Meter-Class Telescope Array Science

Bruce Holenstein and Russ Genet

Second Phoenix Astro-Solar Workshop
October 13, 2012
Talk adapted from presentation given at
Alt-Az Initiative Portland VI Workshop, 7/27-7/29 2012

Overview

- Array SNR
- Science
- Some Plans

Hubble Optics UL20

Inspiration from Big Blue 1-m

Signal-to-Noise-Ratio Dependencies

- Factors that affect the Signal-to-Noise-Ratio (SNR) of program measures

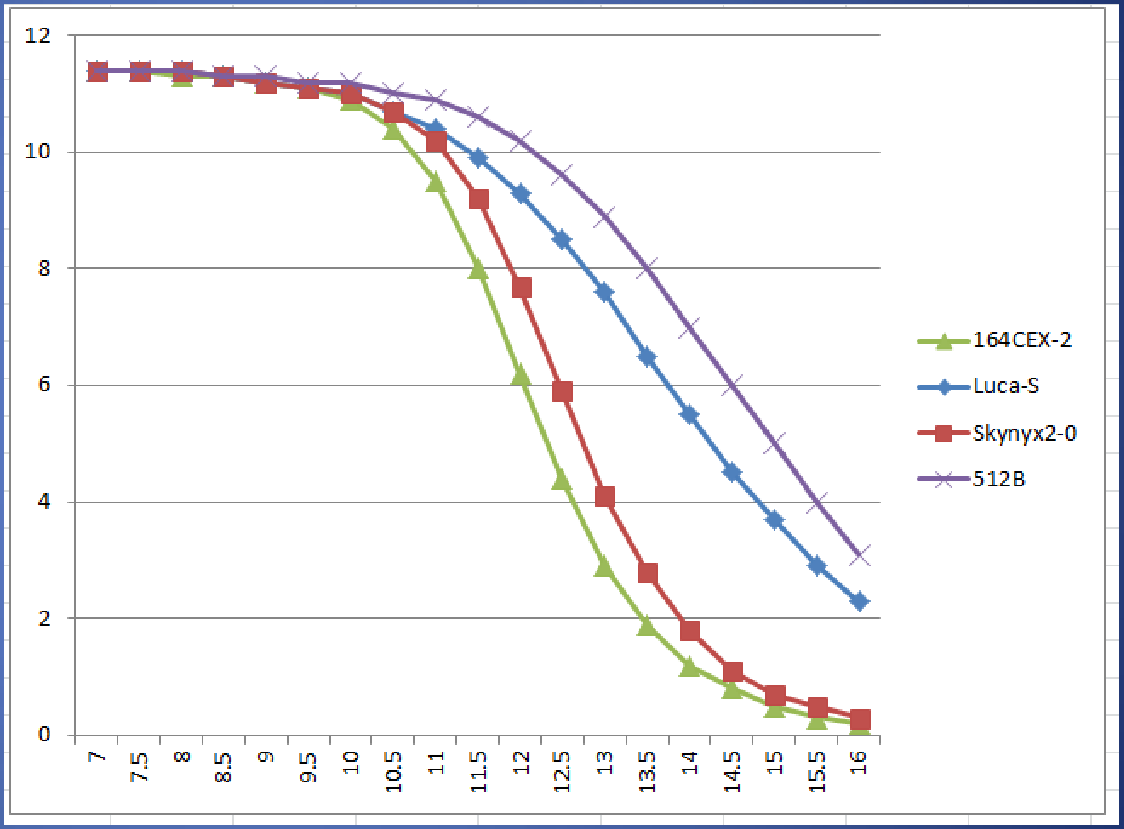
$$SNR = \frac{N_{Star+Sky} - N_{Sky}}{\sqrt{N_{Star+Sky} + N_{Sky} + N_{Detector} + S^2}},$$

where *Ns* are counts and *S* models atmospheric scintillation

SNR Theory for 14” f/4 SCT

- SNR for four cameras vs object mag.

30-fps, 100-m elevation, 1.2 airmass, 20-mag./sq.as.



Scintillation Noise

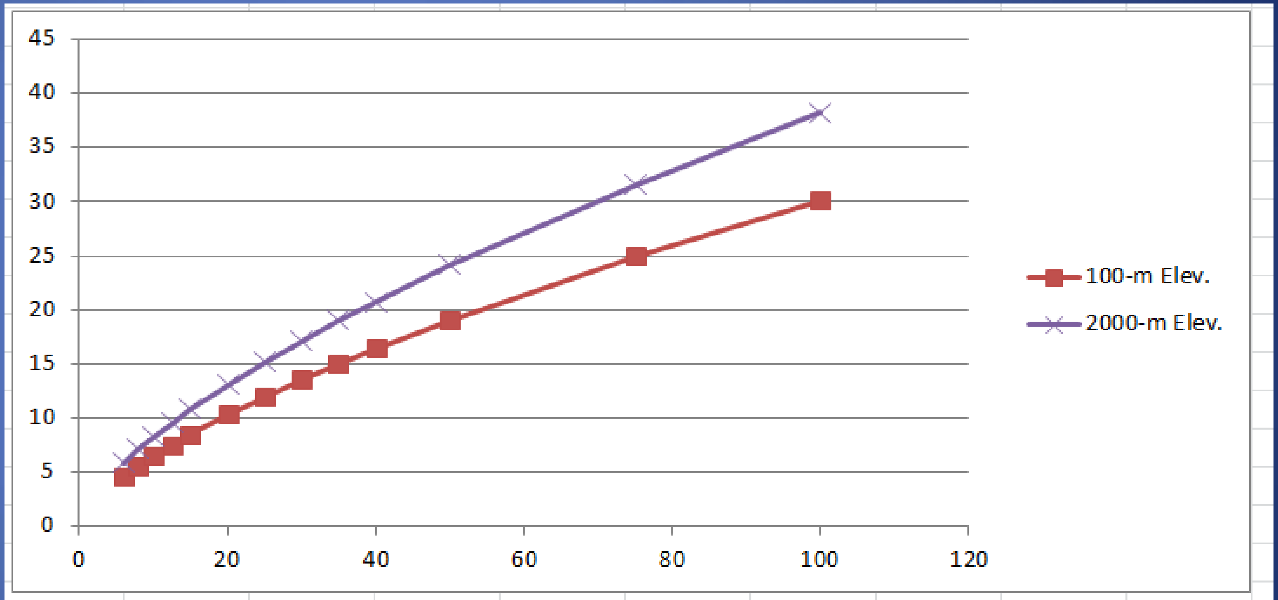
- Some cases we can't increase integration time
  - Need about 30-fps for occultation timings and 200+ fps in visible for lunar occultation diffraction patterns
- Mitigate it
  - Increase objective diameter
  - Move to a higher altitude
  - Utilize arrays of scopes

Low noise, High-speed cameras

Scintillation SNR Theory

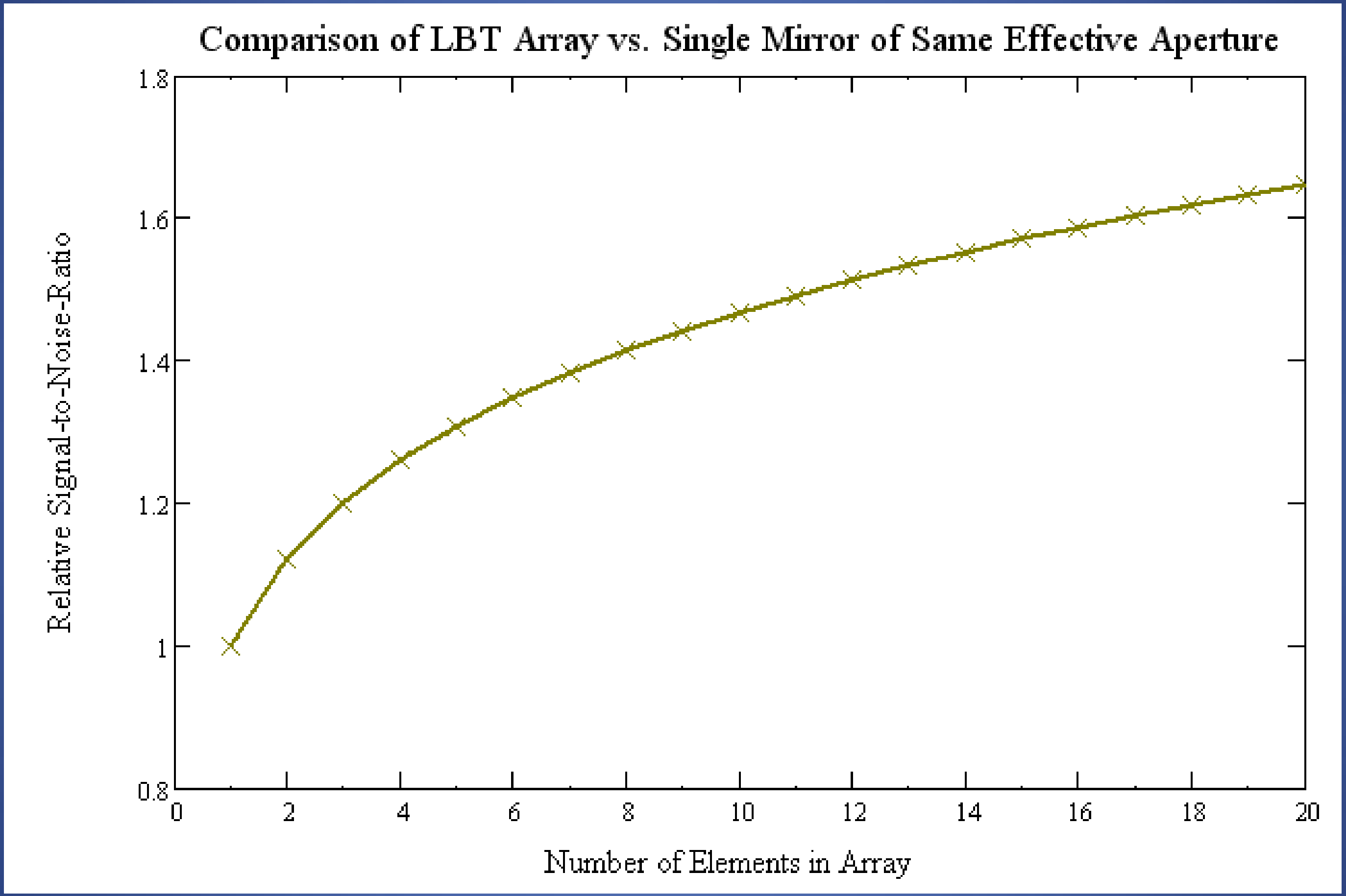
- Scintillation SNR limit vs. aperture

30-fps, two elevations, 1.2 airmass, 20-mag./sq.as.



