LIGHT BUCKET ASTRONOMY

Visions for Large Light Buckets

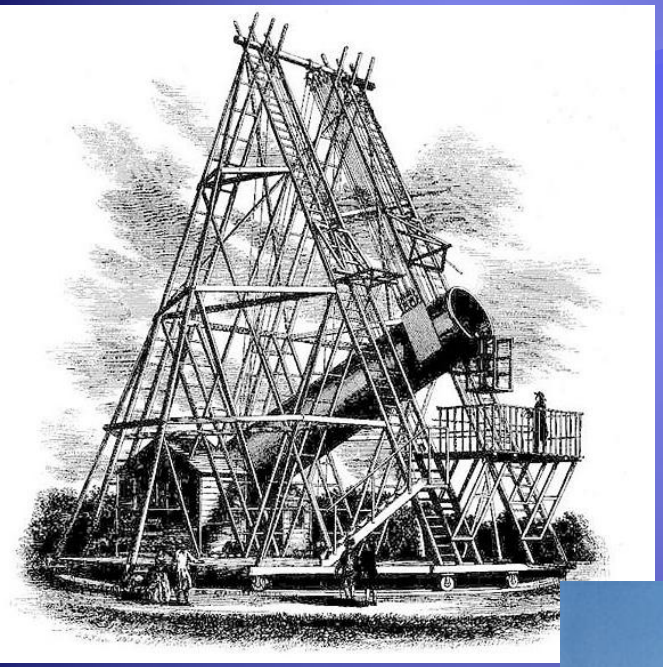
Russ Genet and Bruce Holenstein

2010-2011 Alt-Az Initiative Hawaii Conference on Light Bucket Astronomy

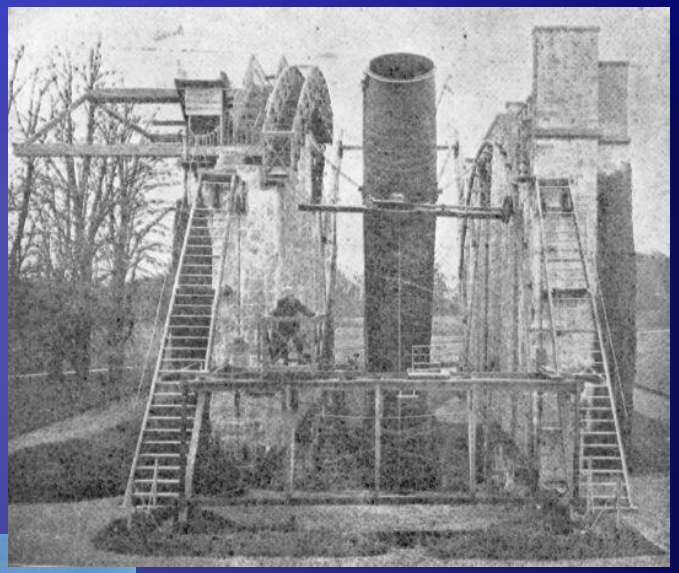
Agenda

- Historical Light Buckets
- Some Current Meter-Class Scopes & Design Issues
- Telescope Arrays
- Stellar Intensity Interferometry Revival
- OSETI Arrays
- Giant Light Buckets

Some Historical Light Buckets



Herschell's 49.5" 40-foot



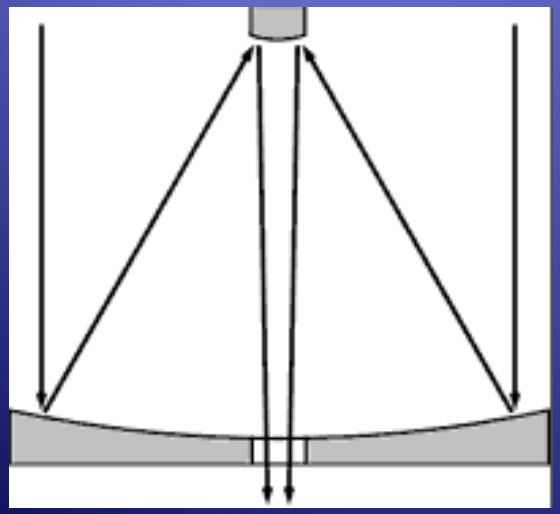
Lord Rosse's Leviathan 72"

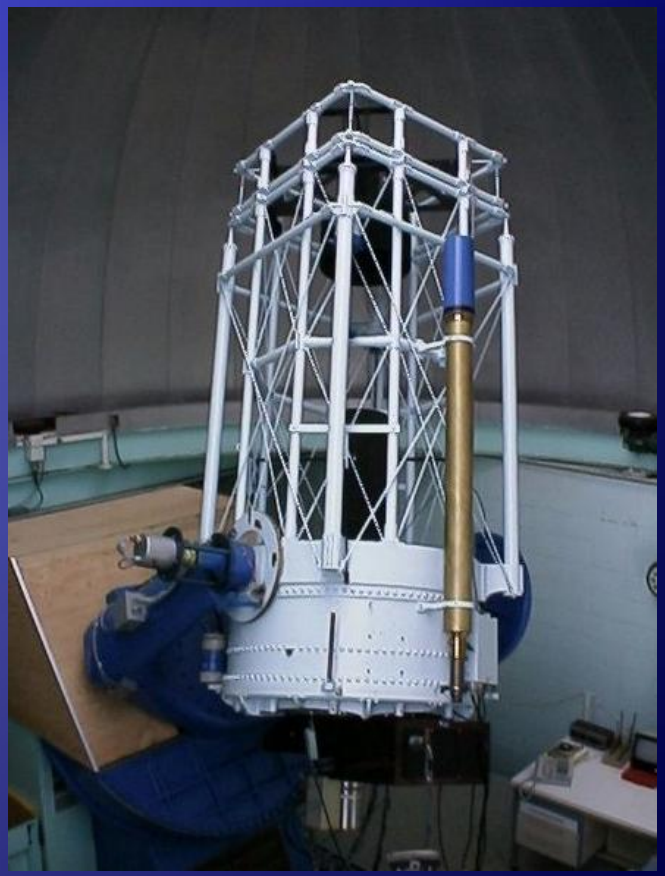
Hanbury-Brown Intensity Interferometer 6.5-m

Wikipedia pictures

Some Current Meter-Class scopes

- Ritchey–Chrétien telescope
- Hyperbolic primary and a hyperbolic secondary mirror, wide SA and coma-free image
- Keck 10-m

