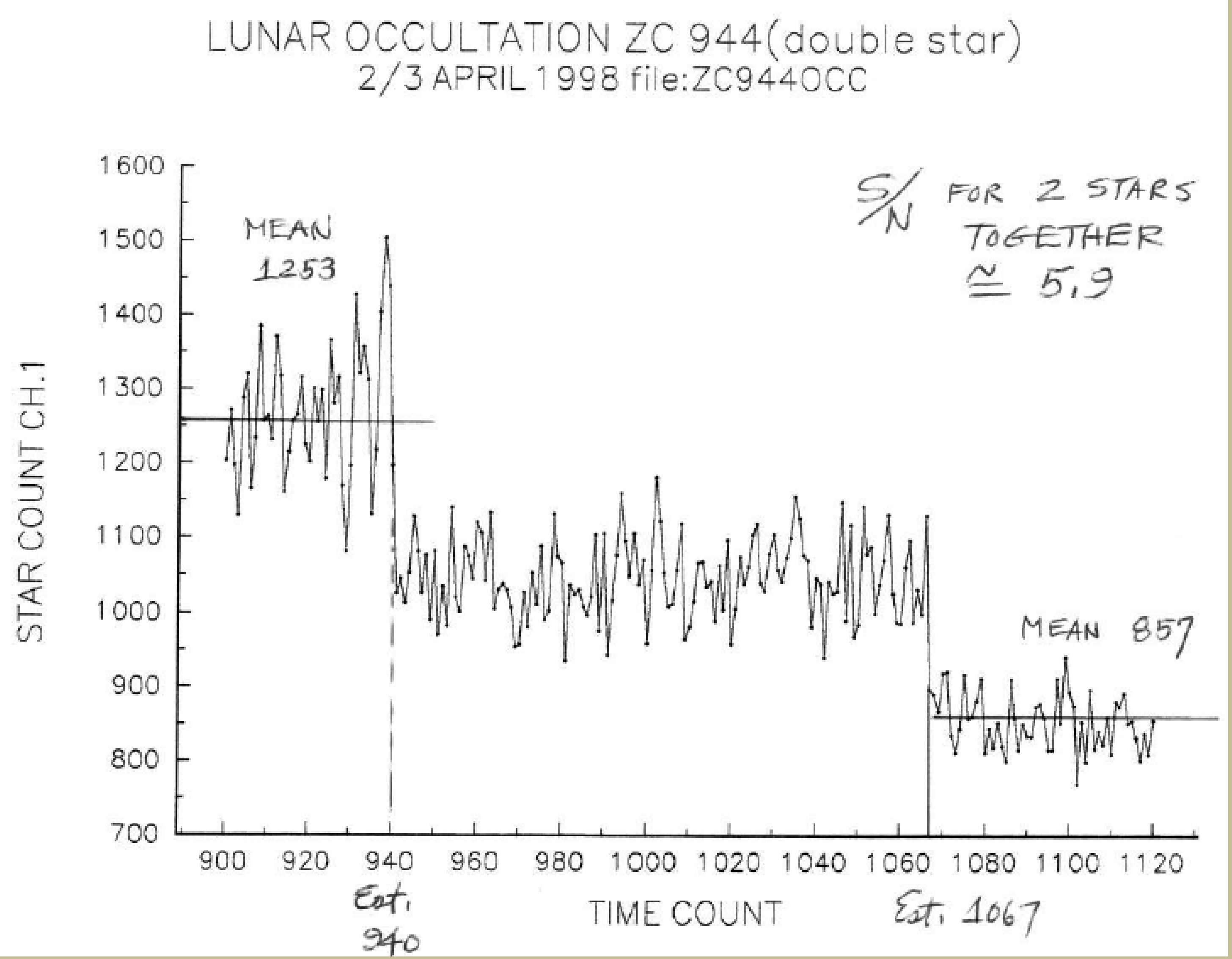
Media, PA C8, Luca-S at 333fps, unfiltered, LiMovie