Scintillation limit on SNR vs. Aperture (cm)

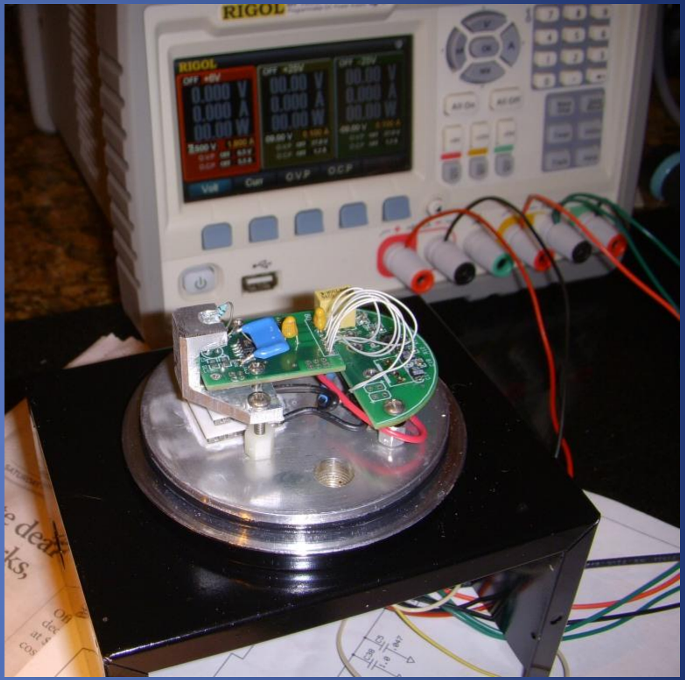
Array Scintillation Noise Reduction



Only Scintillation per Young (1967) counted in noise.

Some Science Uses

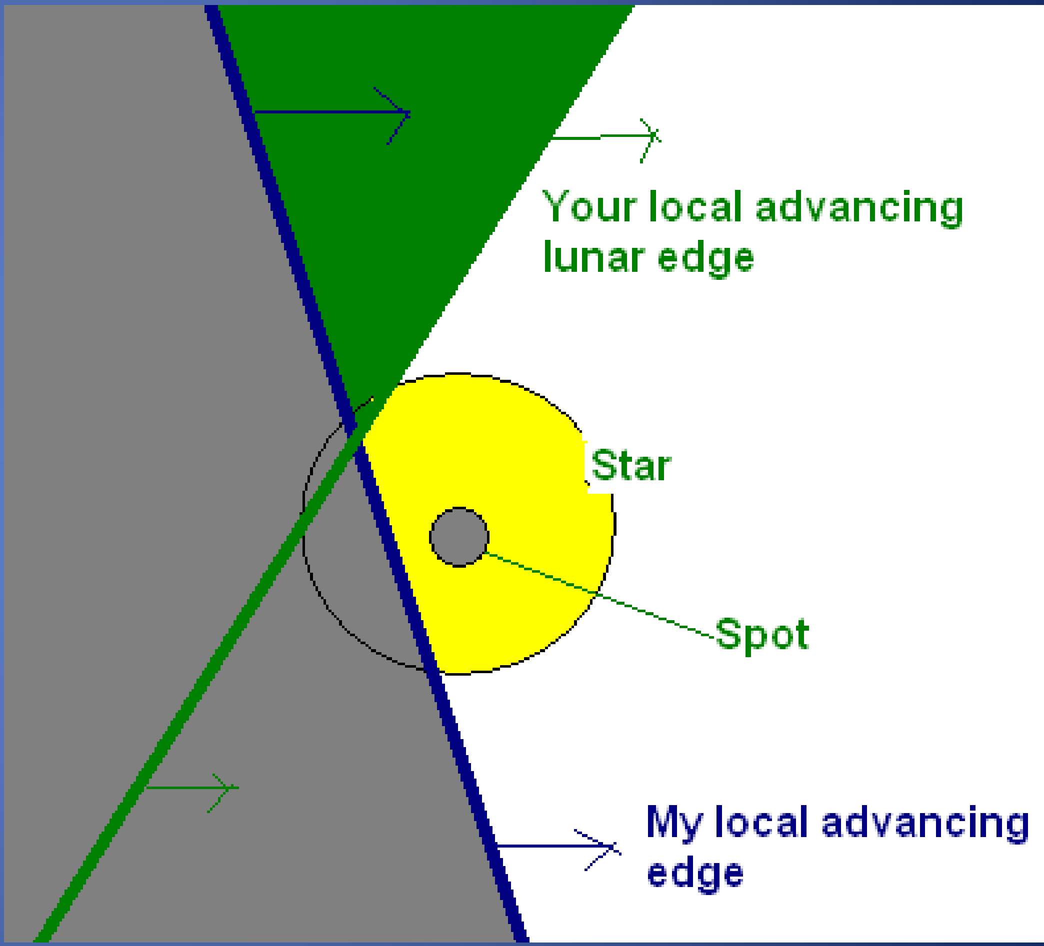
- Discovery searches for supernovae in not-too-faint galaxies
- Size and shape (and hence albedos) of smaller diameter trans-Neptunian objects (TNOs)
- Near IR photometry (especially Ks band), which can benefit from high altitudes and dry skies.
- Spectroscopy: Spectroscopic binaries, Active OB stars, Be stars, Bet Lyr, Del Sco, Symbiotics
- Lunar and asteroid occultations
- Polarimetry
- Intensity Interferometry



Greg Jones's K' NIR photometer

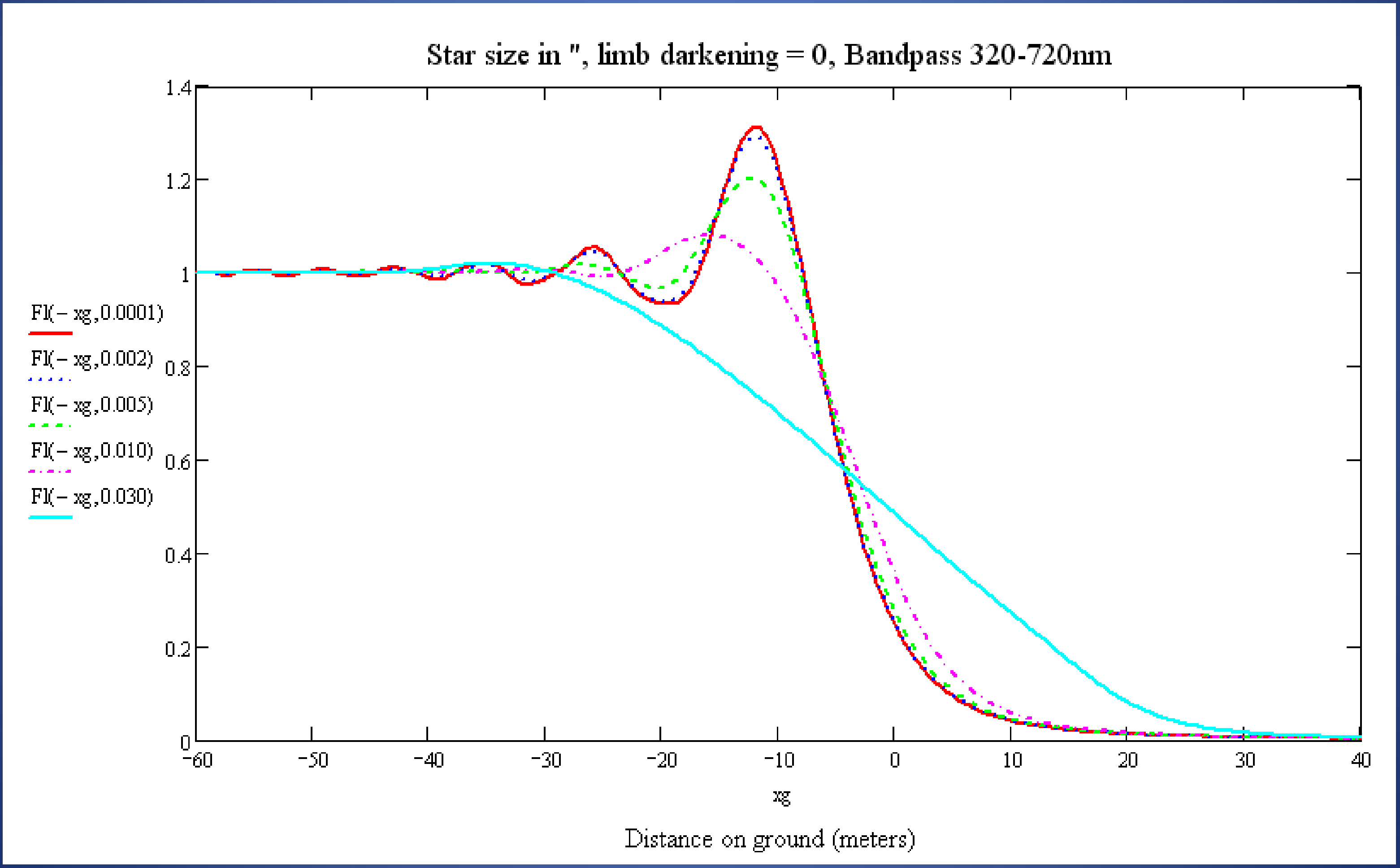
Occulted Object Science Potentials with a Sufficient SNR