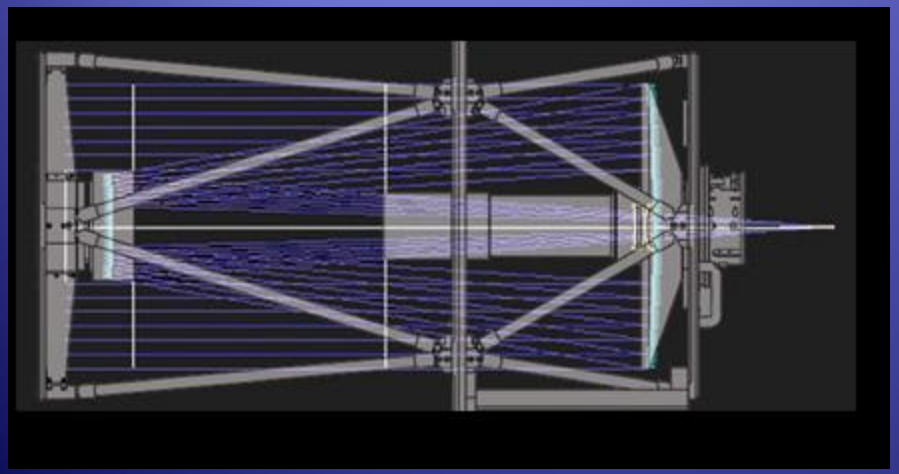




USNO 40-in

Corrected Dall-Kirkham

- No coma, astigmatism, field curvature
- Astrograph- very wide FOV



Source: planewave.com

PlaneWave CDK700 0.7-m

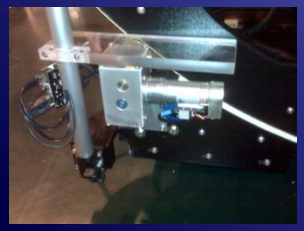
Great Red Spot

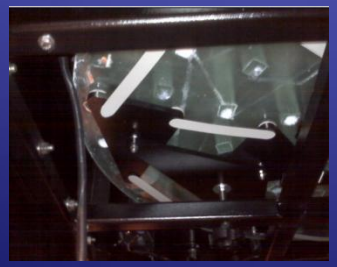
- 40-in f/3.6 Newtonian
- 620 lbs
- Forged AL trunions, Baltic birch rocker and mirror box
- 27-point cell, Lockwood mirror
- $59k USD

Jupiter 40-in at NEAF

Orion Monster

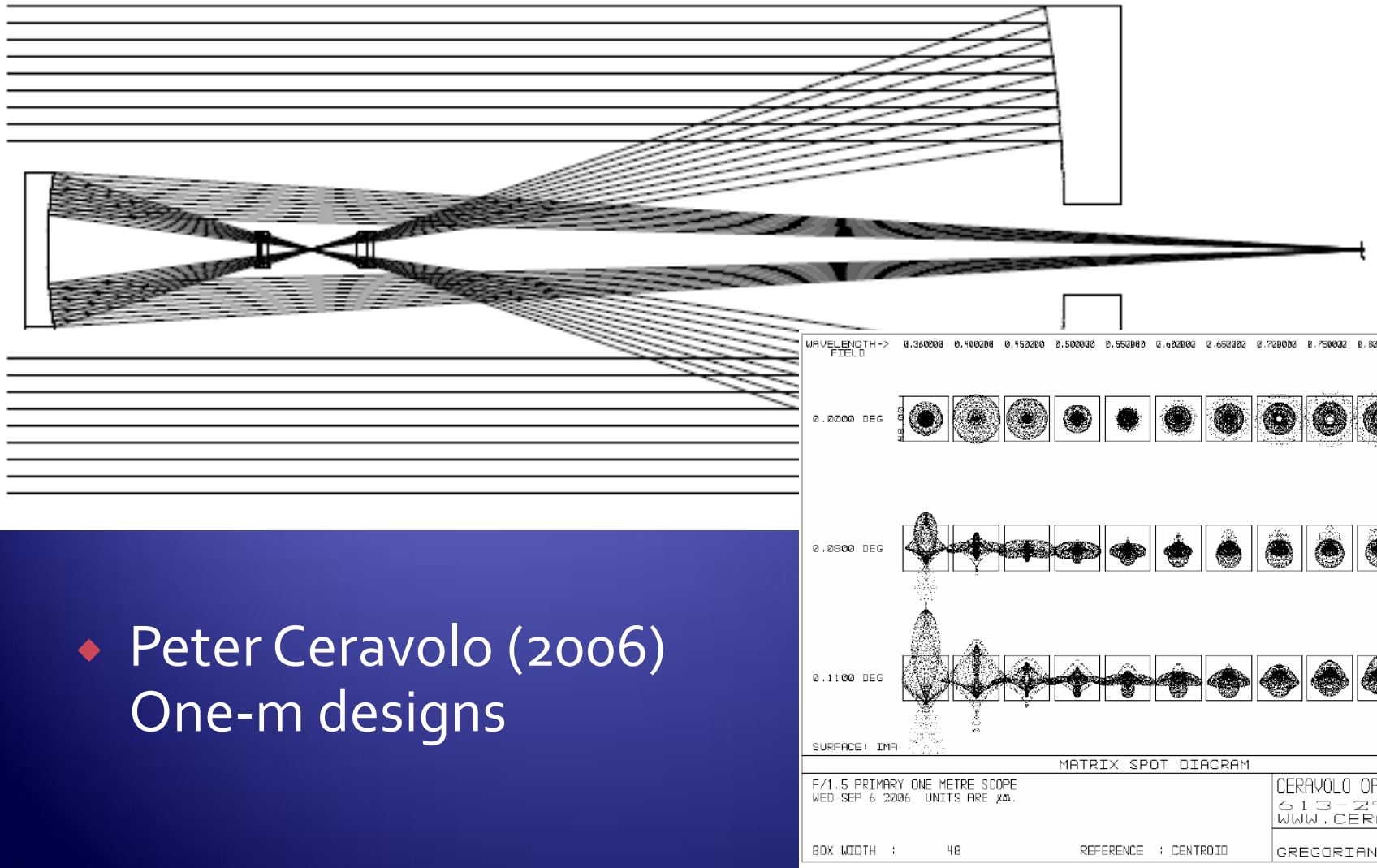
- 36" f/4, 40" f/4, 50" f/3.75 Newtonians
- 375 to 900 lbs
- Sandwich AL trunions
- 27-point cell
- $55 to 123k USD