Lunar Occultations - Binaries

Theoretical diffraction light curves for three different binary systems



SAS 2010 LBA paper

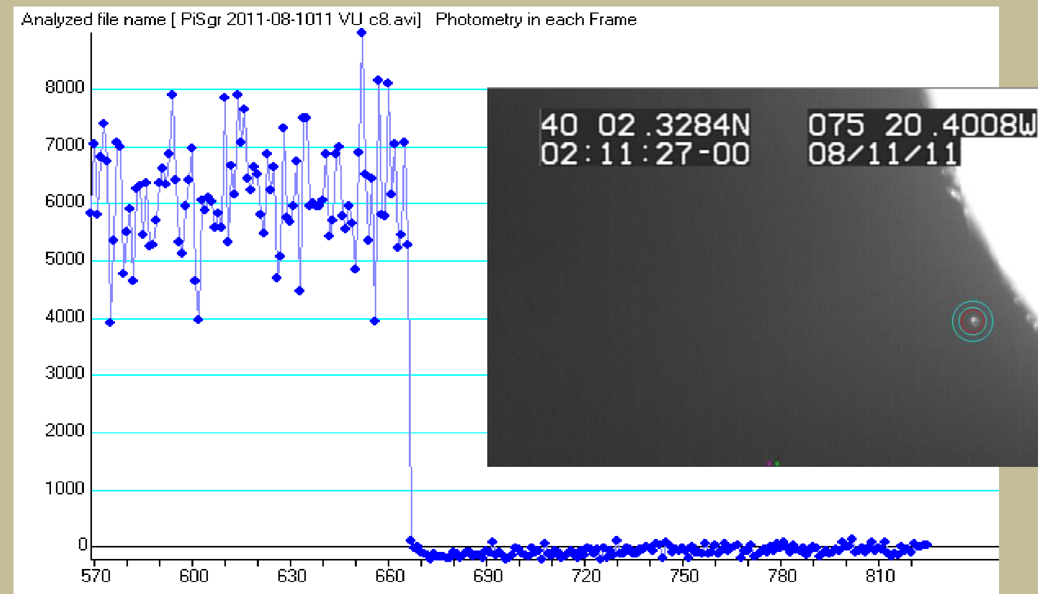


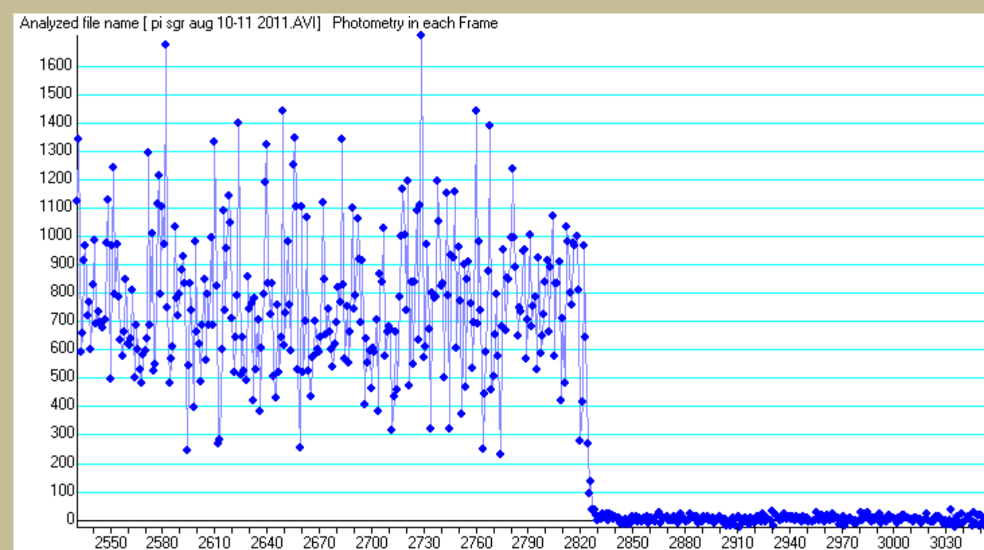
- 15” Siderostat at Flower and Cook Observatory, Malvern, PA by R. H. Koch, R. J. Mitchell and W. J. Blitzstein
- Occult4 lists close double 0.39”, Limb=0.190”/sec
- 127 15-ms samples = 0.362” separation

FPS (speed) - Pi Sgr at Villanova, August 10, 2011

- Villanova C8, 164CEX-2 CCD, no filter, 30fps
- 9.4mas per datum

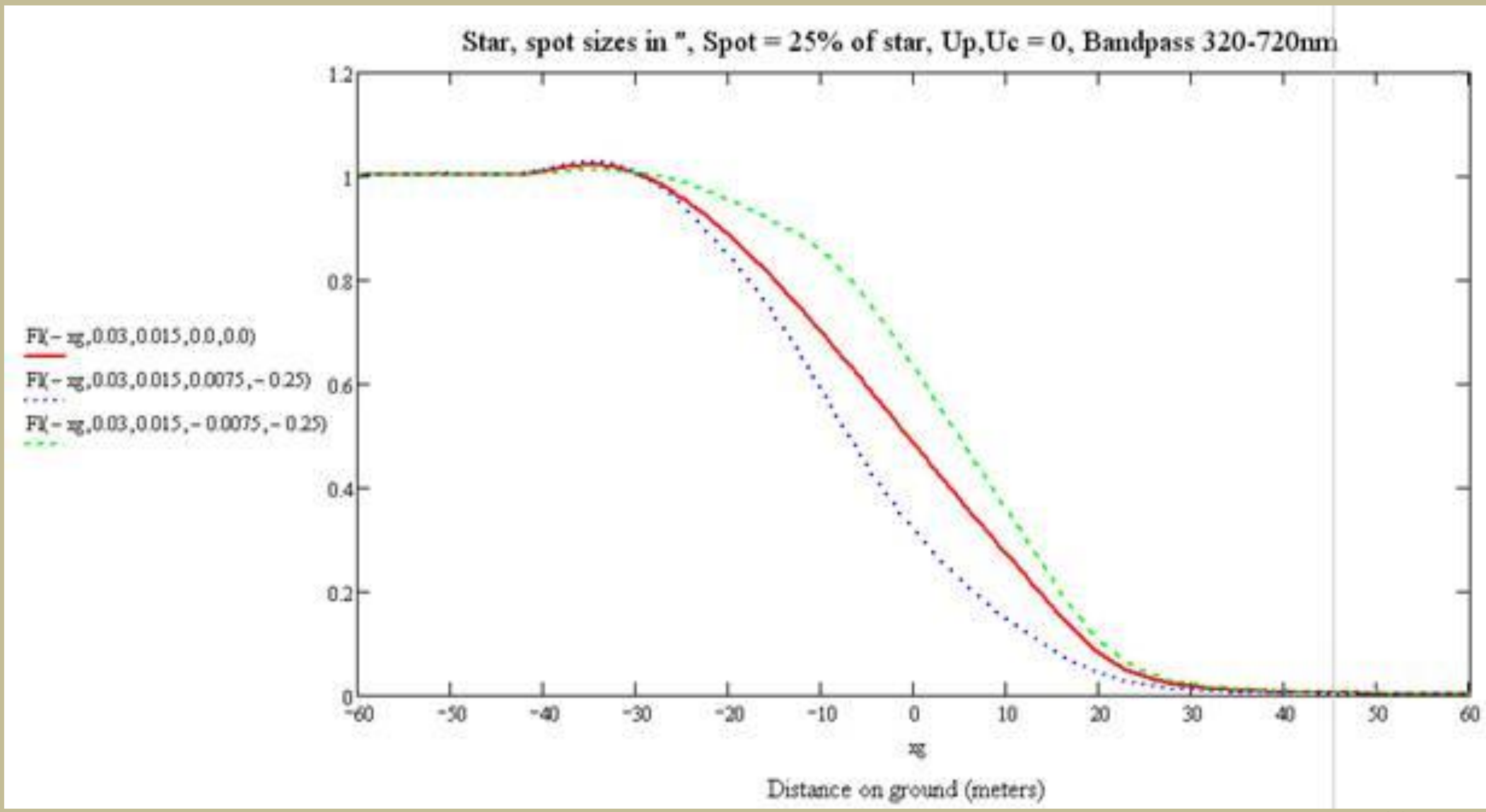
- Gravic C8, Andor Luca-S emCCD, Sloan r filter, 120fps
- 2.4 mas per datum





Lunar Occultations - Spots

Theoretical diffraction light curves for a 30-mas star lacking spots(red), and a dark spot (25%) leading (blue) and trailing (green) by 7.5-mas.