- 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



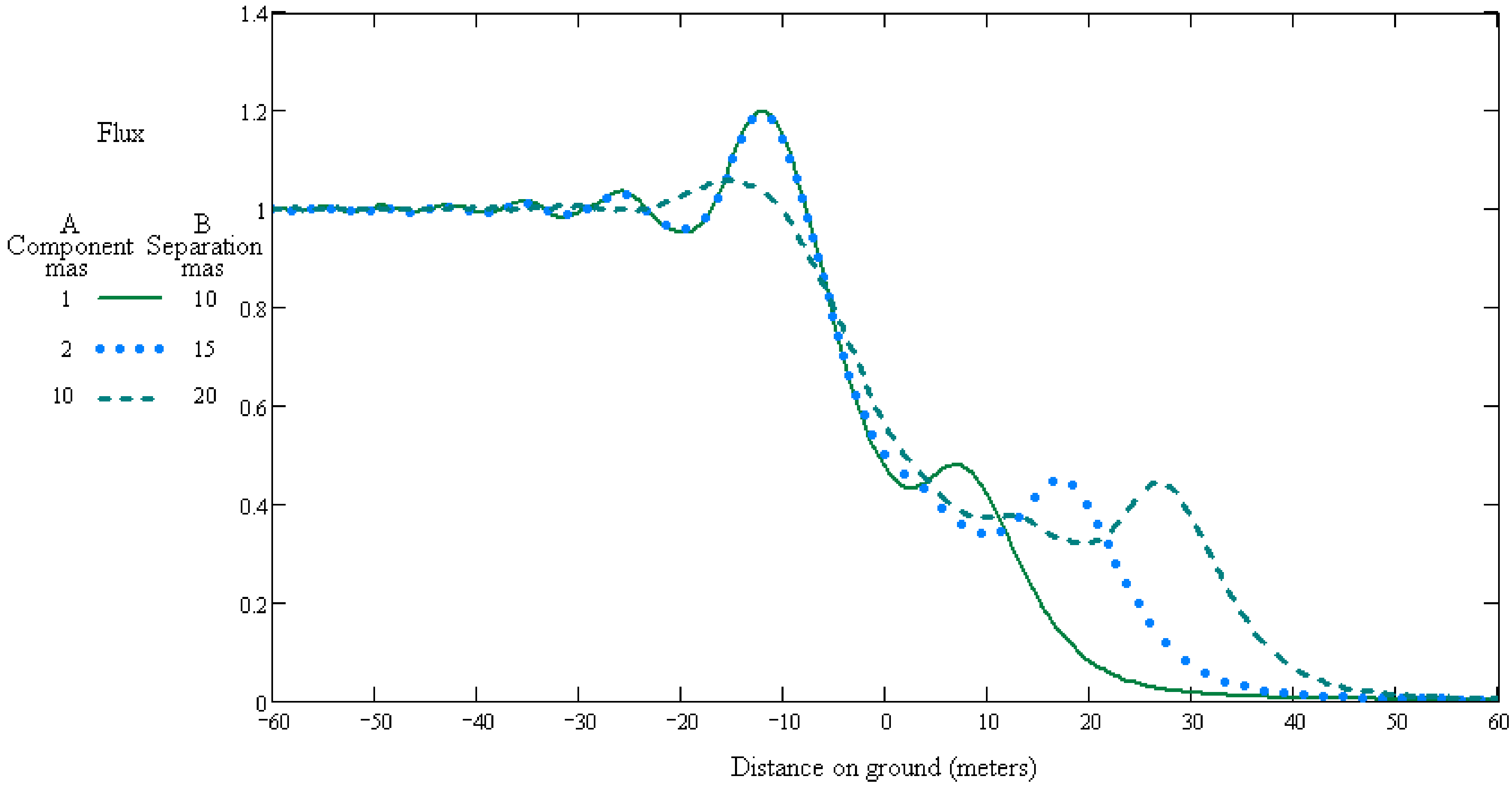
Lunar Occultations Examples

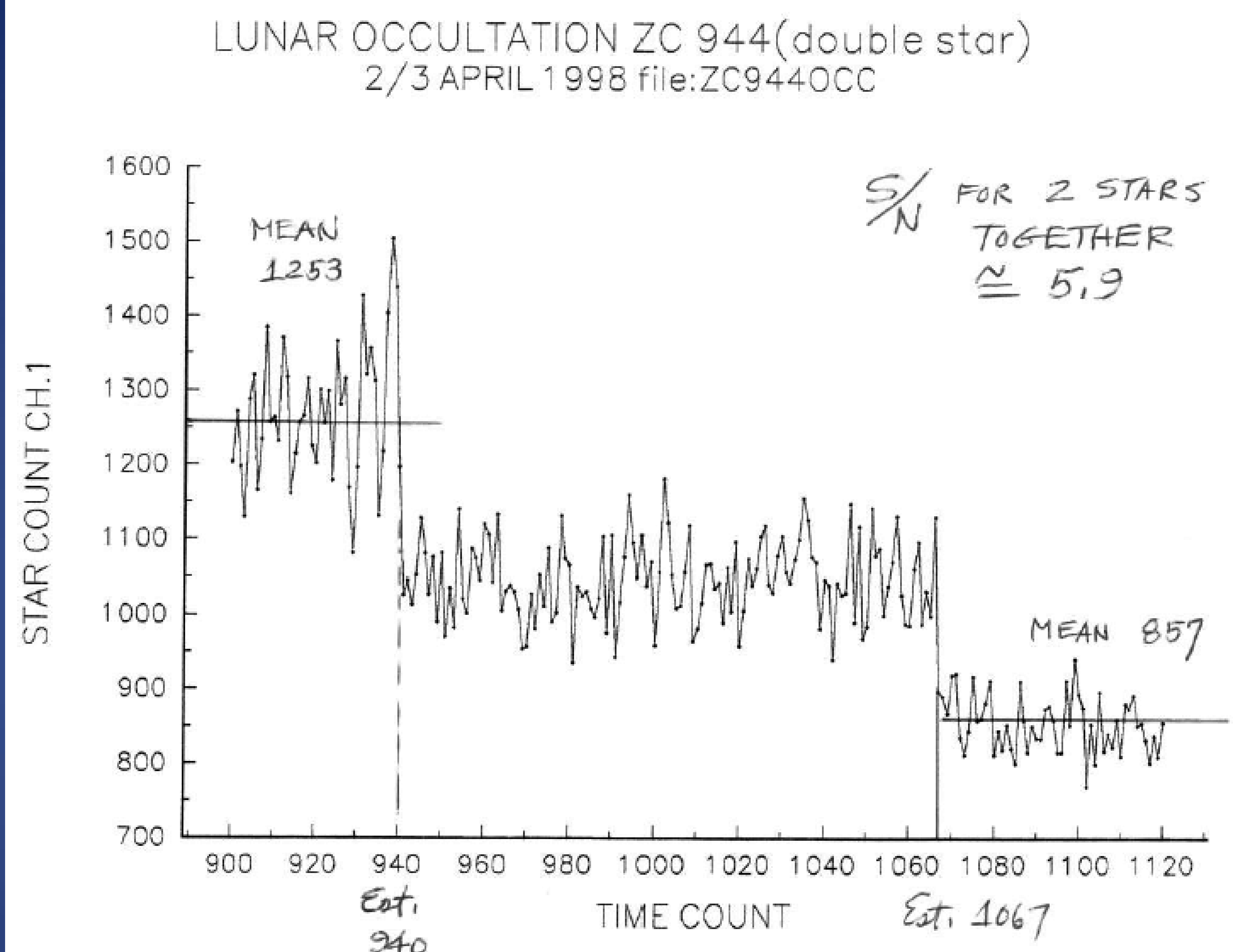
Theoretical diffraction light curves for different sized stars (0.1 to 30-mas)



