Stars, Companions, and their Interactions
A Memorial to Robert H. Koch

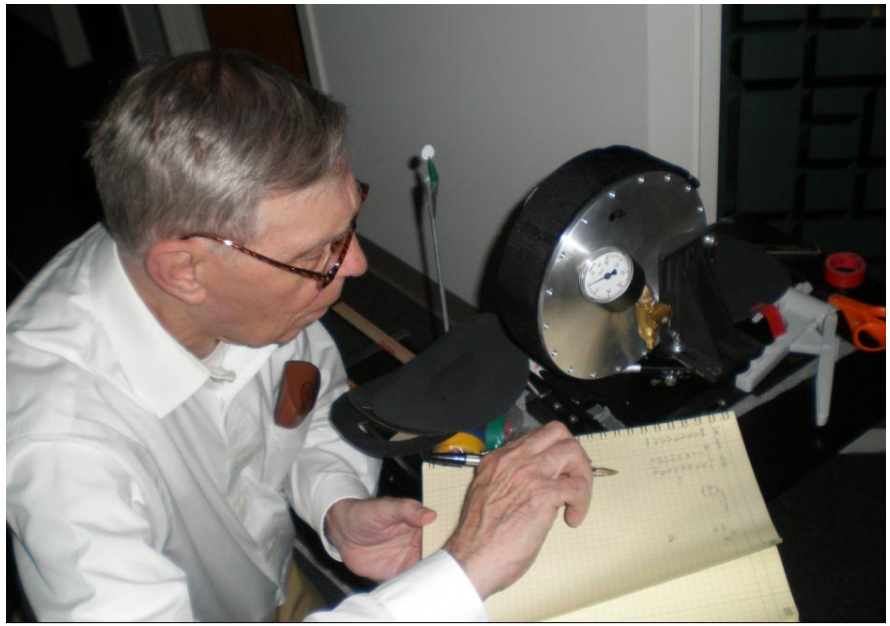
August 10-12, 2011 Villanova, PA USA

Robert H. Koch's Work on Medium Aperture Mirrors

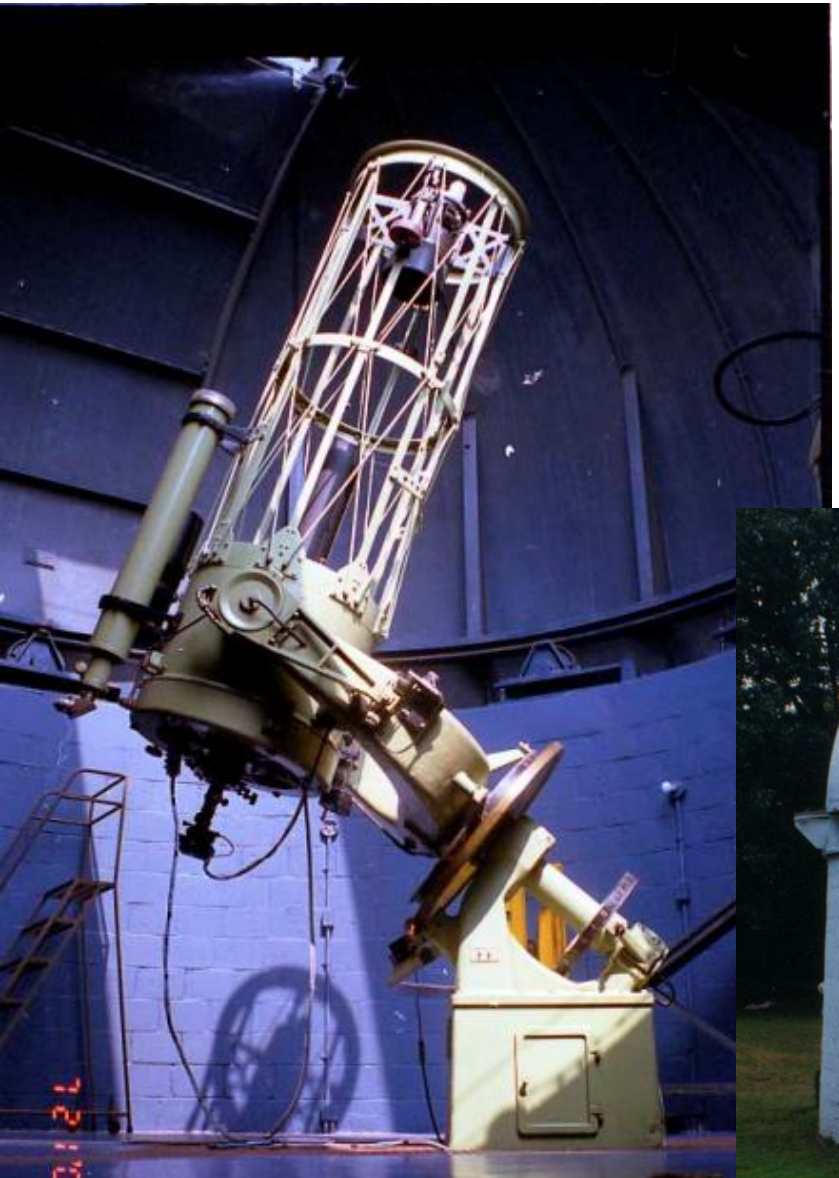
Bruce D. Holenstein and Richard J. Mitchell
Gravic, Inc.