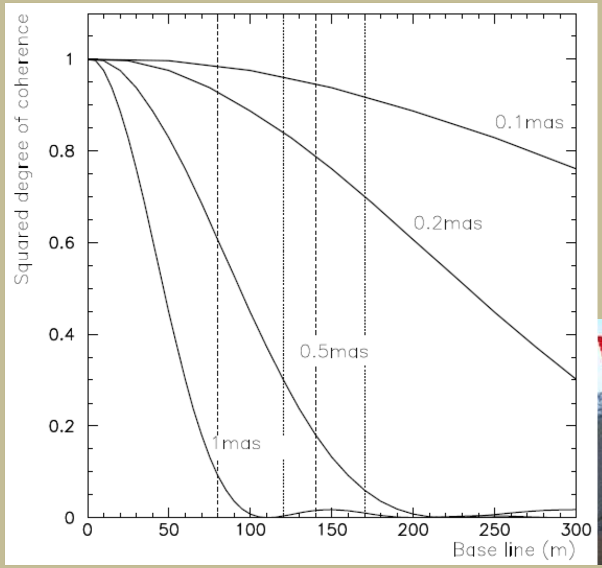


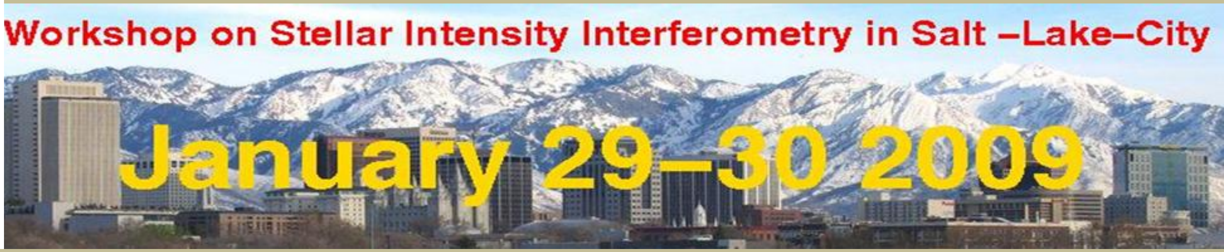
Scintillation

- Can’t increase integration duration
  - Need about 200+ fps in visible for lunar occultation diffraction patterns
- Mitigate it
  - Increase objective diameter to a point
    - About 2-meters max (for lunar occultations).
  - Move to a higher altitude
  - Watch central obstruction size
- Arrays of light bucket scopes (future)

Stellar Intensity Interferometry Arrays

- Hanbury-Brown in 60's measured diameters of 32 stars
- <I1 * I2>/<I1><I2>
- LeBohec *et. al.* revival





Intensity Interferometry LBT Potential

$$SNR_{Hanbury\ Brown} = A\alpha\, n\, |\gamma| \left[\Delta f \, \frac{T}{2}\right]^{1/2}$$

A is the telescope area, α is the photomultiplier quantum efficiency; n is the number of photons incident on the telescope per unit area, per unit time, and optical bandwidth; γ is the degree of coherence of the flux; Δf is the bandpass of the electronics, and T is the observing period.

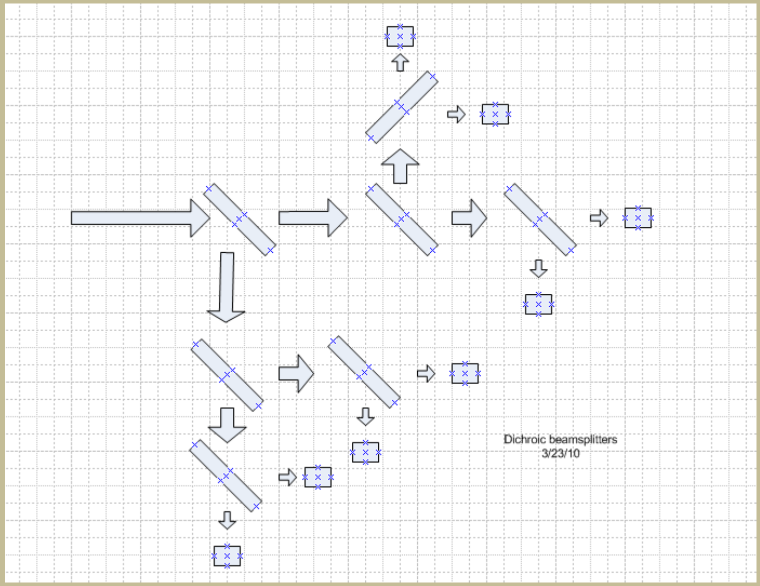
$$SNR_{Overall} = \left[\binom{N_{Array}}{2} N_{Channels}\right]^{1/2} SNR_{Hanbury\ Brown}$$

N_{Array} is the number of elements in the array, and $N_{Channels}$ is the number of simultaneous channels measured, and the noise is modeled as adding in quadrature.