Lunar Occultations - Binaries

Theoretical diffraction light curves for three different binary systems

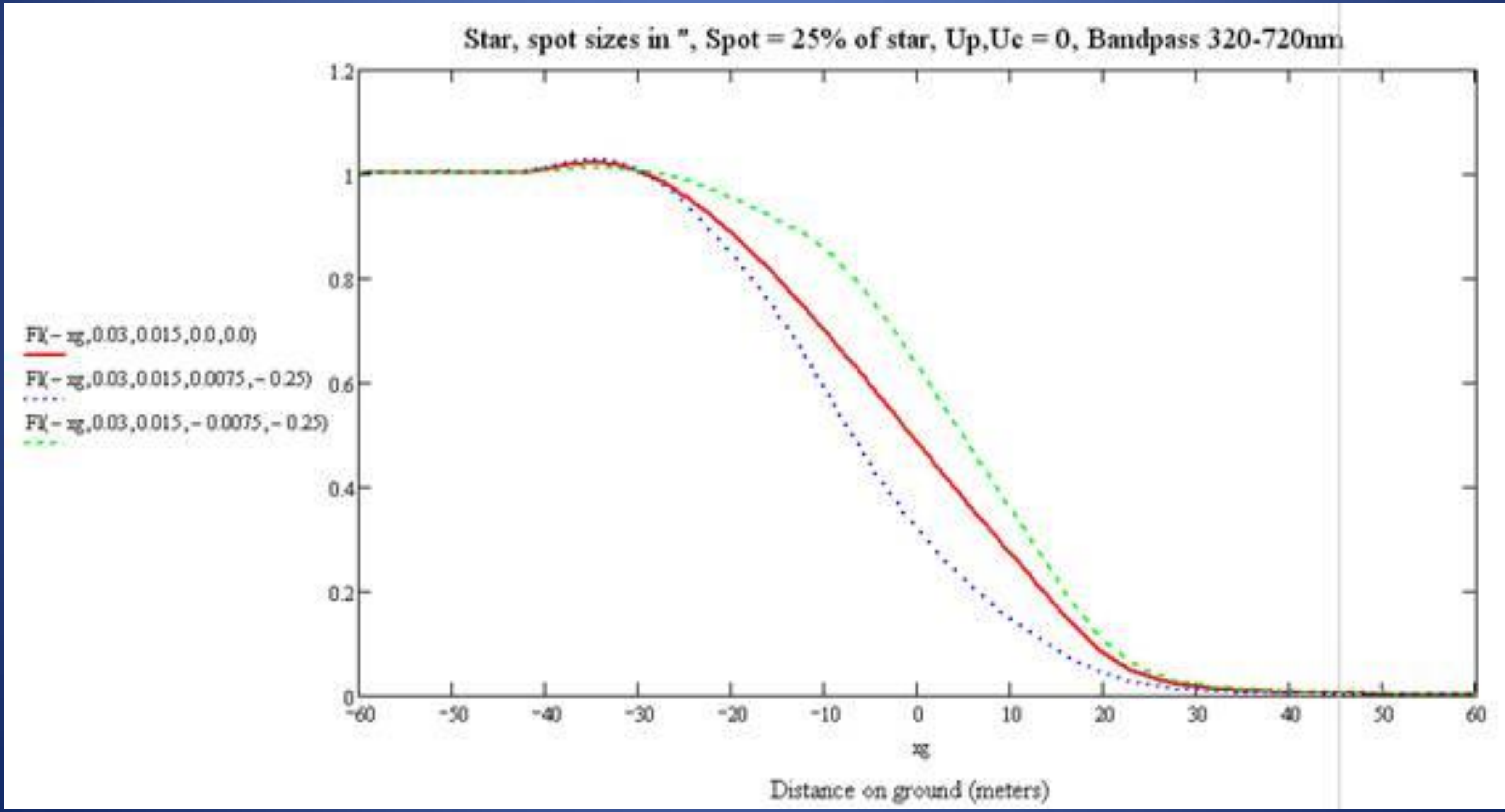




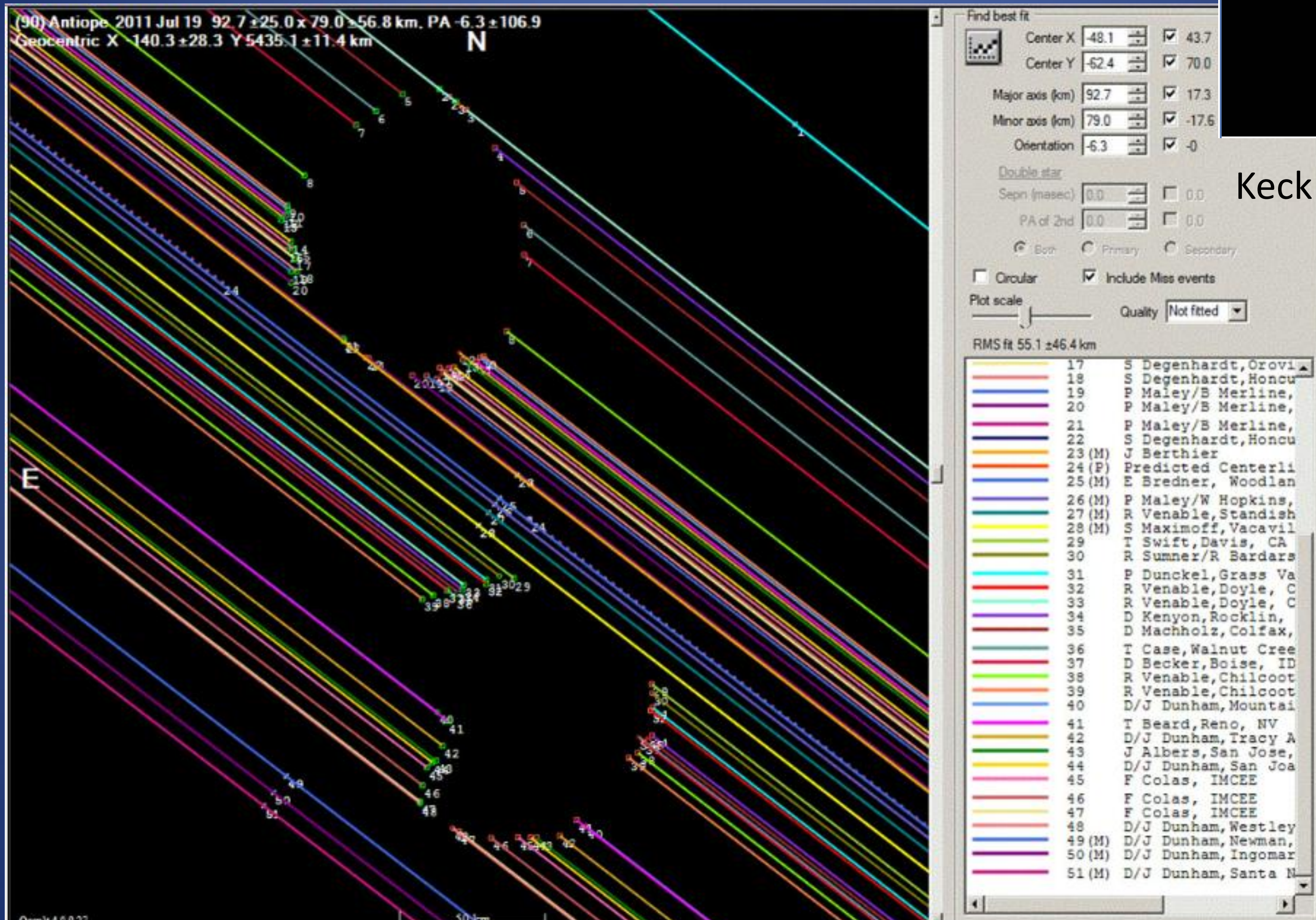
- 15” Siderostat at Flower and Cook Observatory, Malvern, PA by R. H. Koch, R. J. Mitchell and W. J. Blitzstein
- Occult4 lists close double 0.39”, Limb=0.190”/sec
- 127 15-ms samples = 0.362” separation

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.



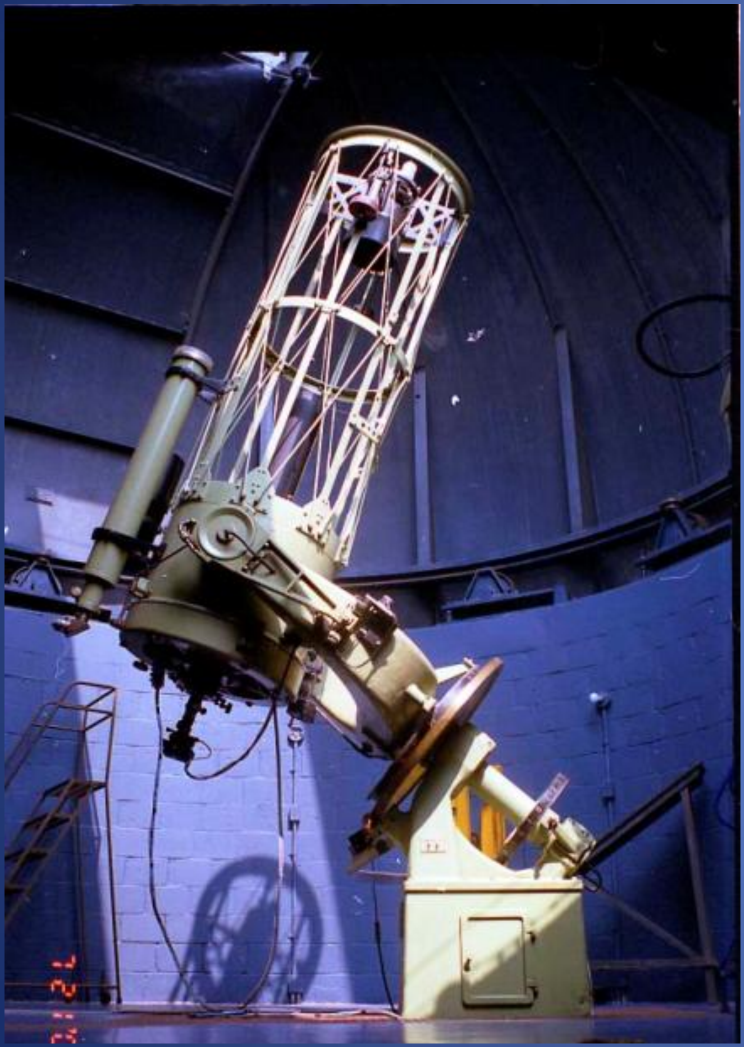
IOTA Asteroid Timing

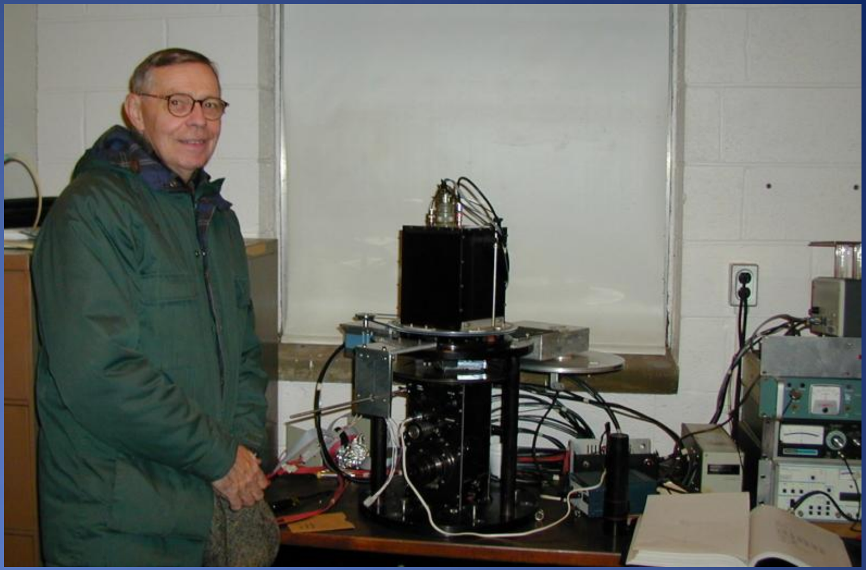


Keck (Sky & Tel)