Agenda

- Background
- Early efforts 1991-1996
- Recent efforts 2006-2010
- Some Future Plans



Background



- FCO housed a 28-in. Cassegrain & 15-in. Siderostat
- Had oversized dome
- RHK had a long-term interest in a bigger primary mirror

Early efforts 1991-1996

1991 Peter Waddell demoed small pneumatic cell at Penn

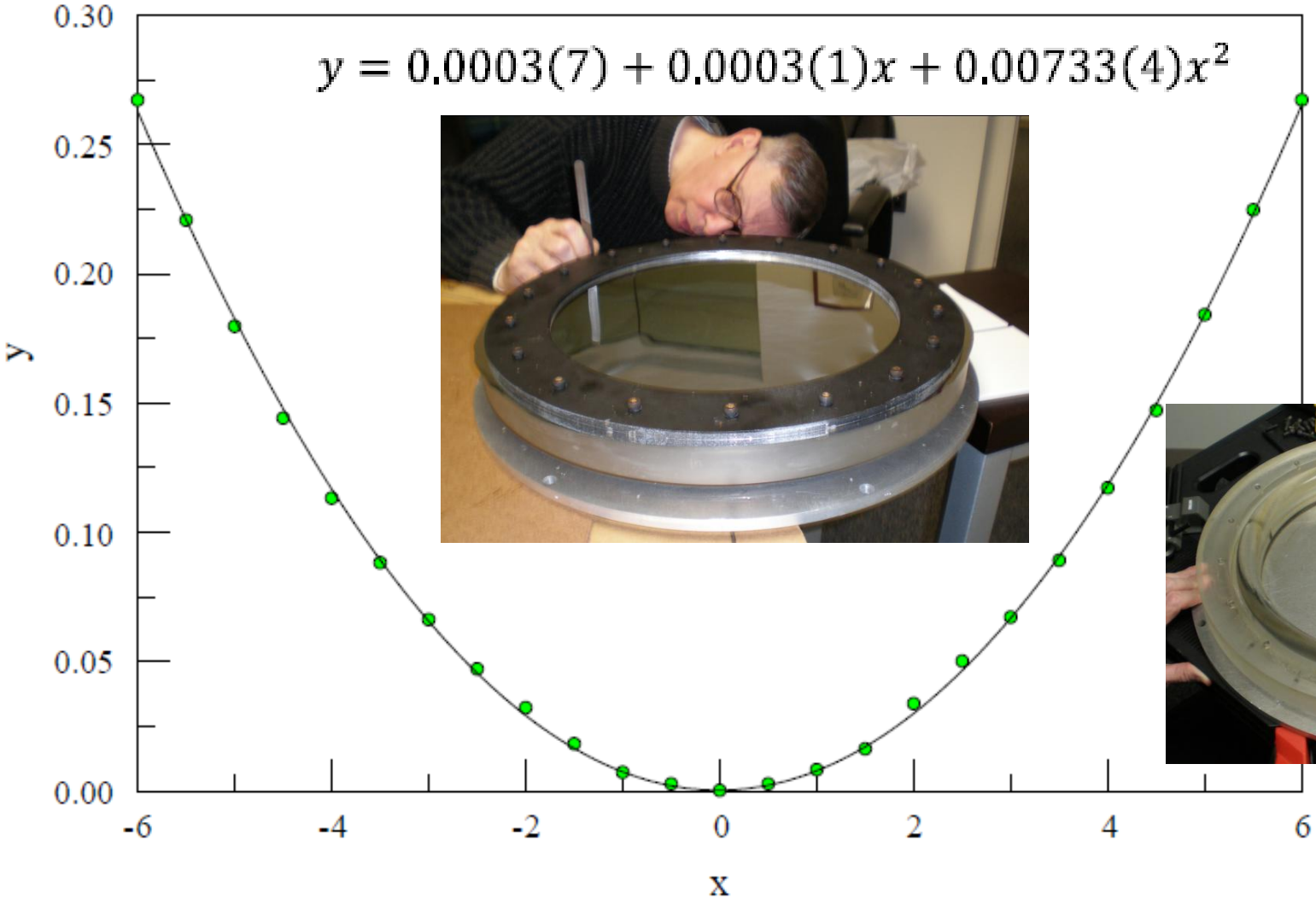
Peter Waddell
SPIE *OE Magazine* Oct. 2001

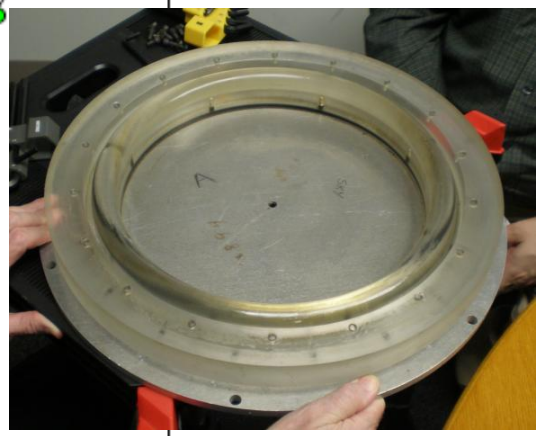
Modern photos of early Penn cells and CF scope

Robert Hee (machinist), RJM (electro-optics), RHK and Samuel Seeleman (optics) plus grad students

Figure for 12-in Penn Cell #2

Mylar deflection in inches





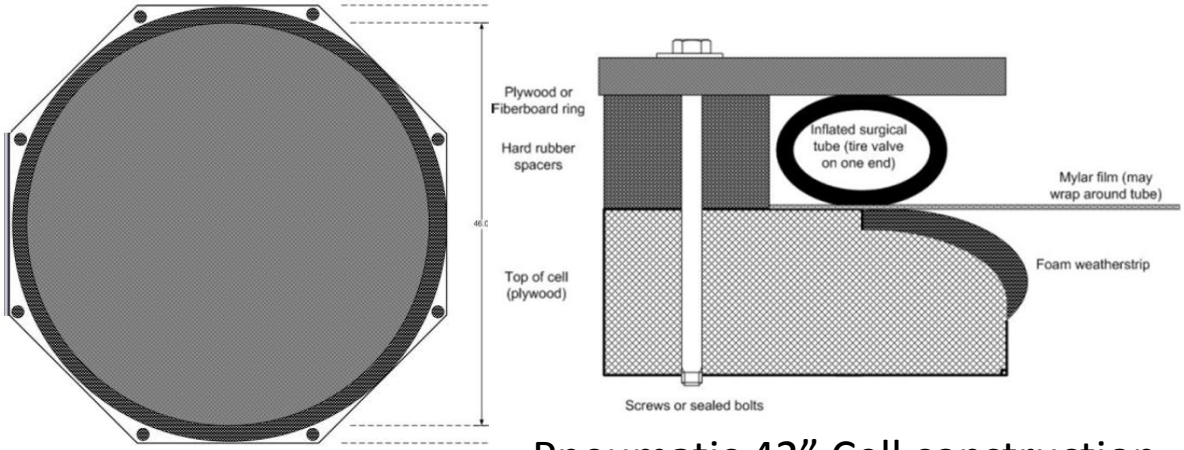
Balloon Flights

NASA's Wallops Island Launch 1995

Recent Efforts: 2006-2010

- 42-in. pneumatic mirror telescope
- Aberration characterization and remediation
- Ancillary technologies
- Future plans