Modern Electronics with pair of 2-m LBTs = 3 magnitudes better than Narrabri - 4.5 mag. with seven 2-m LBTs

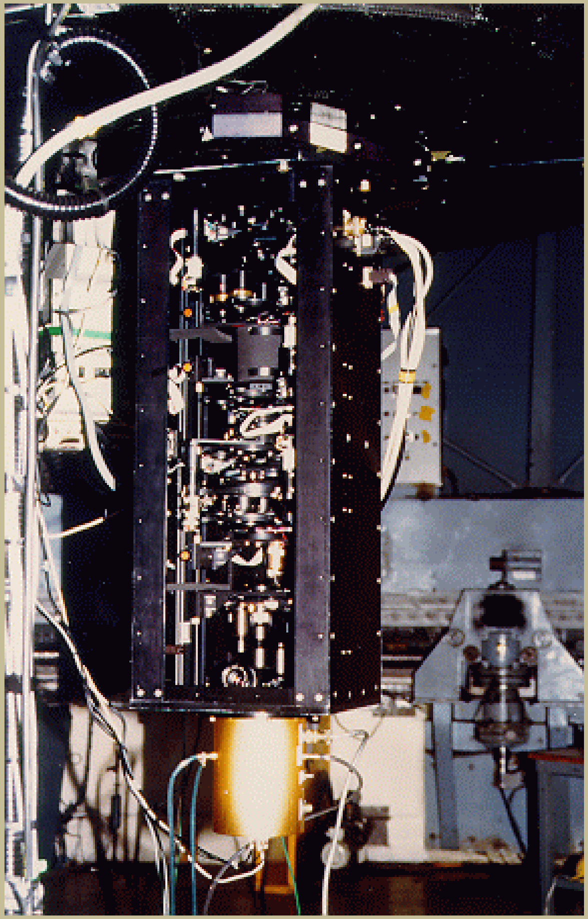
Future HTRA experiments

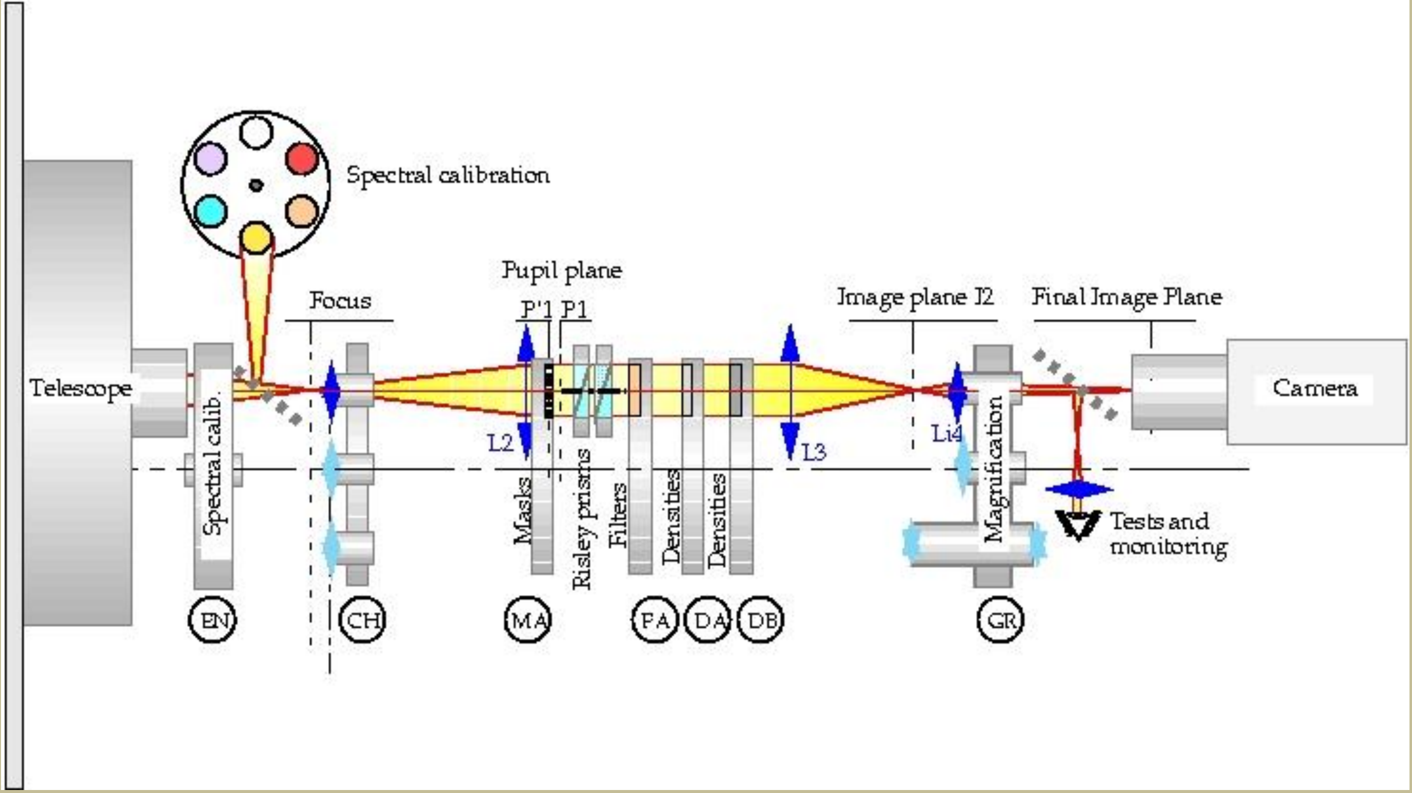
- Three 12-cell Hamamatsu R1463P PMTs
- LeCroy 6100A samples at 10GS/s
- NVIDIA CUDA GPU for photon correlation