Monster 36-in at NEAF

All Spherical Catadioptric Gregorian Designs

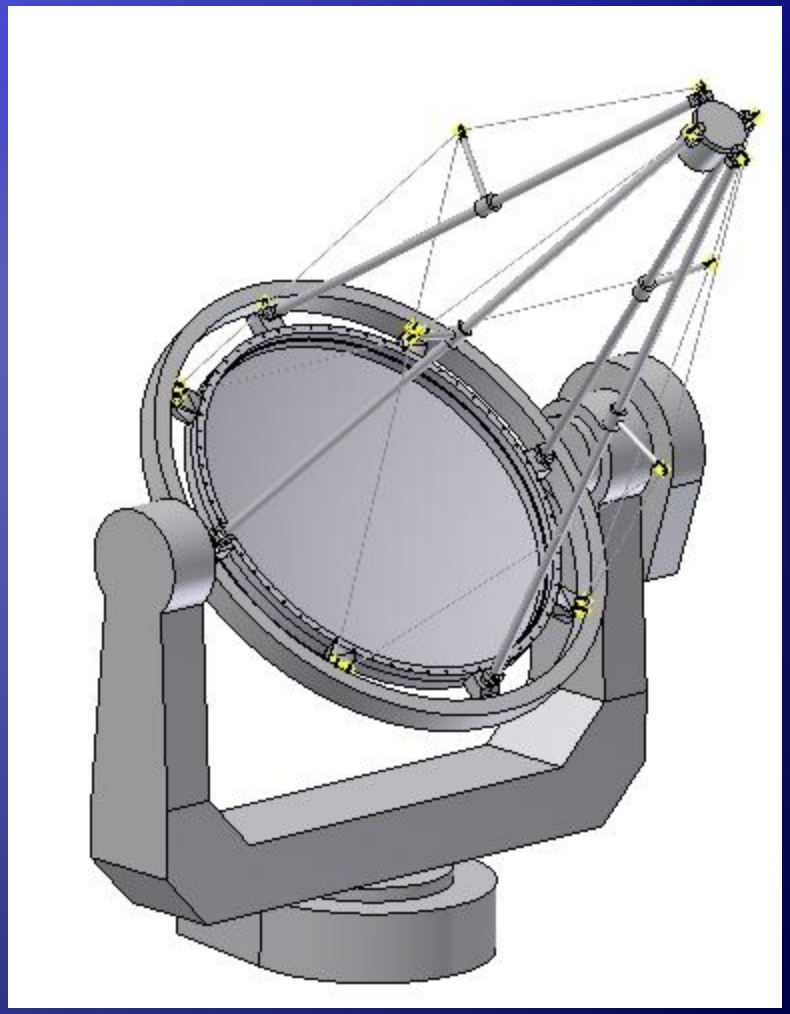


- Peter Ceravolo (2006) One-m designs

Stardust (Big Blue) 1-m f/4

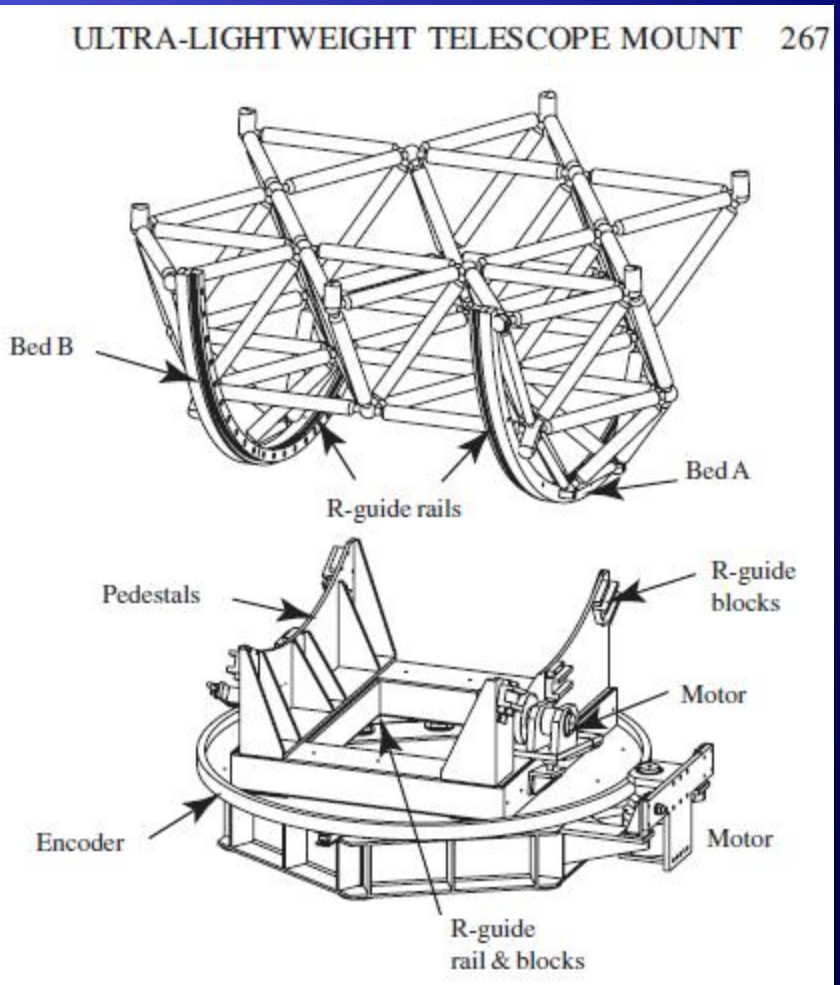
Pneumatic Mylar LBTs

Gravic 42" f/2



1.6-m f/2 concept

2.5-m Ultra-lightweight