42” Cell Construction

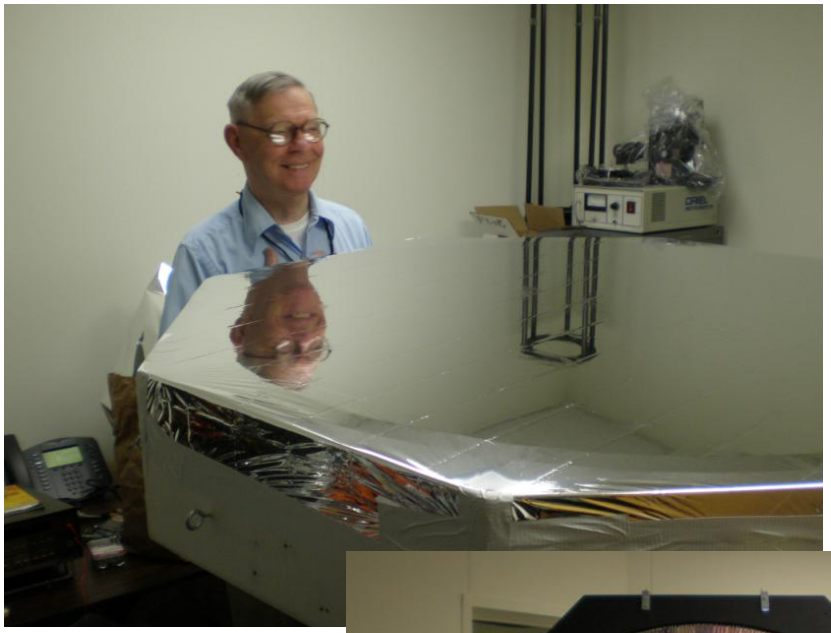


Pneumatic 42” Cell construction

Williamson student carpenter

Rolled Mylar about to be cut

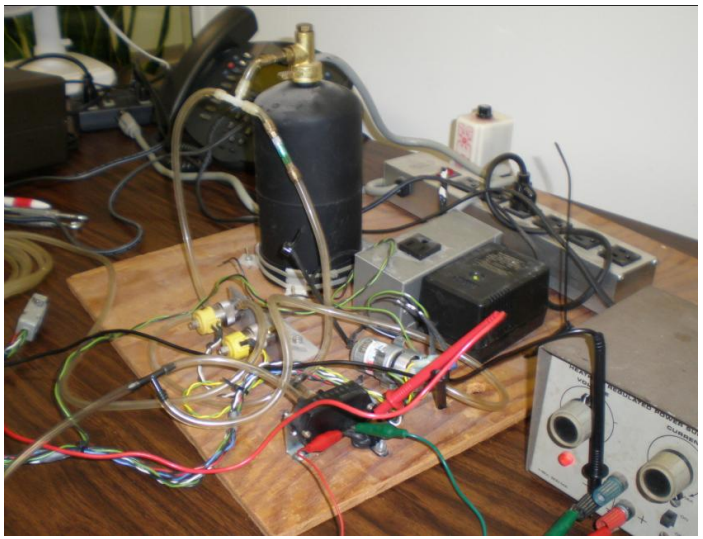
42” Cell Construction II



Good and bad days

Pneumatic Control

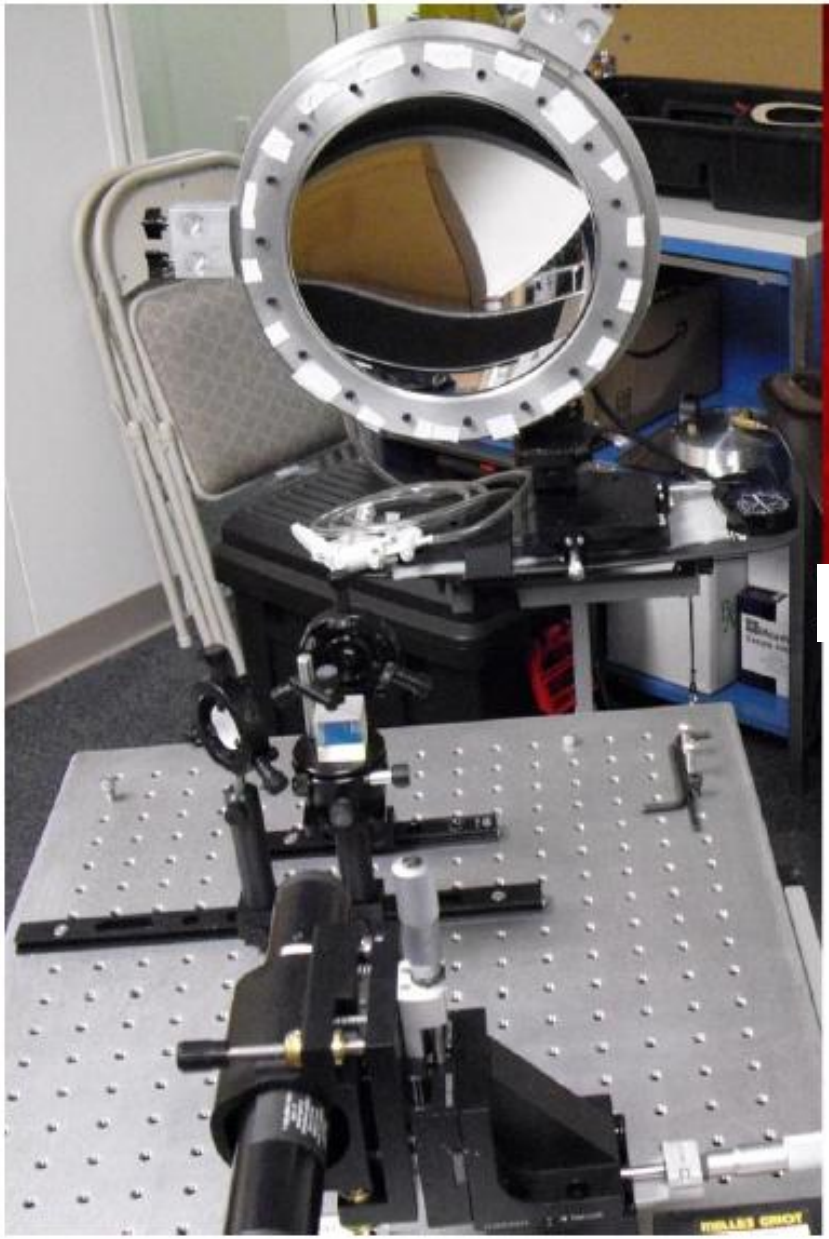
Properly tensioned membrane

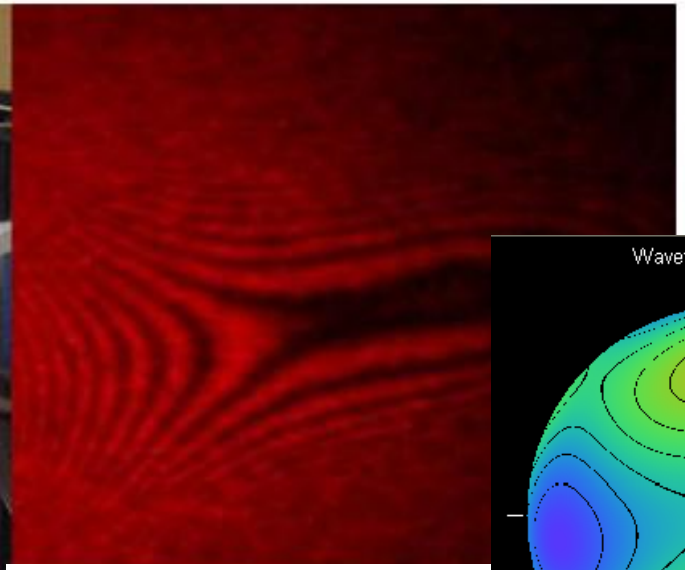


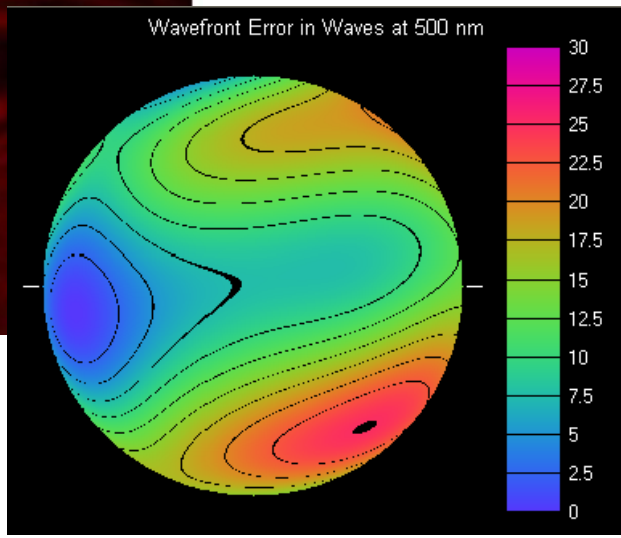
Pneumatic control made with surplus parts

Looking for leaks

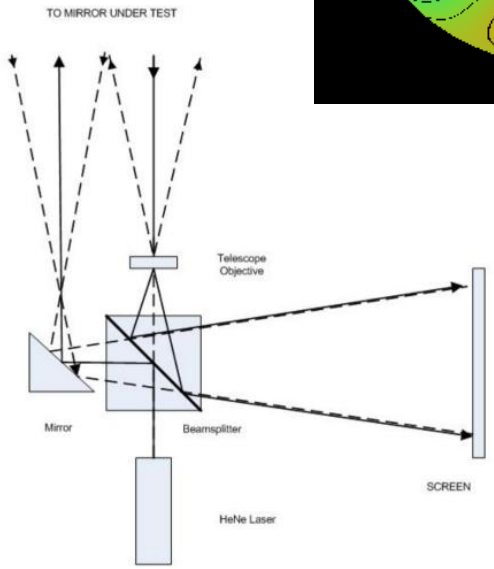
Gauging Progress



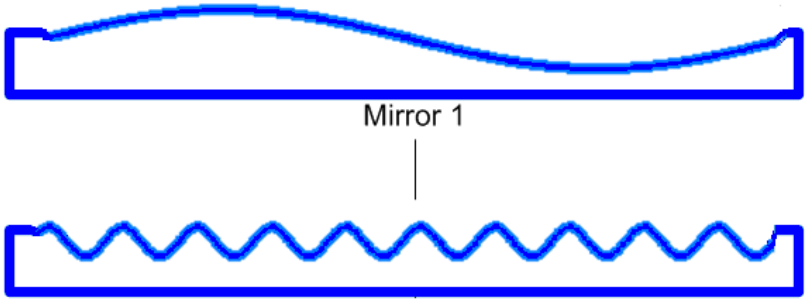




Bath Interferometer



Figures of Merit



P-V and RMS measures are the same for both mirrors!
But, not $|\Delta\varphi|_{rms}$ (rms slope)

Zernike wavefront representation, $W(\rho,\theta)$, is used for the estimation of $\boldsymbol{\sigma}$ and $|\boldsymbol{\Delta\varphi}|_{\mathbf{rms}}$ (rms slope)

1 $$W(\rho,\theta) = \sum_j a_j Z_j(\rho,\theta)$$

2 $$\sigma_W^2 = \langle W^2(\rho,\theta)\rangle - \langle W(\rho,\theta)\rangle^2 = \sum_{i=2} a_j^2$$

3 $$\boldsymbol{\nabla} W(\rho,\theta) = \frac{\delta W}{\delta \rho}\boldsymbol{e_\rho} + \frac{1}{\rho}\frac{\delta W}{\delta \theta}\boldsymbol{e_\theta}$$