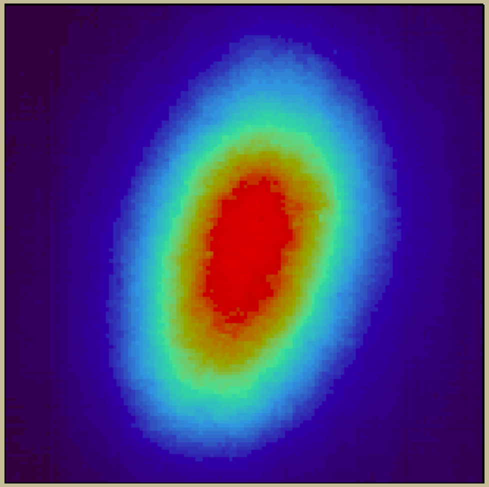


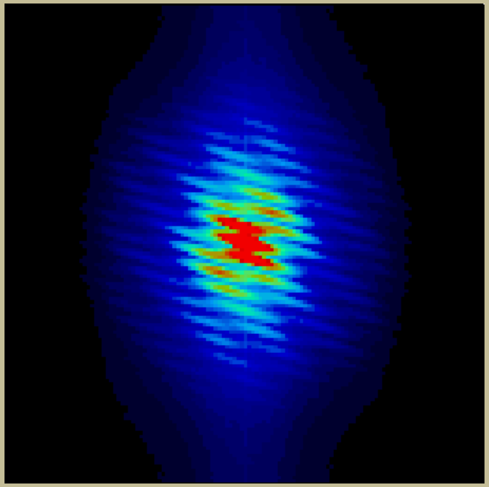
8-band dichroic beam splitter

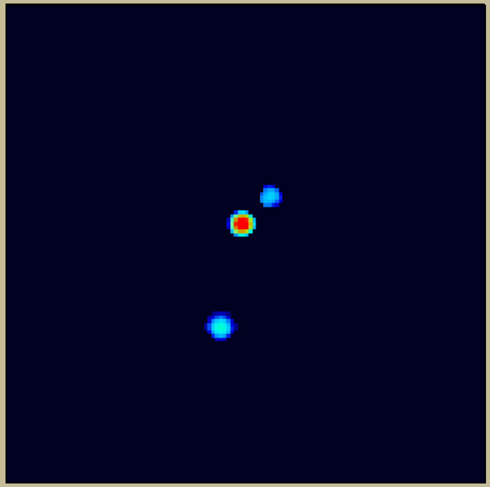
Speckle Interferometry



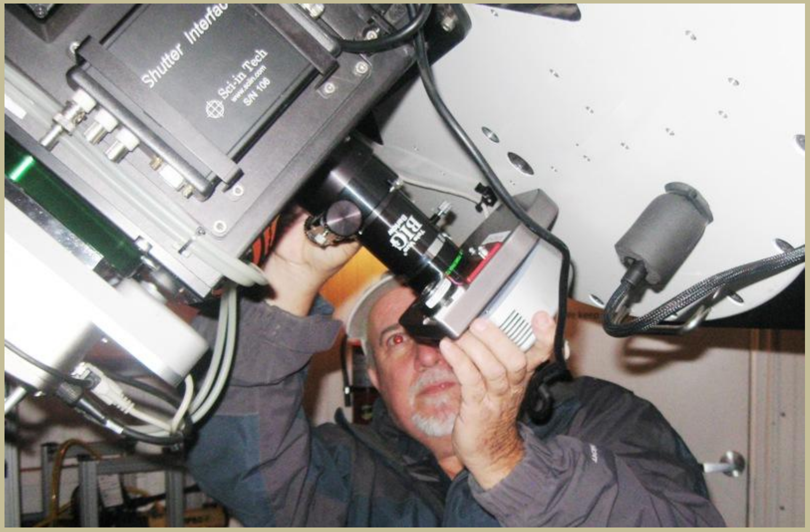

Spectral calibration
Pupil plane
P'1 P1
Focus
Image plane I2
Final Image Plane
Telescope
Camera
Spectral calib.
L2
L3
Li4
Masks
Risley prisms
Filters
Densities
Densities
Magnification
Tests and monitoring
EN
CH
MA
FA
DA
DB
GR