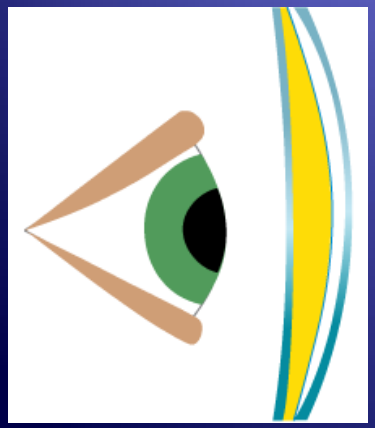


5 ton, f/2

Kurita et. al. PASP 2009 121:266

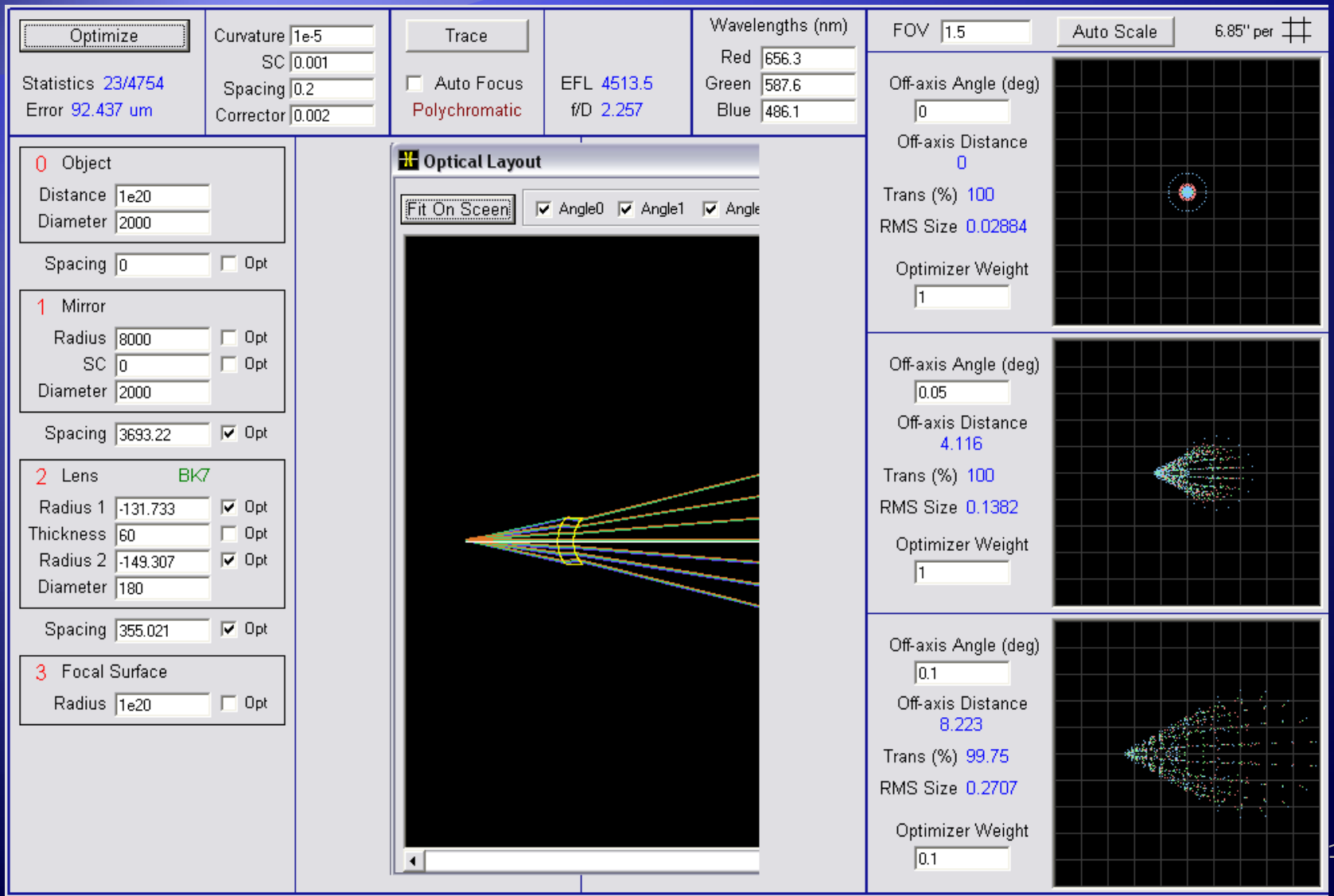
Meter-Class Correctors

- Spherical Aberration
  - Custom spherical surfaces
  - Aspherics
- Astigmatism
  - Low-cost "eyeglass" lenses 75-mm astigmatism correctors