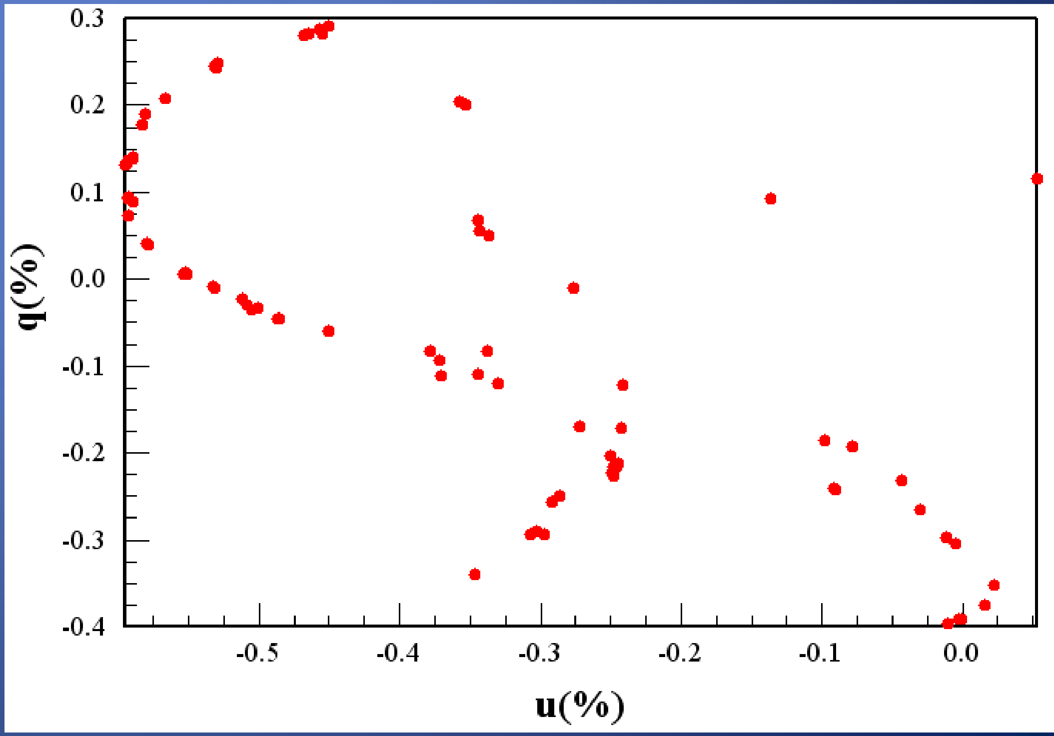
- Antiope success – July 19, 2011

Polarization





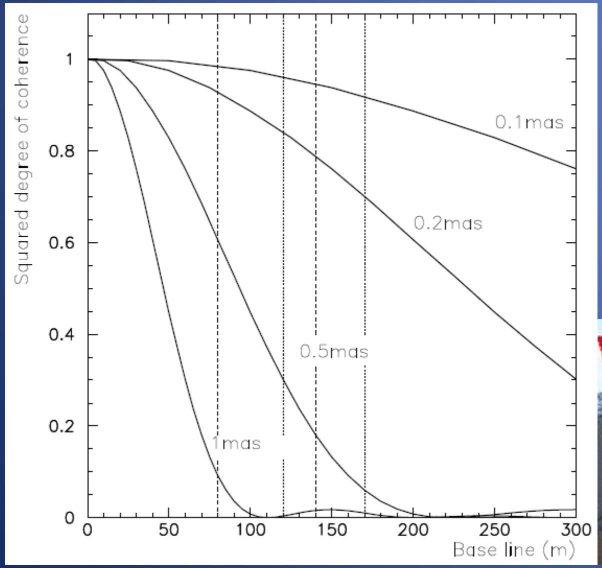
Above: R H Koch 2000, Below: Alp Ori, R filter, Interstellar removed, 3 seasons, Holenstein (1991)

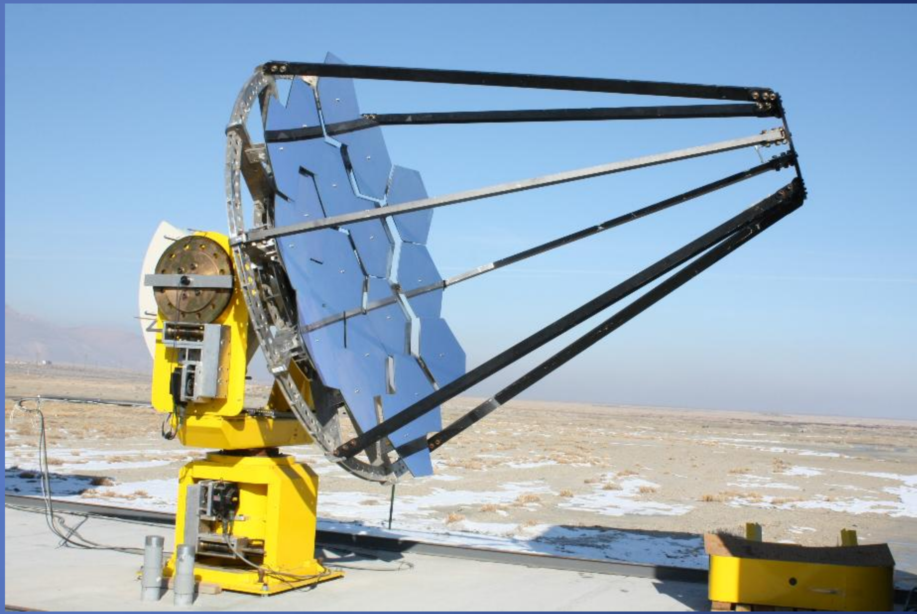


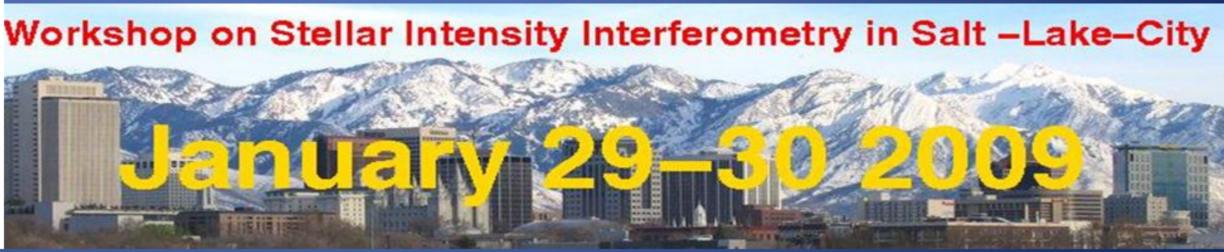
- FCO 28-in. Cassegrain

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.

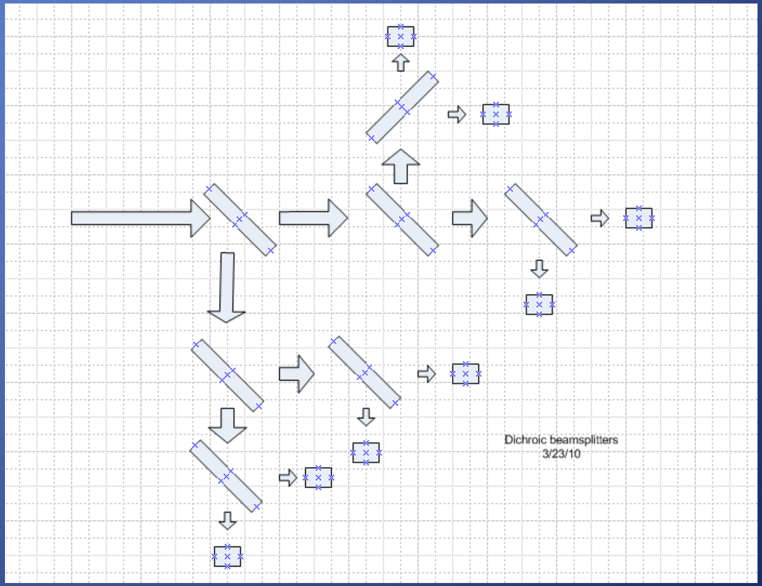
$$SNR_{Overall} = \left[\binom{N_{Array}}{2} N_{Channels}\right]^{1/2} SNR_{Hanbury\ Brown}$$