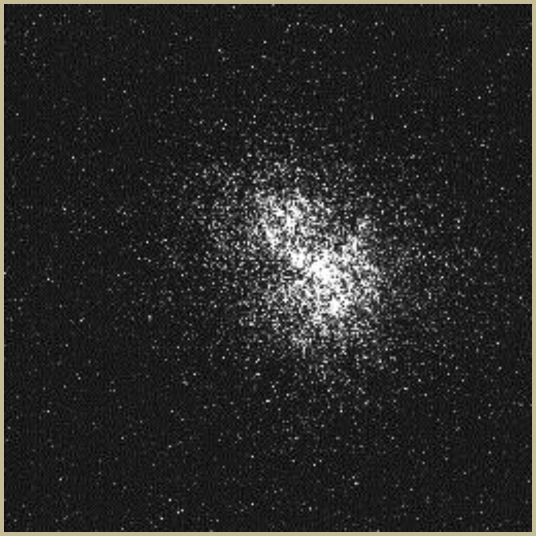


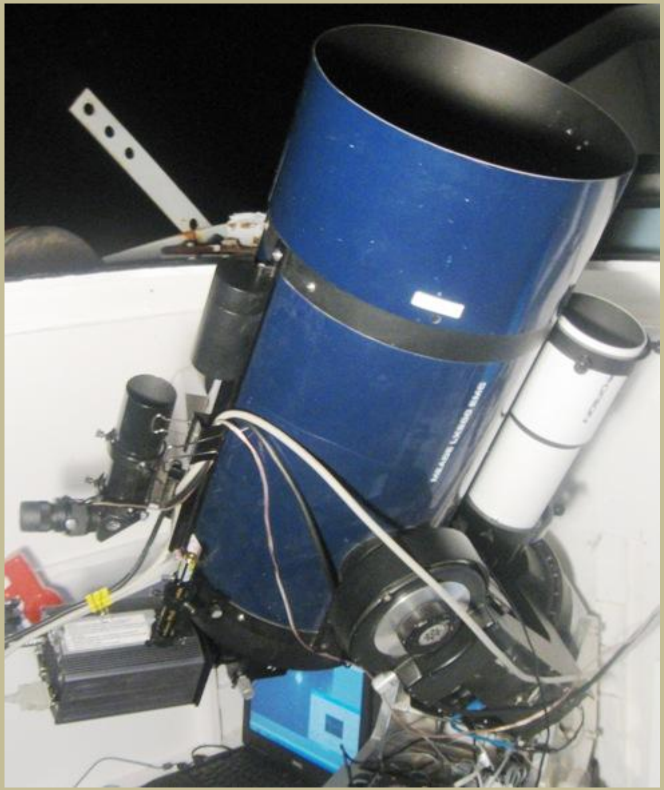


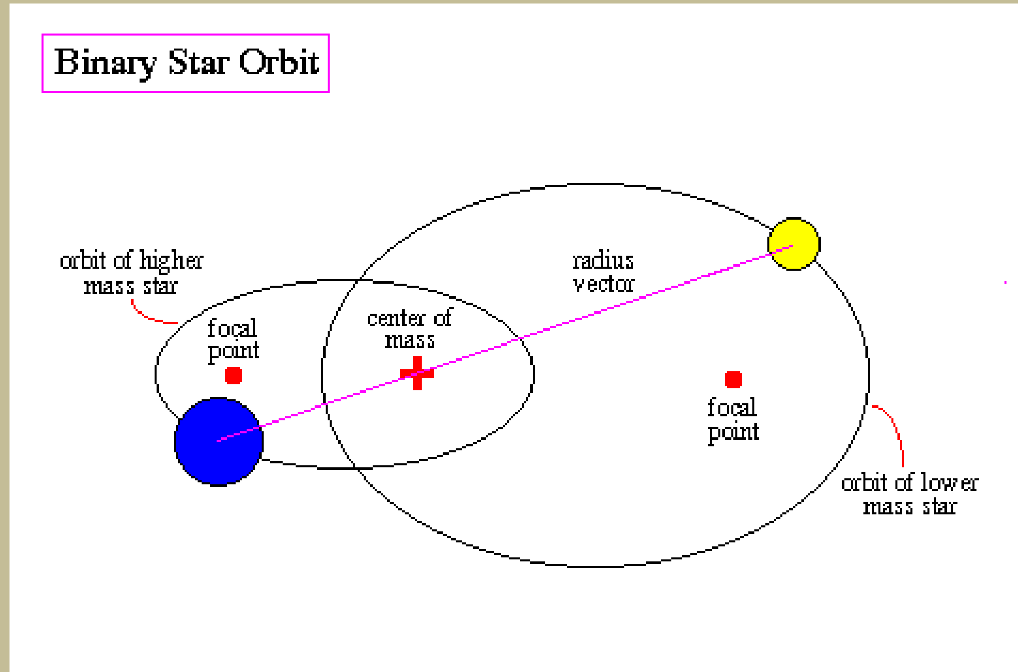


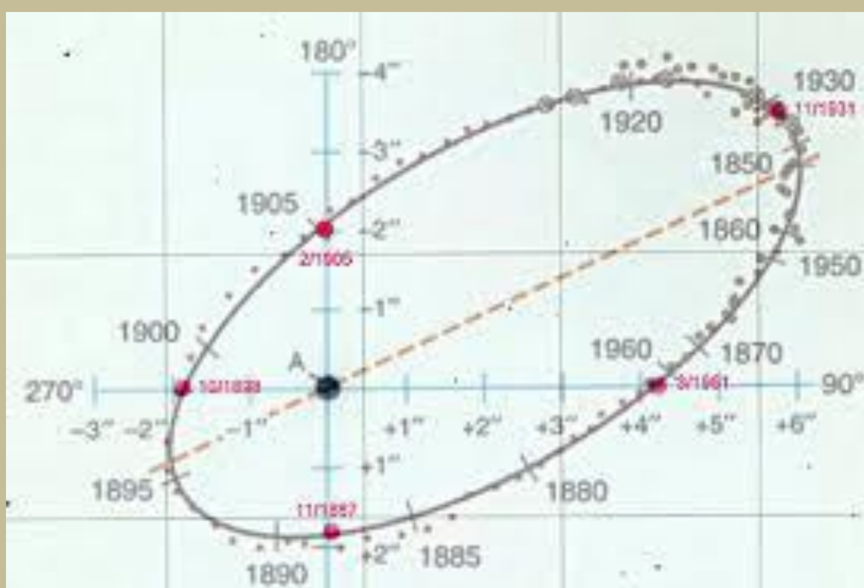

LCOGT

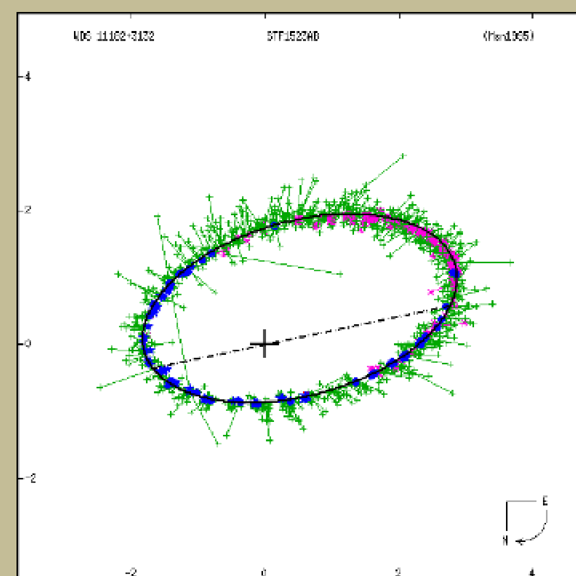