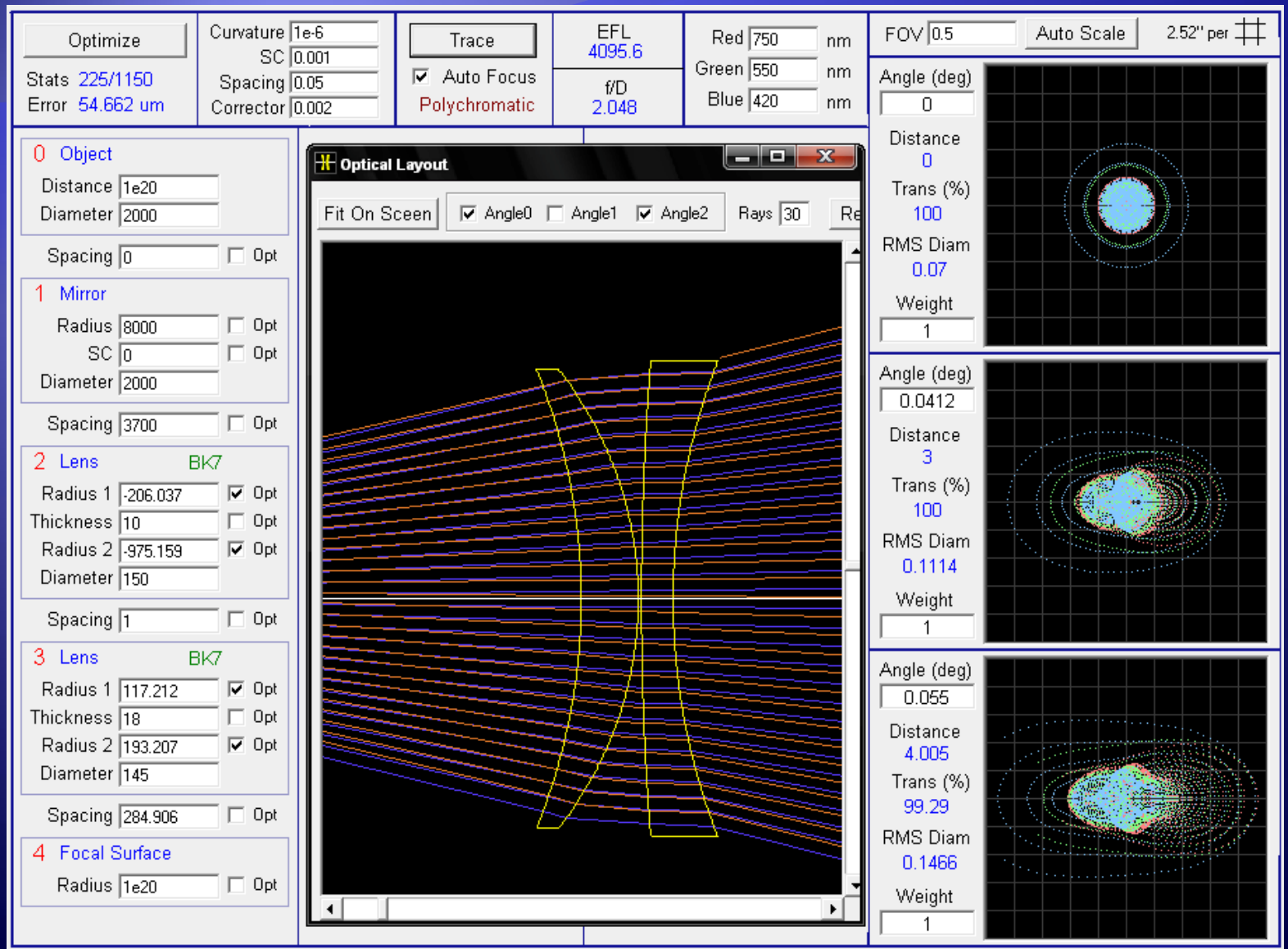


TruFocals liquid filled

2-m One Element Corrector



Dave Rowe's 2-m Corrector



Silvering and Overcoating

- Vacuum AL
  - OTF Designs 60" chamber
  - Transport to facility
- Polished AL
- Cold Silver
  - Peacock Labs
  - Overcoat – Permalac, Sol-Gel, Nanopool

Technical Support Package

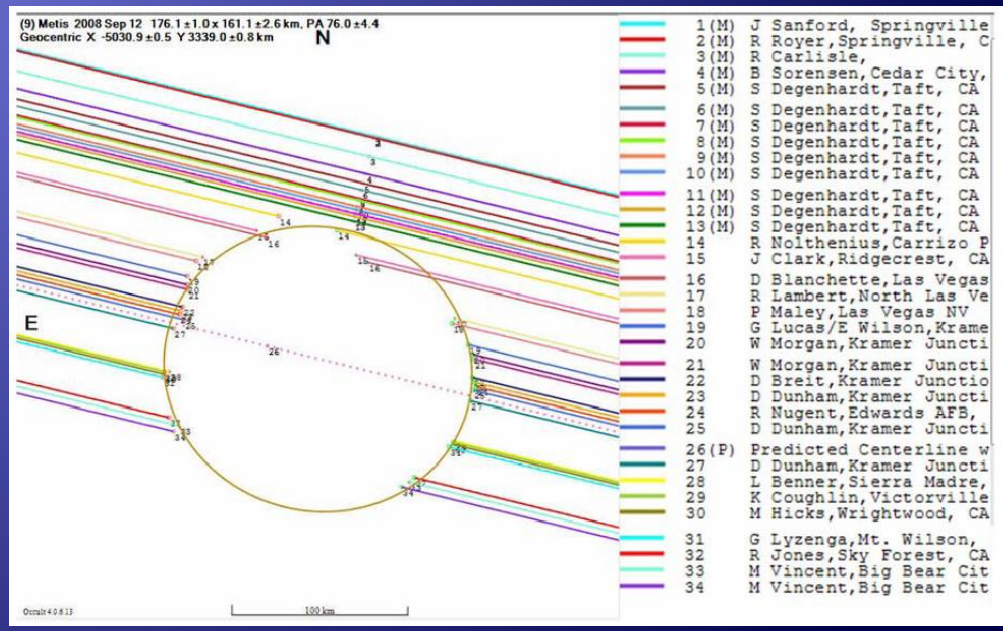
Process for Polishing Bare Aluminum to High Optical Quality

NASA Tech Briefs
GSC-14147

Telescope Arrays

- Fairborn Observatory
- Federated
  - IOTA arrays
  - World Telescope
- Dedicated Arrays
  - Cherenkov Radiation
  - Solar
- Future types
  - Alt-Az Initiative Goals

Source: fairobs.org



IOTA 2009 Newsletter (Metis)

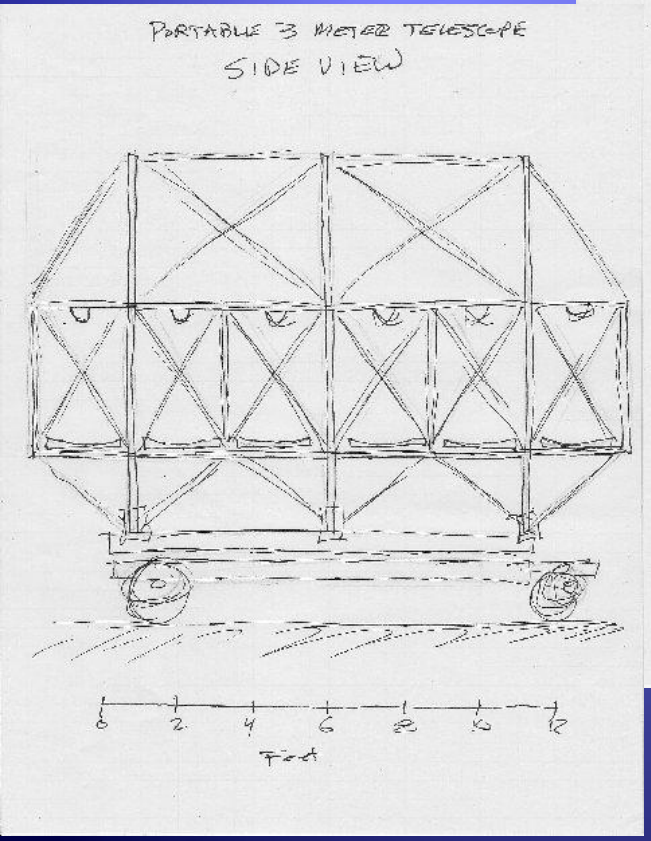
Multiple Mirror Scopes

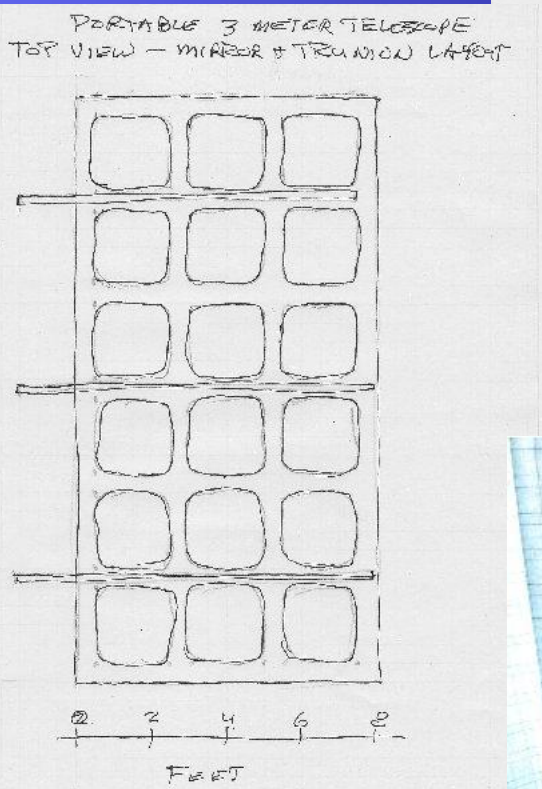
- Keck example: Two 10-m
- Large LBTs may need multiple spherical mirrors to keep down costs
- Various tradeoffs.
  - e.g. Fiber feeding central detector vs. individual detectors