4 $$|\Delta\phi|_{rms} = \frac{\|\boldsymbol{\nabla} W\|_{rms}}{D/2}$$

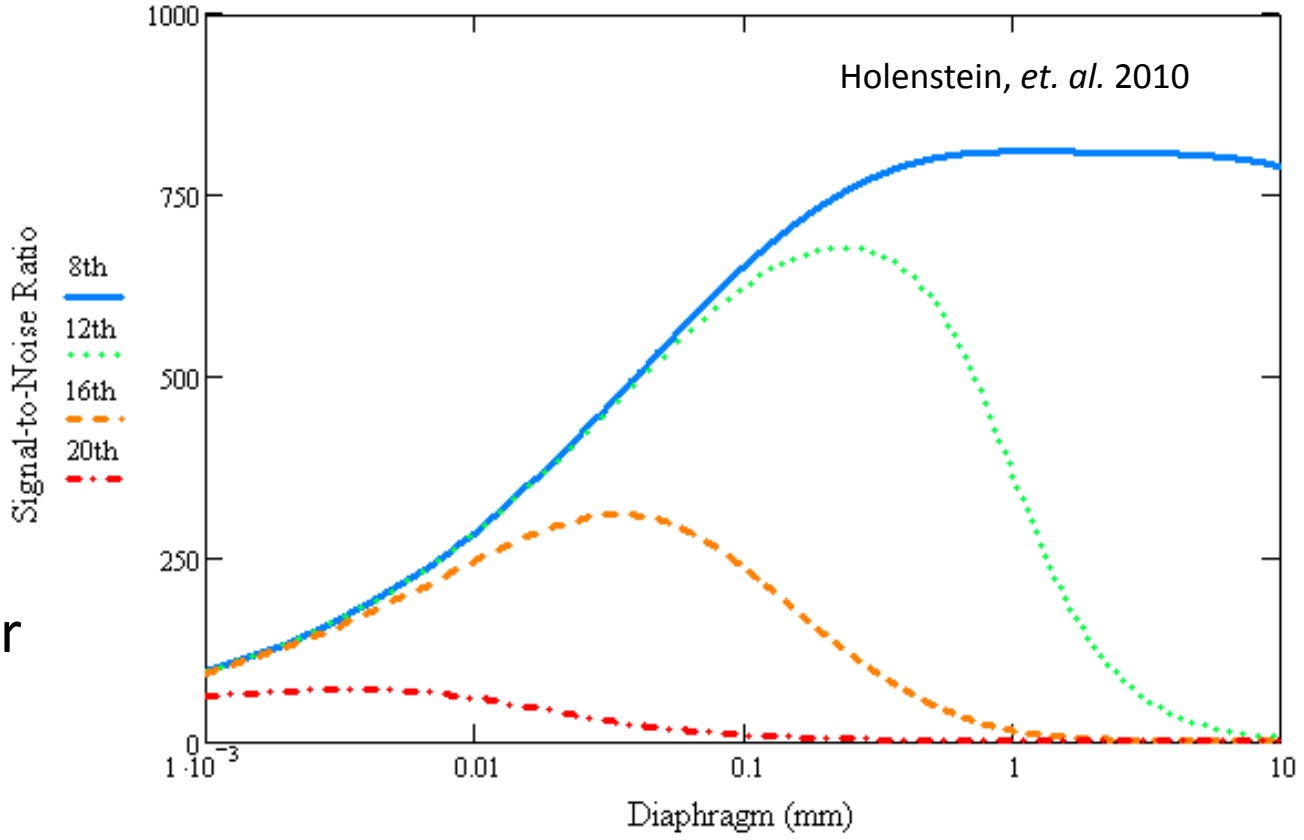
Diameter of CoC from local slope flaws

5 $$d_{CoC,local\ slope}(n') \approx 4n'F\,|\Delta\phi|_{rms}$$

F focal length, and *n*' multiplier determines the encircled flux fraction

Figures of Merit II

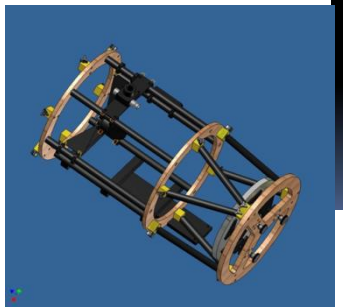
- Local slope aberrations : 10 waves rms gradient norm
- 4 program star cases; *V* = +21 / arcsec squared background
- *f*/1.9, 1.6-m mirror
- Scintillation 1000-m, air- mass 1.5