Sci-in Tech

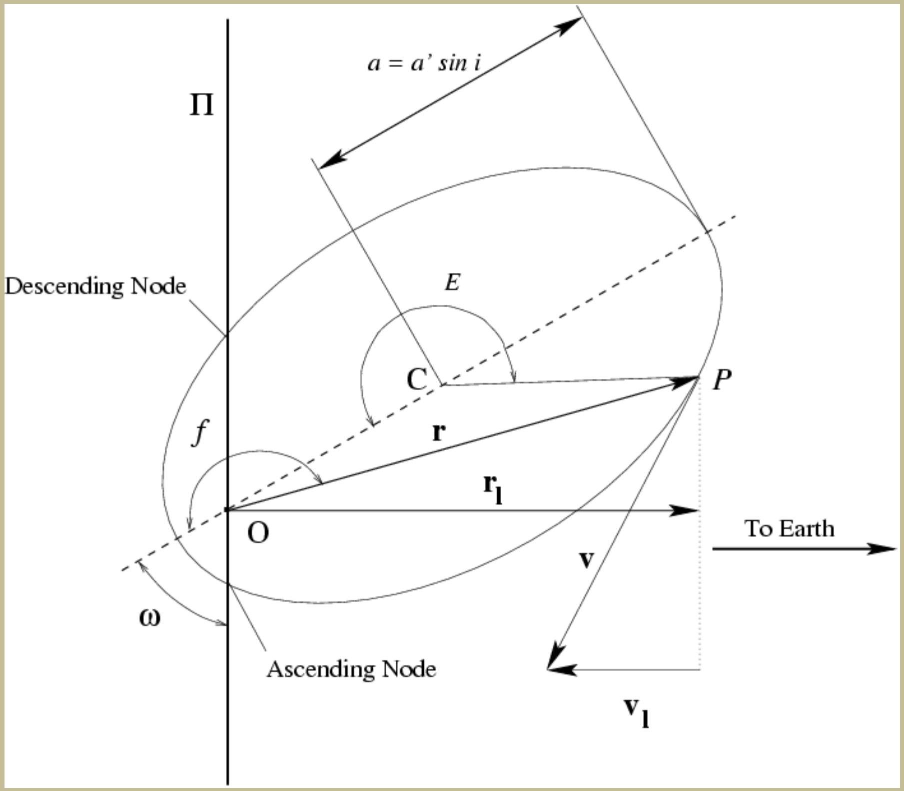


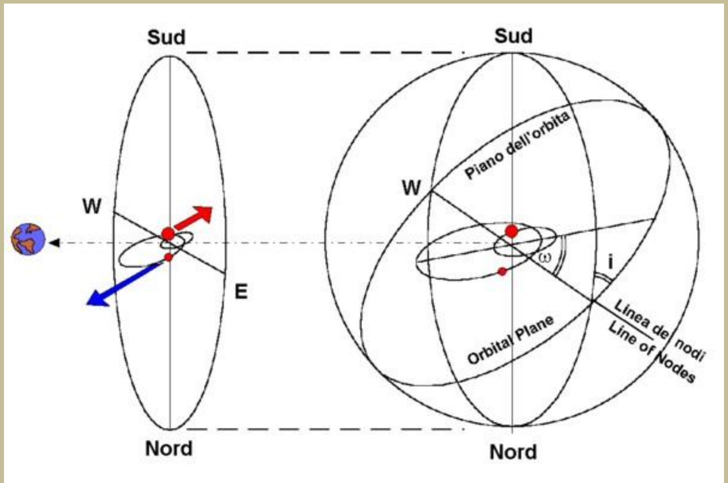



Binary Star Orbit
orbit of higher mass star
focal point
center of mass
radius vector
focal point
orbit of lower mass star