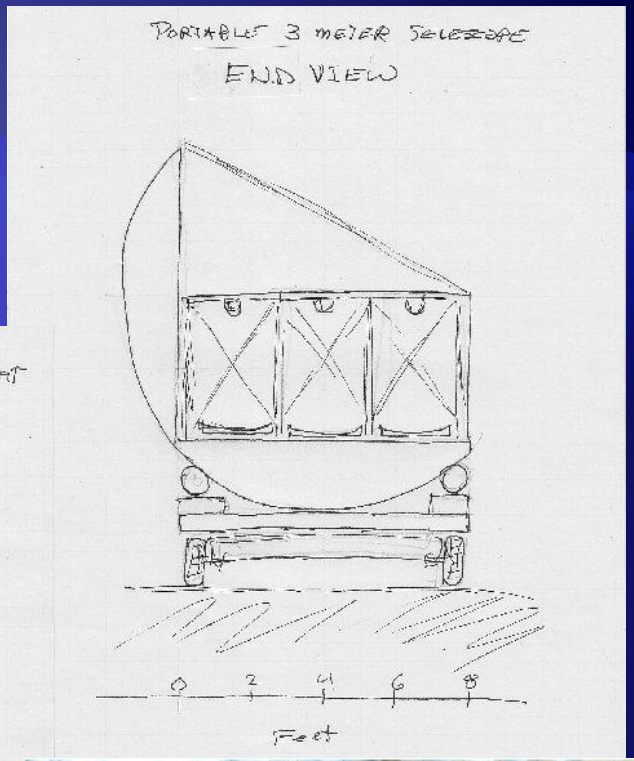
Synergy with Solar?

LPI-Solar

Russ Genet's 3-m Concept







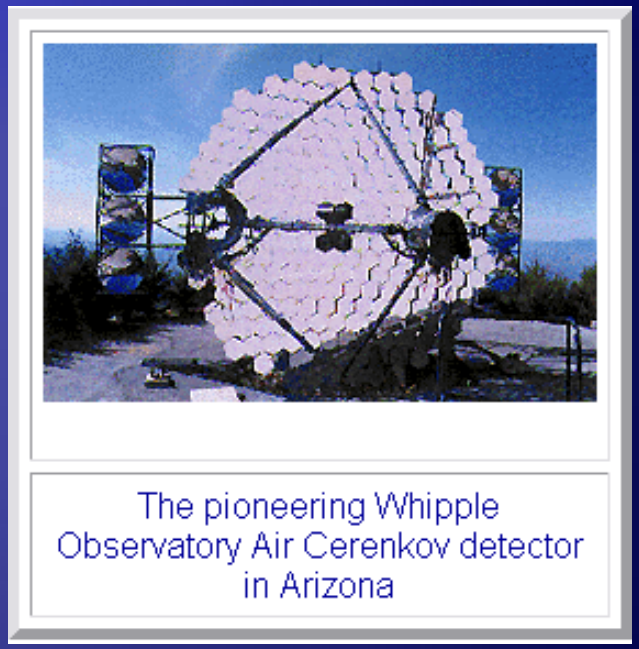
Primary Sol Focus mirrors. 2 mm thick. They make 6000 a day.
Idea is to have an array of these each feeding a fiber.
The fibers come together for the sensor.

Cherenkov Radiation Arrays

The VERITAS Array

Veritas Four 12-m

MAGIC 236-m² carbon fiber frame, 50-cmx50-cm



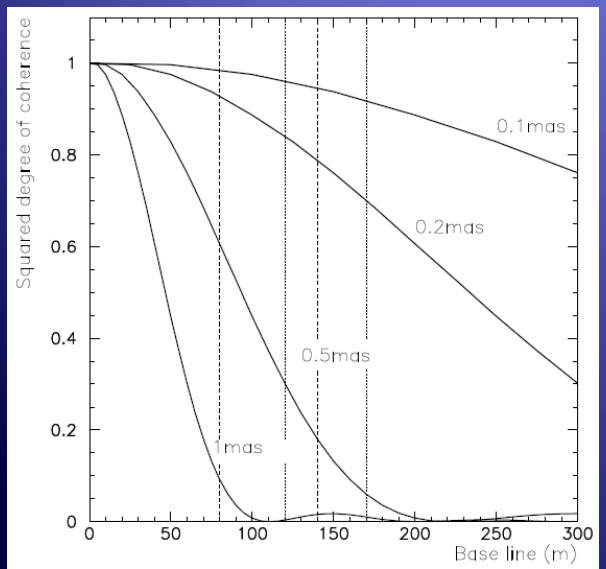
The pioneering Whipple Observatory Air Cerenkov detector in Arizona

gsfc.nasa.gov

FUTURE: **The Cherenkov Telescope Array (CTA)**
10,000-m²

Stellar Intensity Interferometry Revival

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



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.

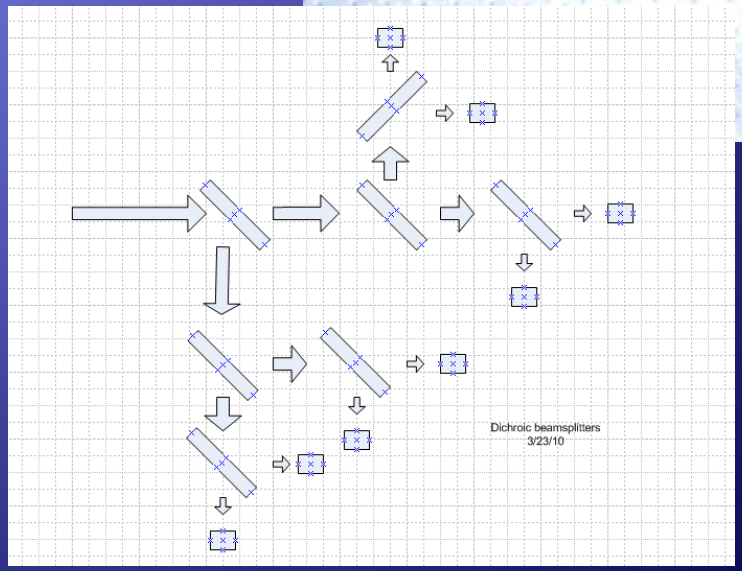
$$SNR_{Overall} = \left[\binom{N_{Array}}{2} N_{Channels}\right]^{1/2} SNR_{Hanbury\ Brown}$$