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

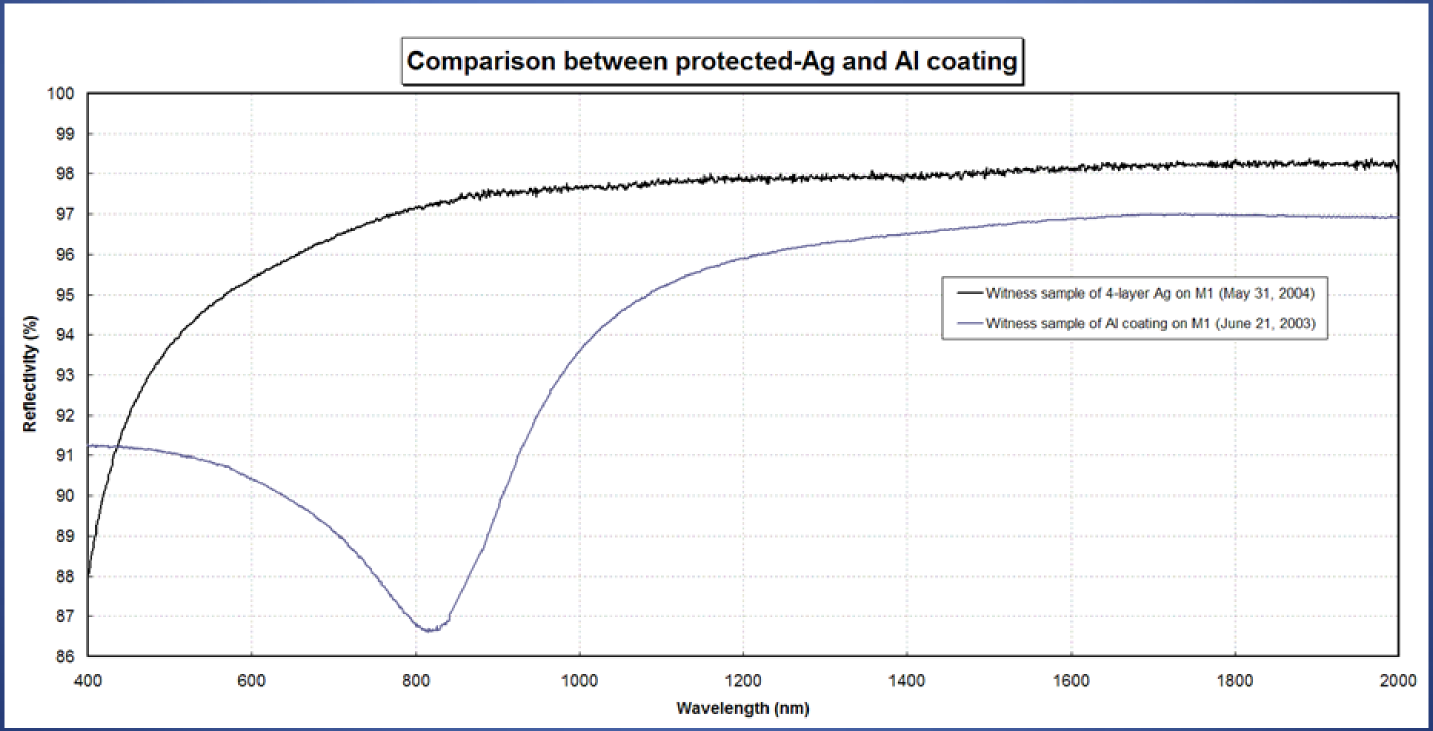
- Three 12-cell Hamamatsu R1463P PMTs
- LeCroy 6100A samples at 10GS/s
- NVIDIA CUDA GPU for photon correlation



8-band dichroic beam splitter

NIR & LWIR

- Silver is a traditional cold overcoating material
  - Reflectivity is very good out to NIR & beyond

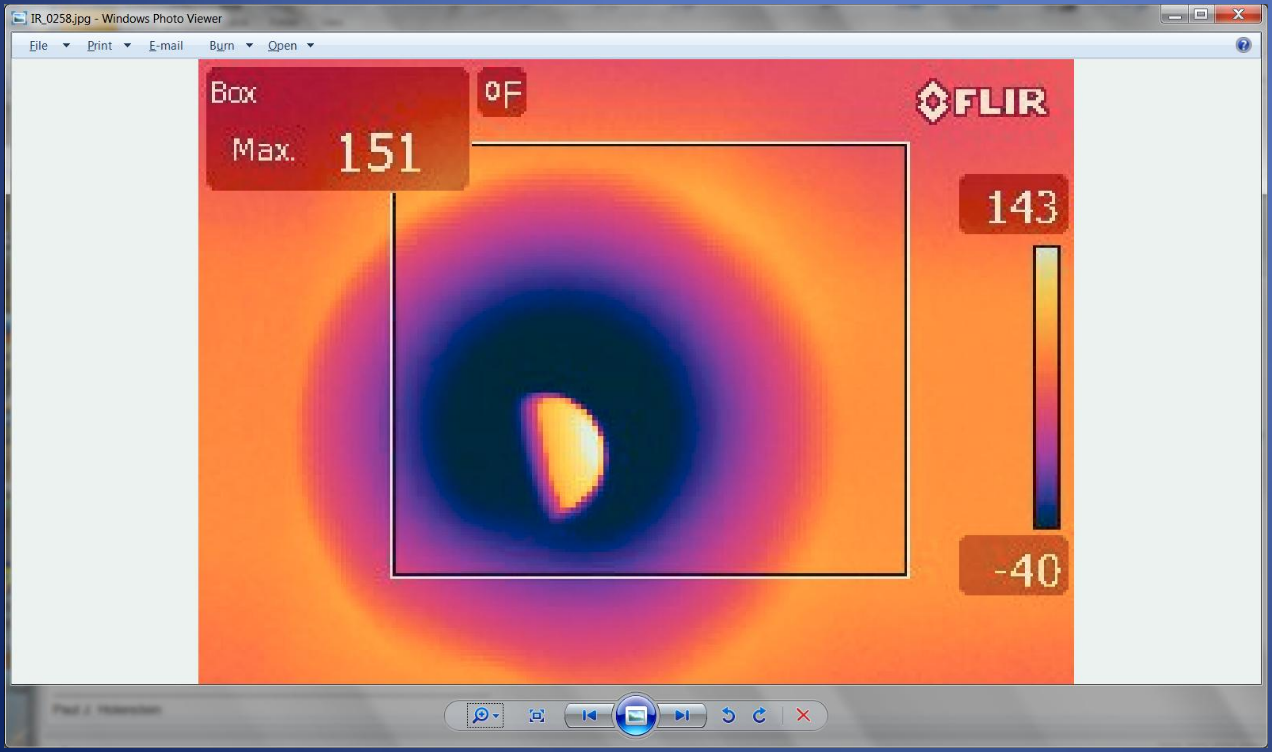


Source: gemini.edu

LW IR

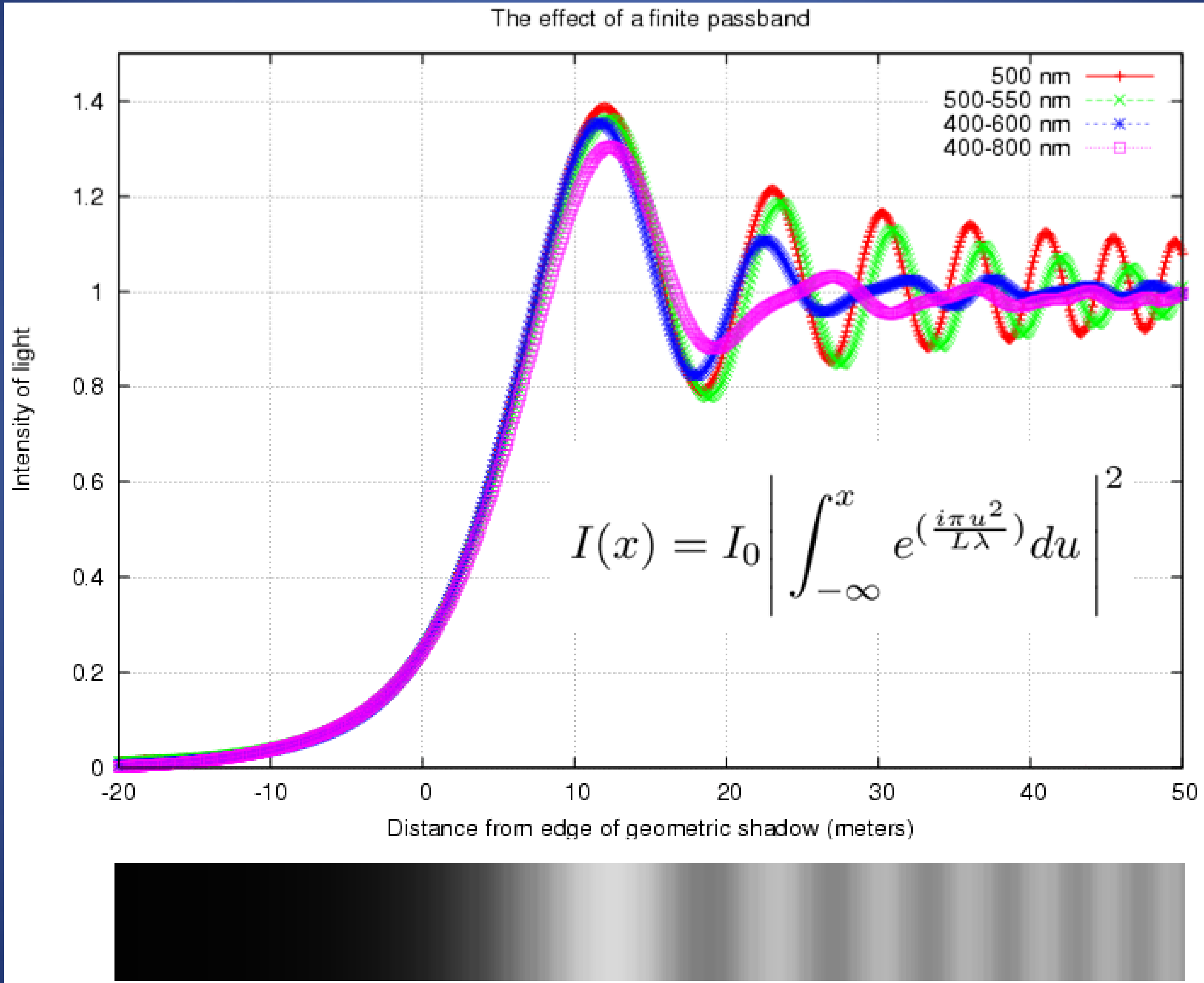
- FLIR e30, 7.5 - 13.5 µm (N-band) microbolometer technology

FLIR e30, 10” f/5 mirror, moon



Fresnel Diffraction

Dependencies on bandpass and geometry



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

Gravic's (Evolving) Astro Plans

- 7 to 10 elements 1 to 2-m
- Configurable
  - Minimize scintillation
  - Maximize coverage
- East Coast location
  - <2500 ft. elevation typical
  - 1-2 arc second seeing
- Automated, Queue Scheduling
- Min. 3 astronomers, 1 tech.

Coudersport, PA (5 hrs.)