180°
270°
90°
1930
11/1931
1920
1850
1905
2/1905
1860
1950
1900
1960
1870
12/1898
A
3/1961
1895
11/1887
1880
1890
1885

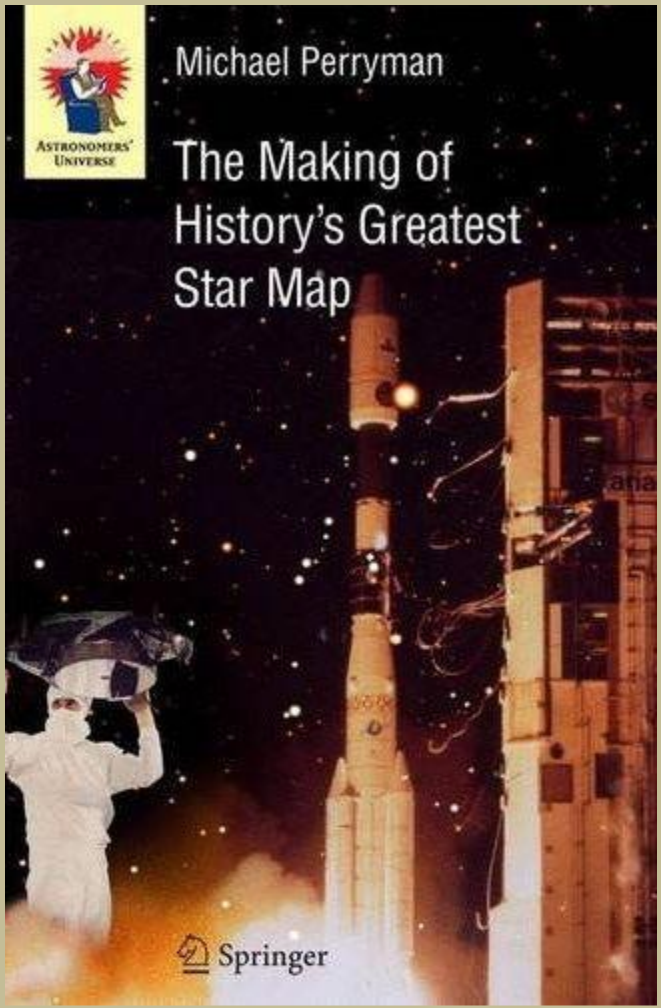


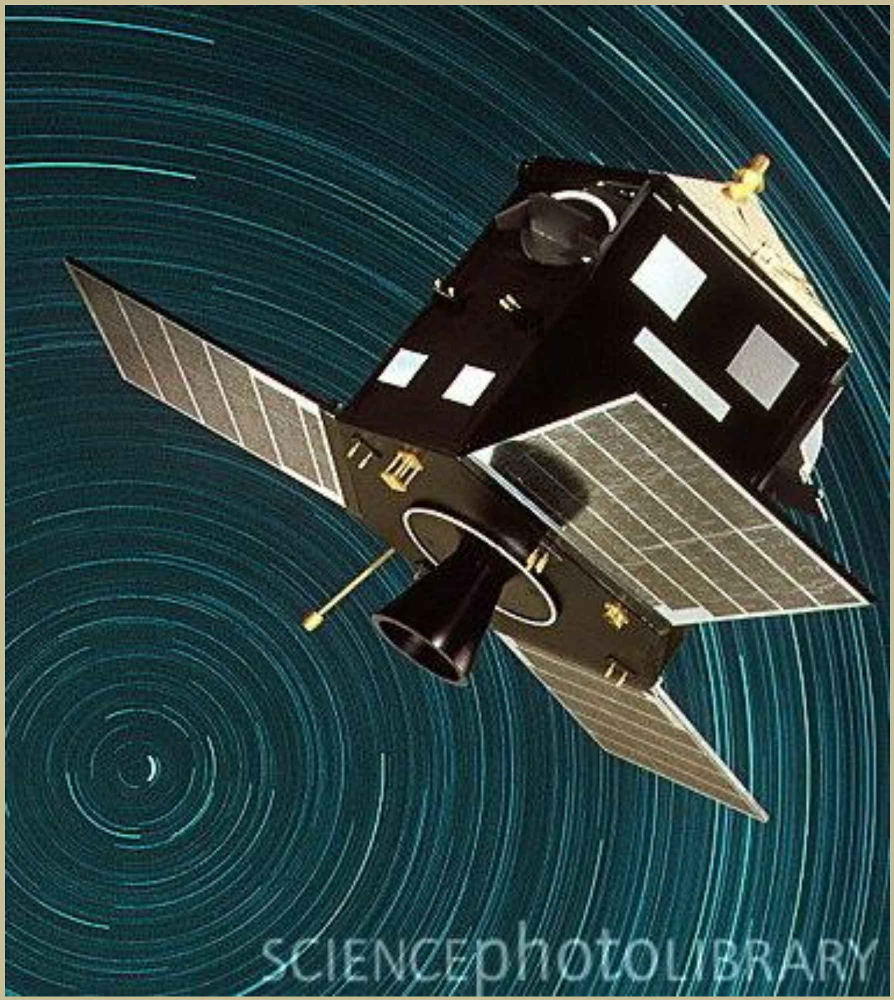

a = a' sin i
Π
Descending Node
E
C
P
f
r
r_l
O
To Earth
v
ω
Ascending Node
v_l

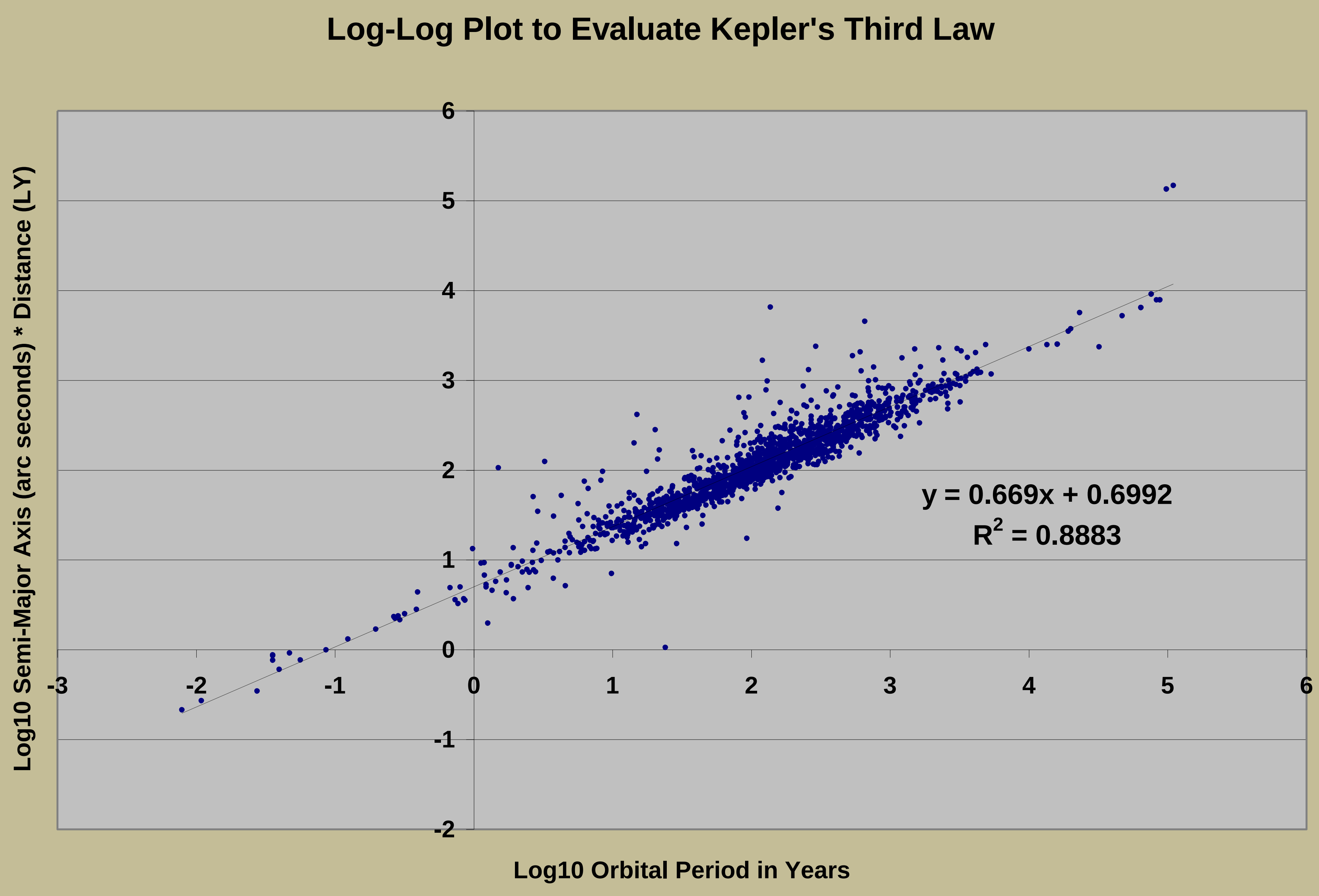

Sud
Sud
W
W
E
Piano dell'orbita
ω
i
Linea dei nodi
Line of Nodes
Orbital Plane
Nord
Nord

$$P^2 = \frac{a^3}{(M_1 + M_2)}$$

P = years,
M = solar masses,
a = separation in au


Michael Perryman
The Making of History's Greatest Star Map
Springer


SCIENCEphotoLIBRARY


Log-Log Plot to Evaluate Kepler's Third Law
y = 0.669x + 0.6992
R2 = 0.8883
6
5
4
3
2
1
0
-1
-2
-3
-2
-1
0
1
2
3
4
5
6
Log10 Semi-Major Axis (arc seconds) * Distance (LY)
Log10 Orbital Period in Years

Contact

- Emails: russmgenet@aol.com, bholenstein@gravic.com
- Initiative Website - www.AltAzInitiative.org
- Yahoo Discussion Group - http://groups.yahoo.com/group/AltAzInitiative