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
- NVIDEA CUDA GPU for photon correlation



8-band dichroic beam splitter

Future experiments

- Oriel M125 Spectrograph (1/8 m) vs. dichroics

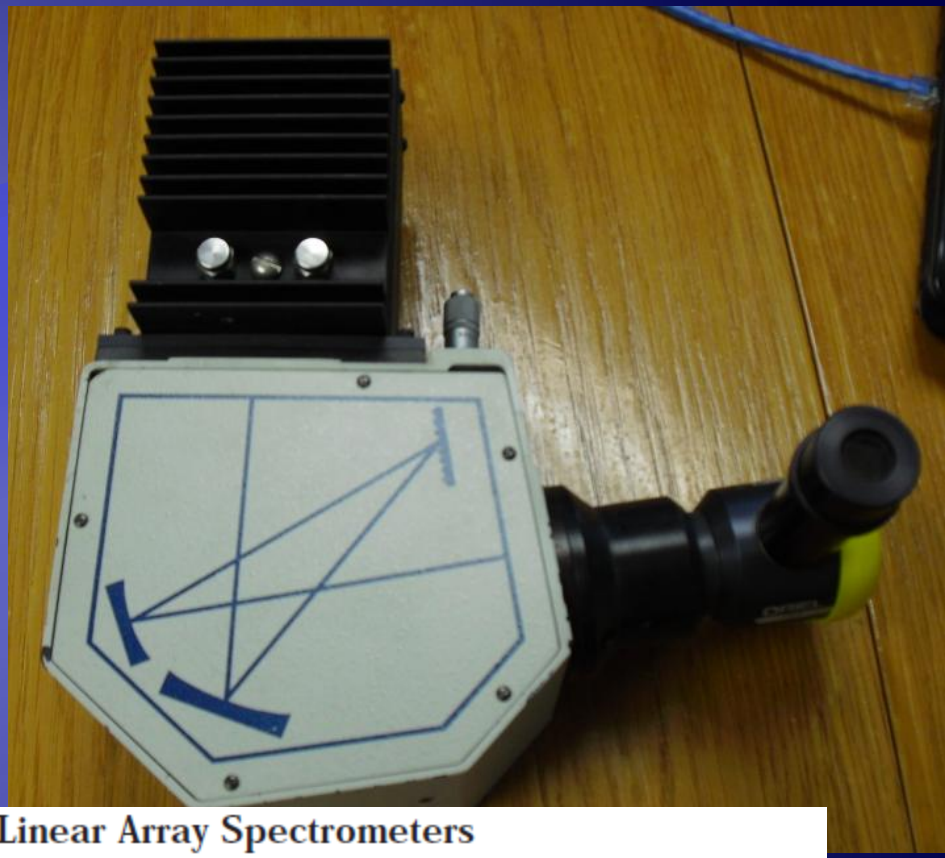


Table 1 Grating Options for LineSpec InGaAs Linear Array Spectrometers

Line Density (l/mm)	Blaze Wavelength	Type	Spectral Resolution (nm)*	Array Bandpass (nm)*	Primary Wavelength Region (nm)**	Grating Model
1200	1000	Ruled	0.44	160	550 - 1600	77463
1200	750	Ruled	0.44	160	450 - 1000	77412
600	1000	Ruled	0.86	338	600 - 2500	77465
600	1250	Ruled	0.86	333	750 - 2000	77455
600	1600	Ruled	0.86	325	900 - 2000	77456
400	1600	Ruled	1.3	505	900 - 2900	77457
300	1000	Ruled	1.72	675	575 - 2500	77458

* Measured with 10 µm x 2 mm slit and 512 array detector.

** The primary wavelength region is where the grating efficiency is ≥20%. System efficiency will also be affected by the reflectivity of the spectrograph's mirrors and the grating angle, at any wavelength.