Mount for 42-in. Cell

Gravic's IPI393 mount at NEAF

l.-r. Rich Mitchell, Bob Koch, Joanne Koch, Kevin Iott Gravic, 2009



Almost completed IPI 262 Mount

PlaneWave Asension 200HR

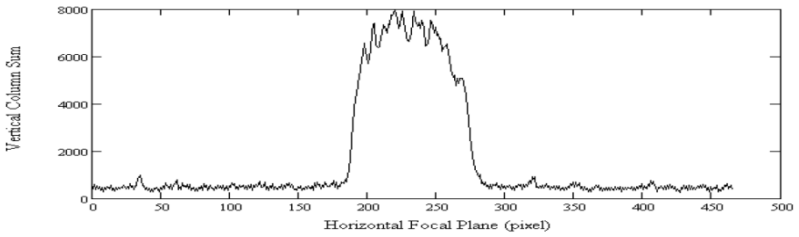
42-in First Light

Pneumatic Mirror Results

42-in. scope with Gravic high-speed photometer

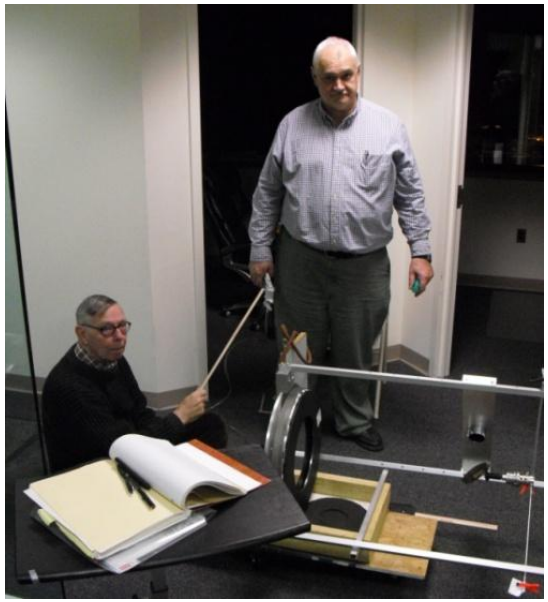
Image of tower shows astigmatism

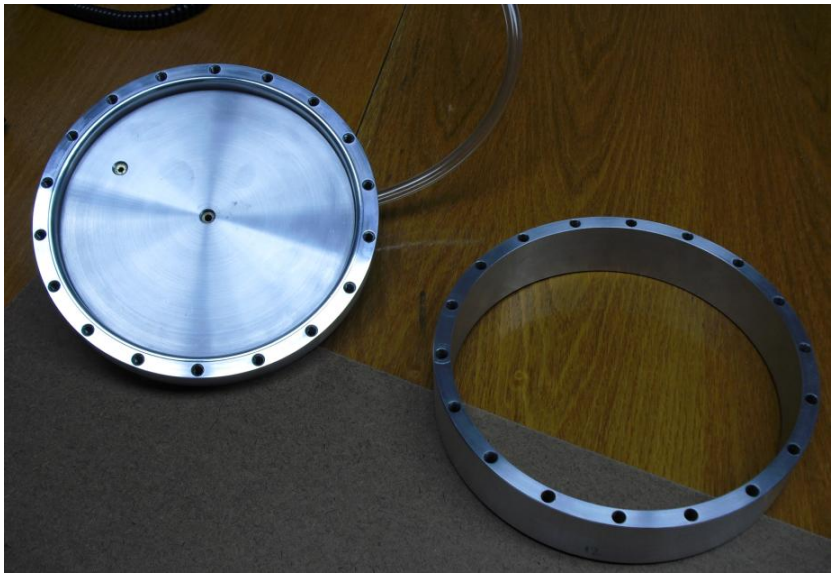
Vega 12-in cell, f/4 w/0.5 FR, 5.0 µm/pixel



Holenstein, *et. al.* 2010

Back to the drawing board



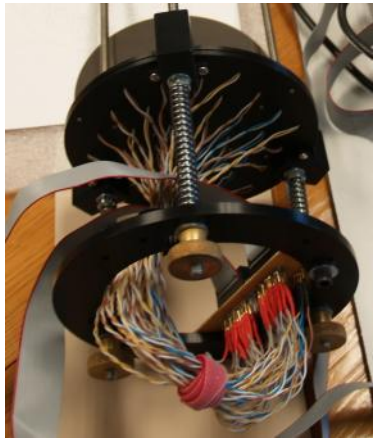


Rim edge and tensioning are critical

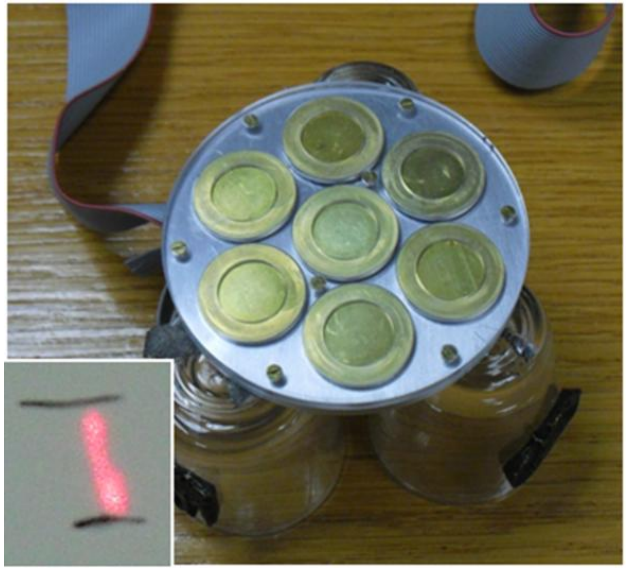
Limit of 1 arc minute PSF was reached with our technology.

Active Mirrors

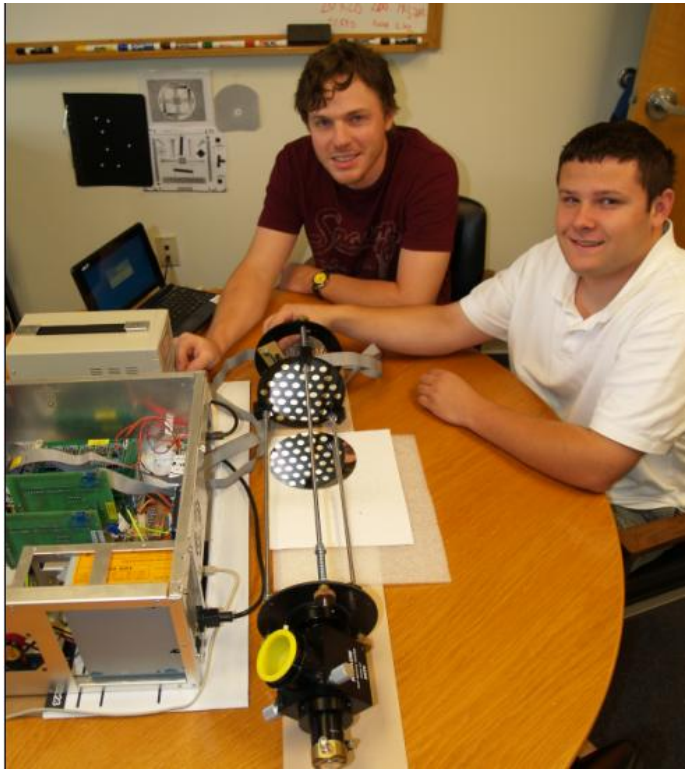
Active secondary mirrors built to conjugate primary aberrations