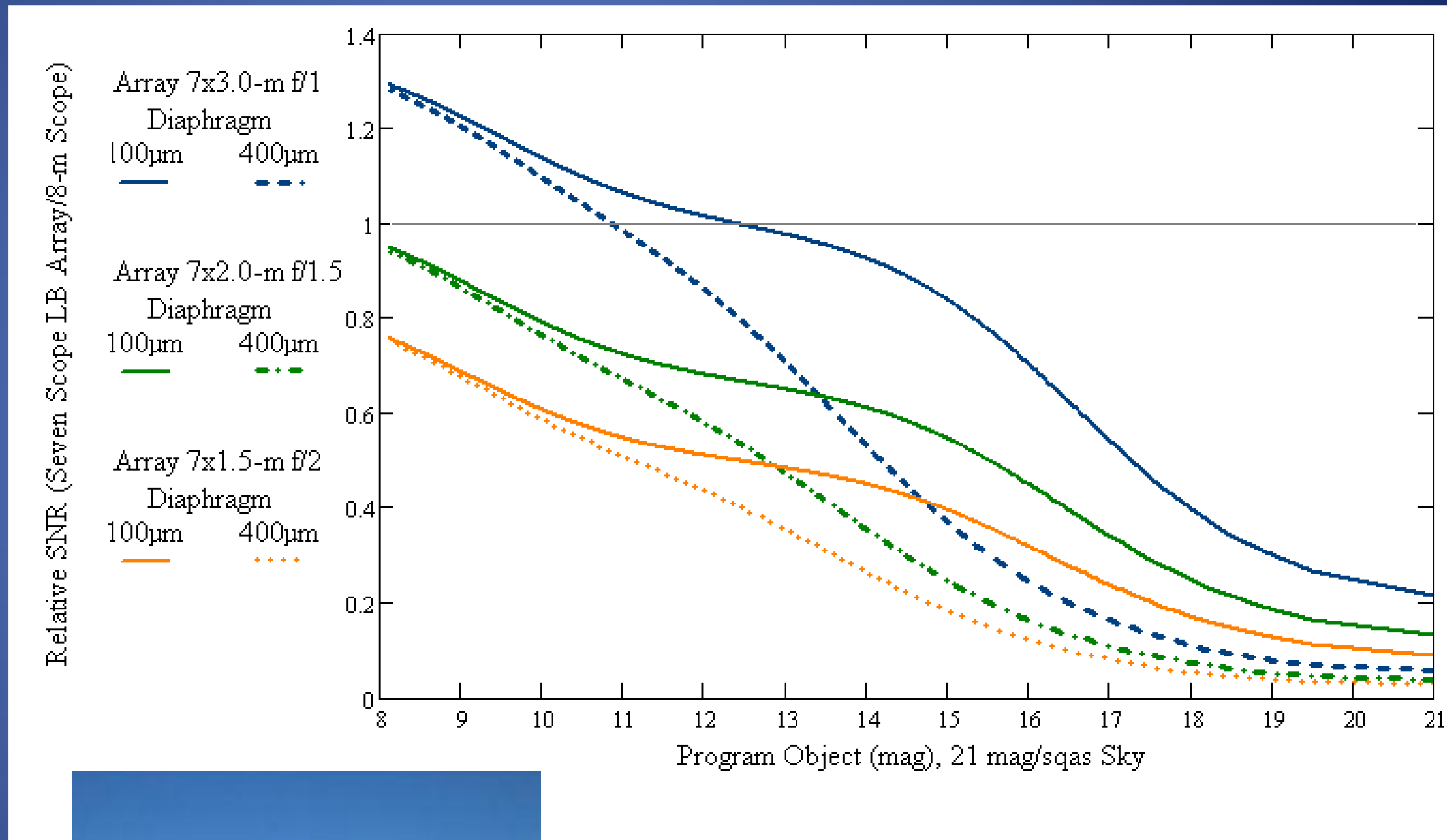
International Dark Sky Park

7-Element Arrays vs. Traditional

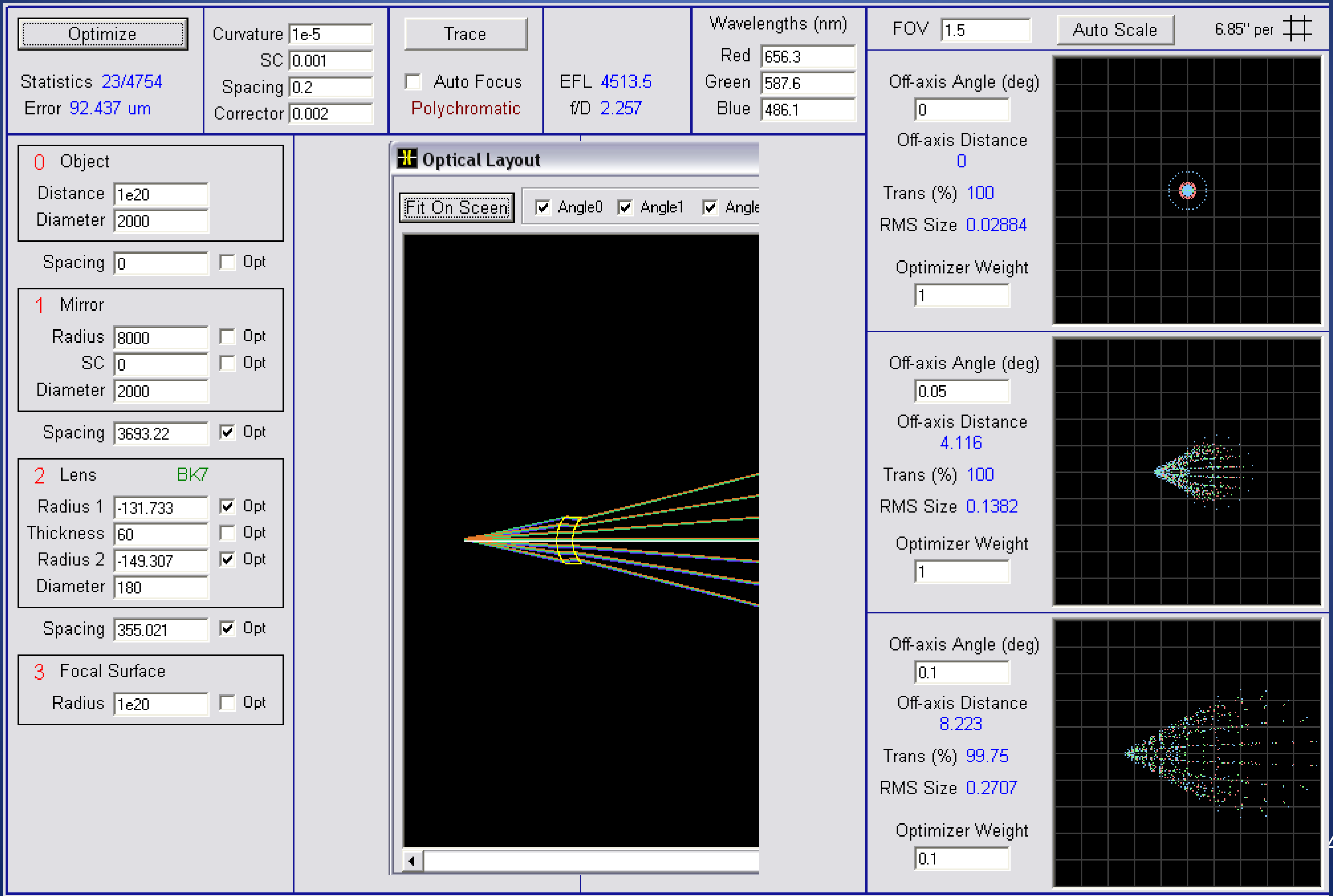
7-element LBT array *vs* . One 8-m f/1 scope

2 relative diaphragm diameters (400, 100 vs 40 micron on 8-m)