Newport
Experience | Solutions

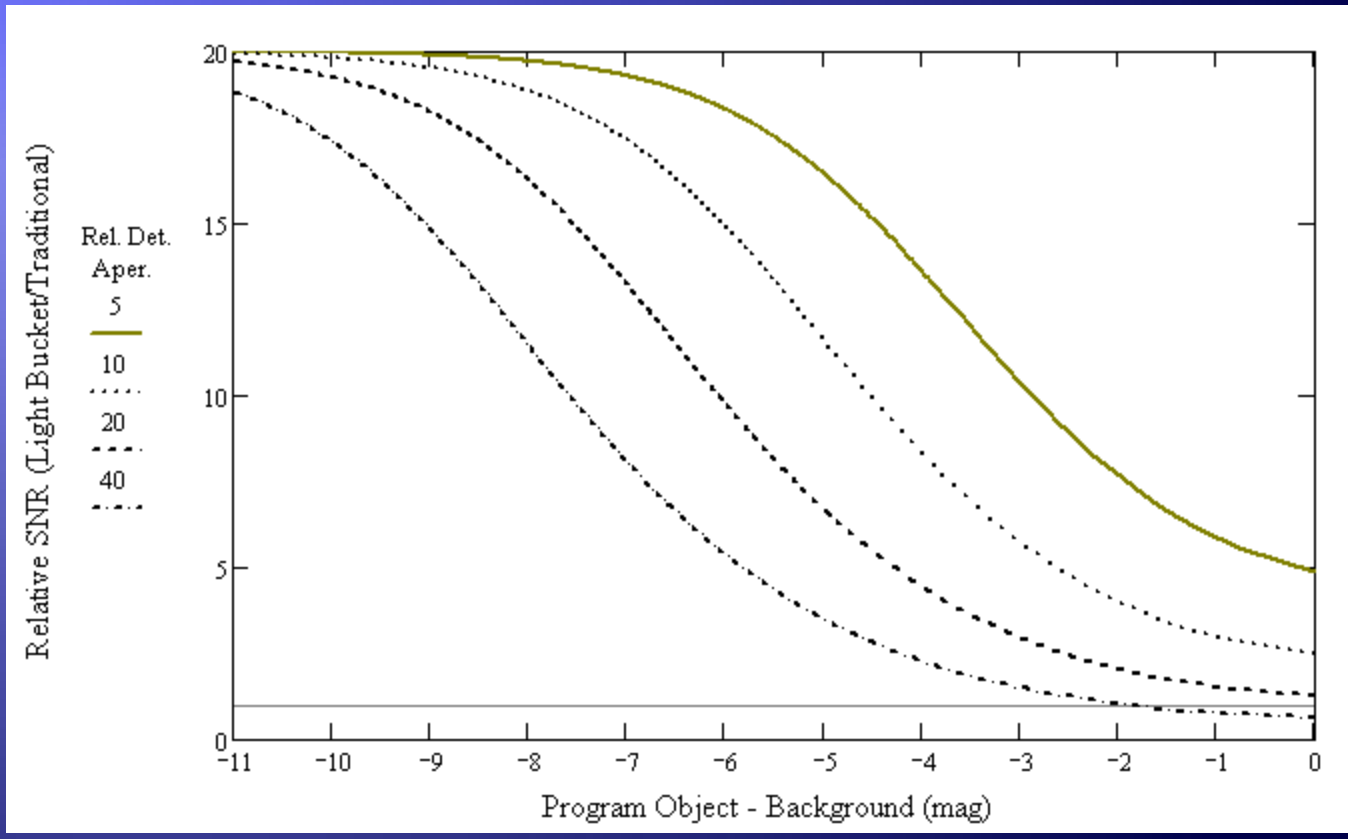
OSETI

- Optical SETI version of the Allen Telescope Array
- Active groups at Columbus, Princeton, Harvard, Berkeley & others

ATA on Wikipedia

Giant (Space-Based) LBTs

- Webb 25-m²
- Giant Light Bucket 500-m²
- Four relative apertures sizes
- No scintillation
- Shot noise only
- Gossamer structure?



Contact

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- Initiative Website - www.AltAzInitiative.org
- Yahoo Discussion Group - http://groups.yahoo.com/group/AltAzInitiative

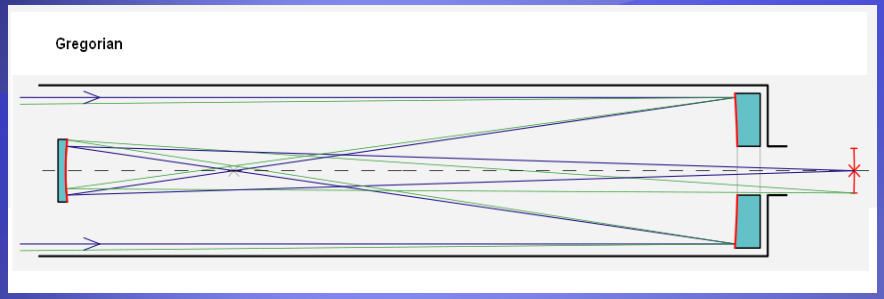
More details:
The Alt-Az Initiative: Telescope, Mirror, & Instrument Developments, eds. Genet, Johnson, & Wallen, (Payson, AZ: Collins Foundation Press) 2010

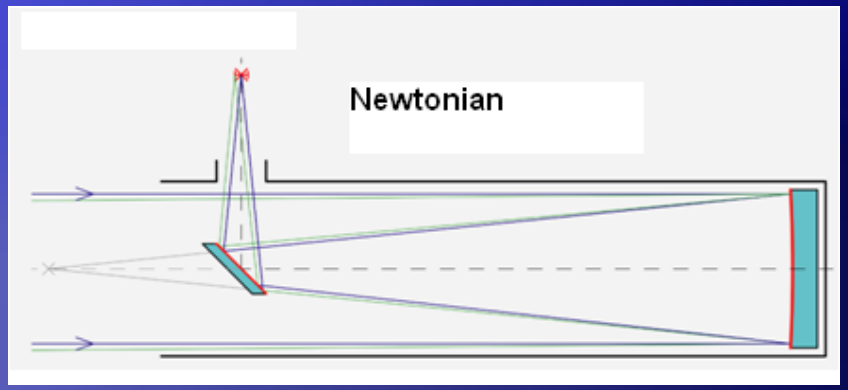
Utility slides follow

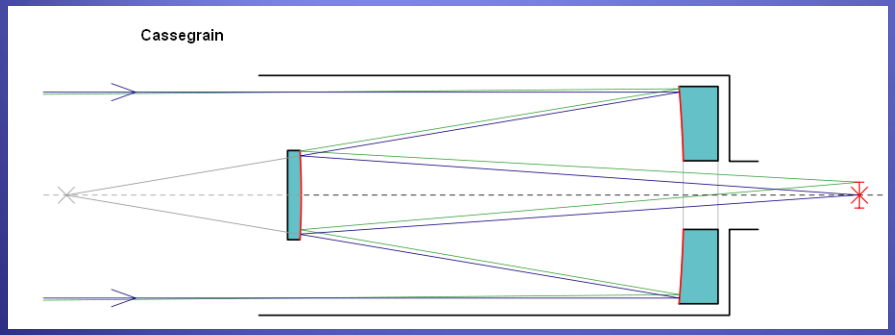
Some Terminology

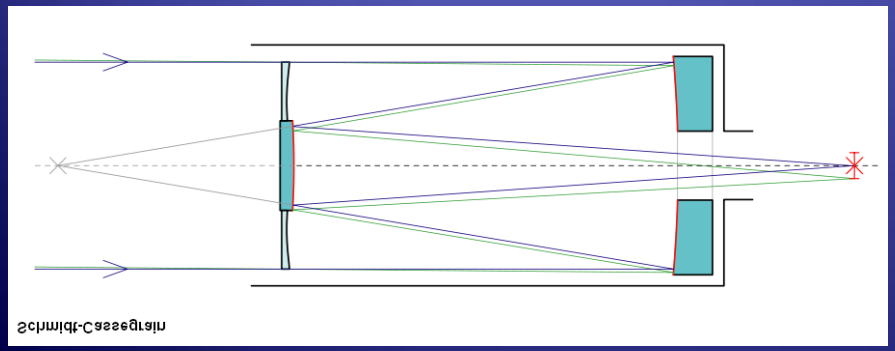
- Optical Tube Assemblies (OTAs) types
  - Newtonian, Cassegrain, SCT, Dall-Kirkham, Corrected DK, Nasymth focus
- Mounts & controllers
  - Alt-Az, Equatorial, field rotator, slew, pan, track, periodic error
- Nomenclature
  - F/#, back focus, vignette, PSF, spherical aberration, astigmatism, Zernike, …

Some OTA Types









Source: Wikipedia