37-actuator 6-in. diameter design ready for final assembly



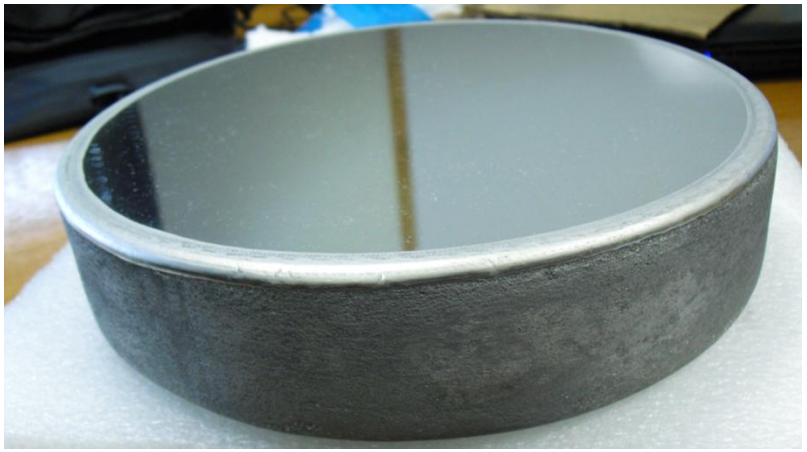
- Unblocked piezo deflection of +/-35 microns over 120VAC
- About 0.2microns/Volt
- 10-g swing +/- 150V



Controller, actuators, high-speed photometer

2011

Alt-Az Initiative Mirrors Considered

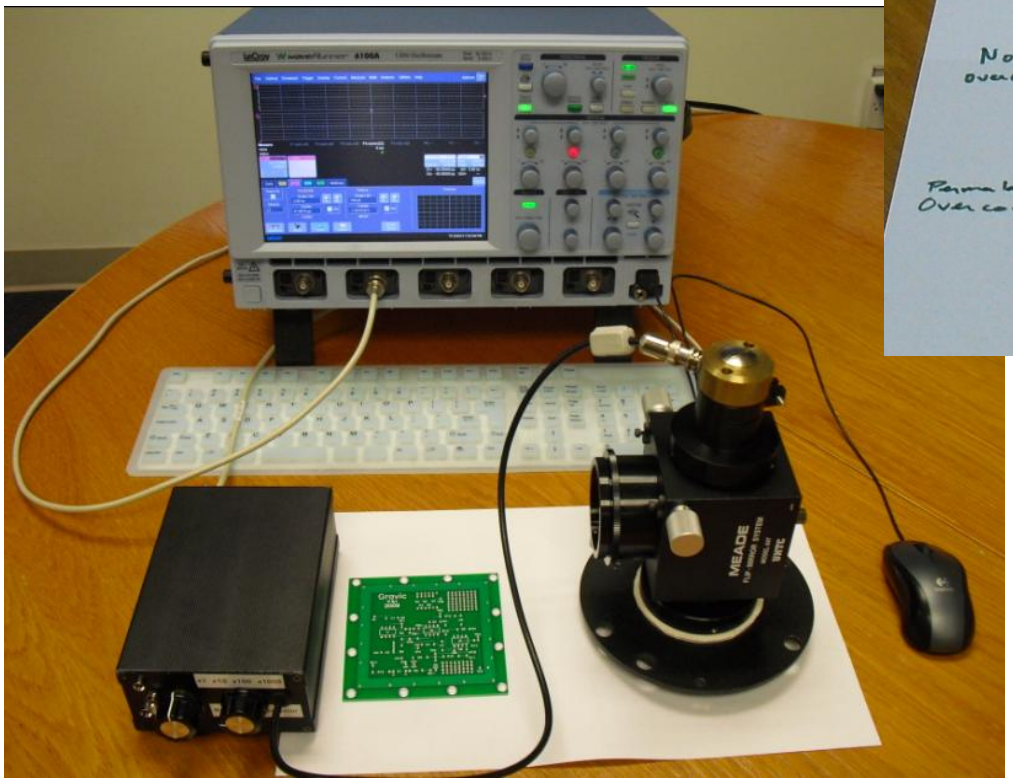


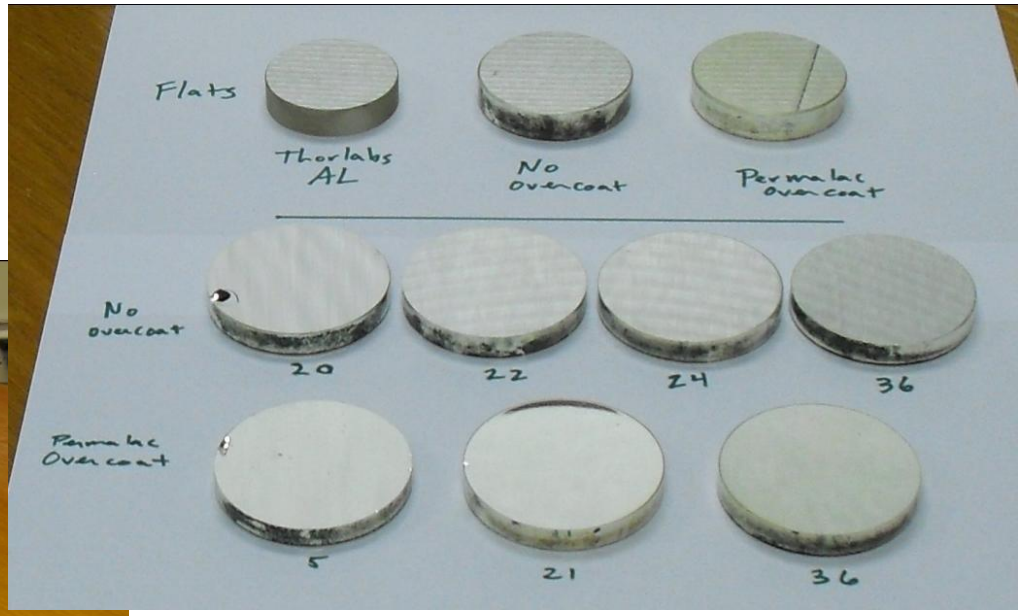
OTF Designs plate glass slumped over foamed glass substrate mirror (8-in.)