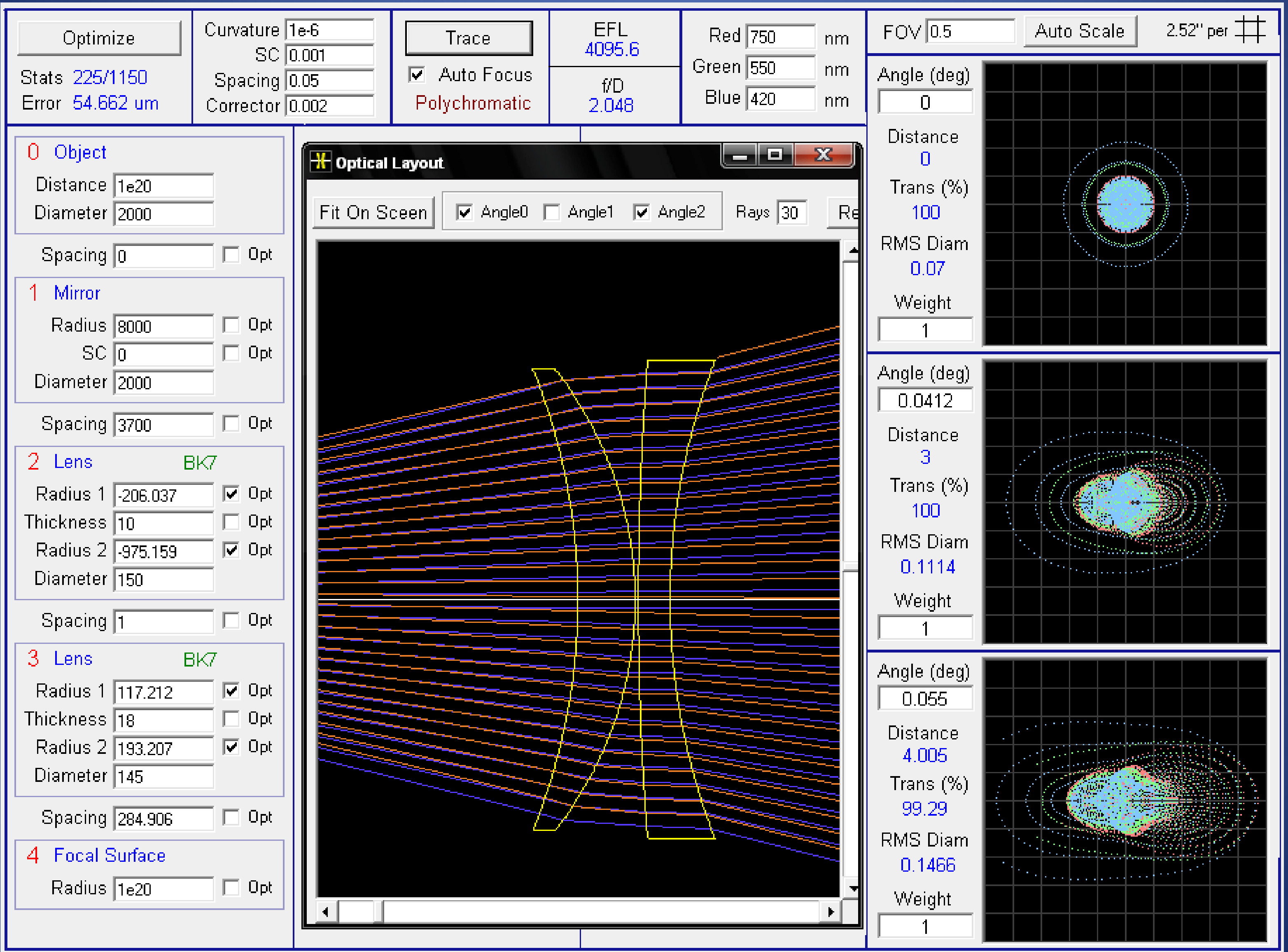
Scintillation at 3000-m, 1.5 air-mass



2-m One Element Corrector

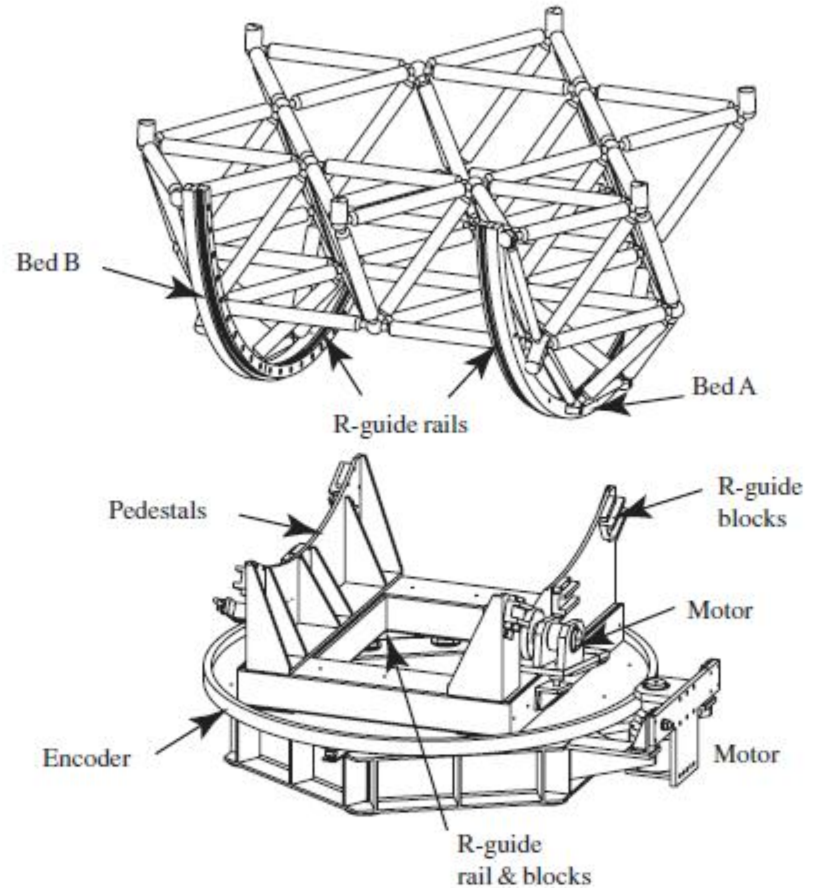


Dave Rowe's 2-m Corrector



One 2.5-m “Ultra-lightweight”

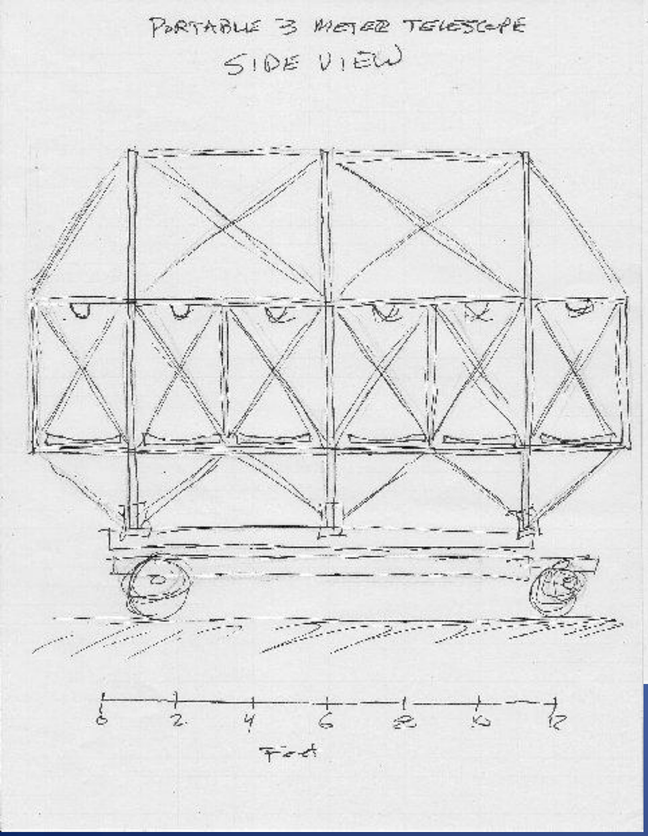
ULTRA-LIGHTWEIGHT TELESCOPE MOUNT 267

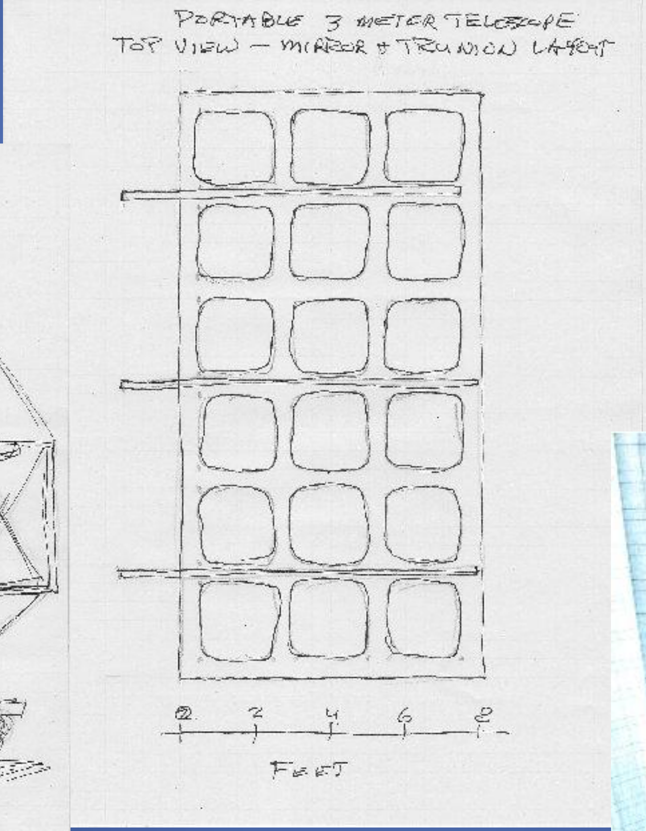


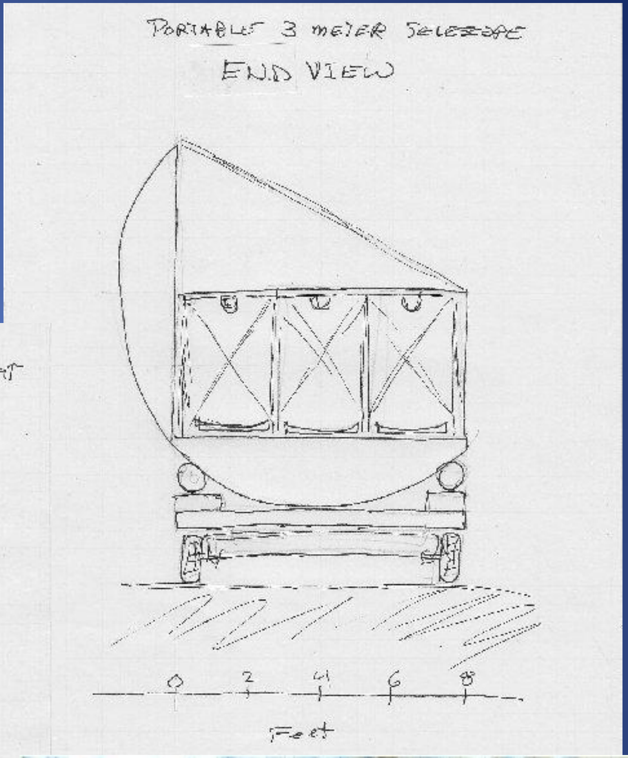
5 ton, f/2

Kurita et. al. PASP 2009 121:266

Russ Genet's 3-m Concept







Primary Sol Focus mirrors. 2 mm thick. They make 6000 a day.
Idea is to have an array of these each feeding a fiber.
The fibers come together for the sensor.

Contact

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

More details:
The Alt-Az Initiative: Telescope, Mirror, & Instrument Developments, eds. Genet, Johnson, & Wallen, (Payson, AZ: Collins Foundation Press) 2010