David Davis's 60-in. tessellated glass over foamed glass (D.D. with suspenders, Russ Genet with hat)

Related R&D Projects

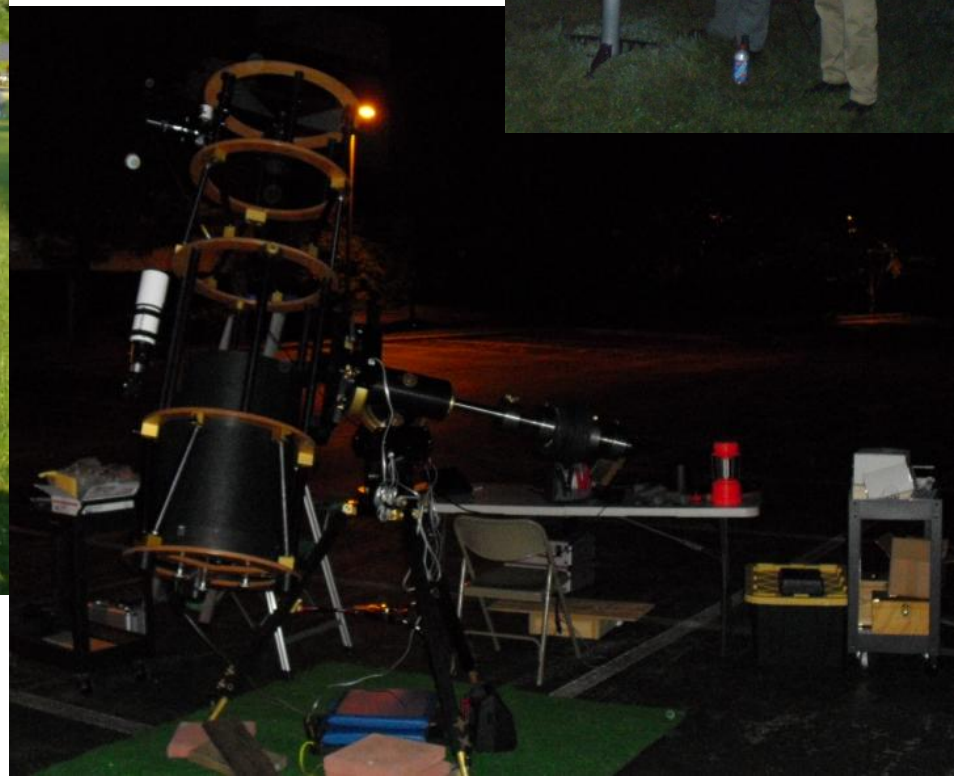
Gravic high-speed TIA and photometer





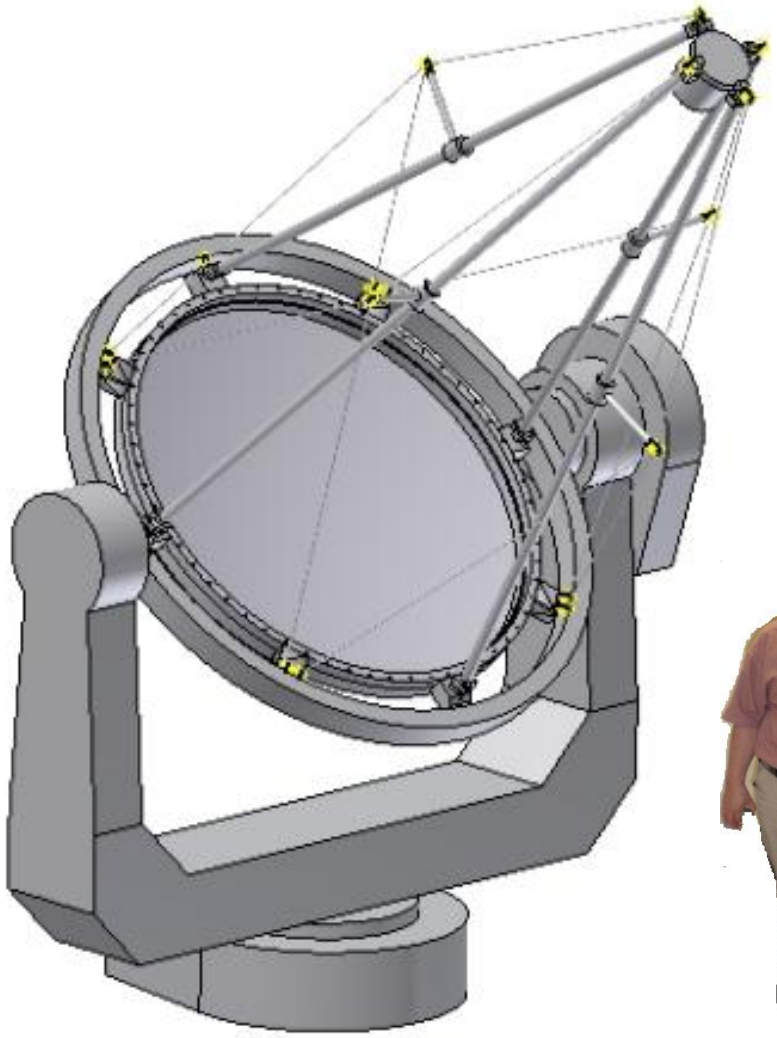
Cold silvering and overcoating experiments

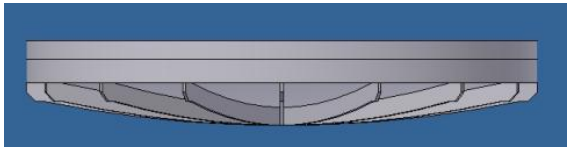
High-Speed Occultations

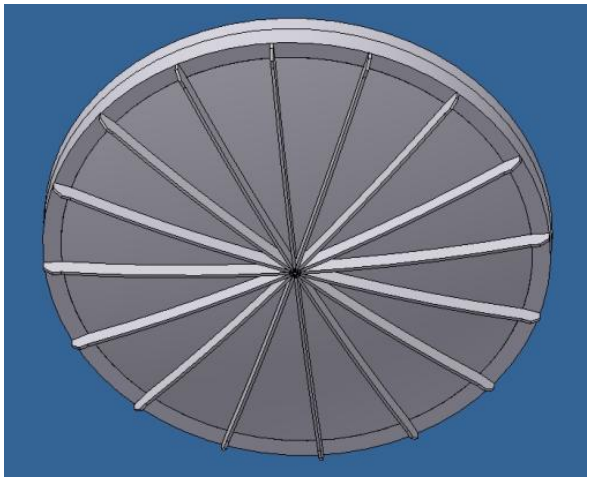


Preparing for Lunar occultation of Antares – June, 2009

1.6-m Alt-Az Design







500lbs OTA, $65k construction cost

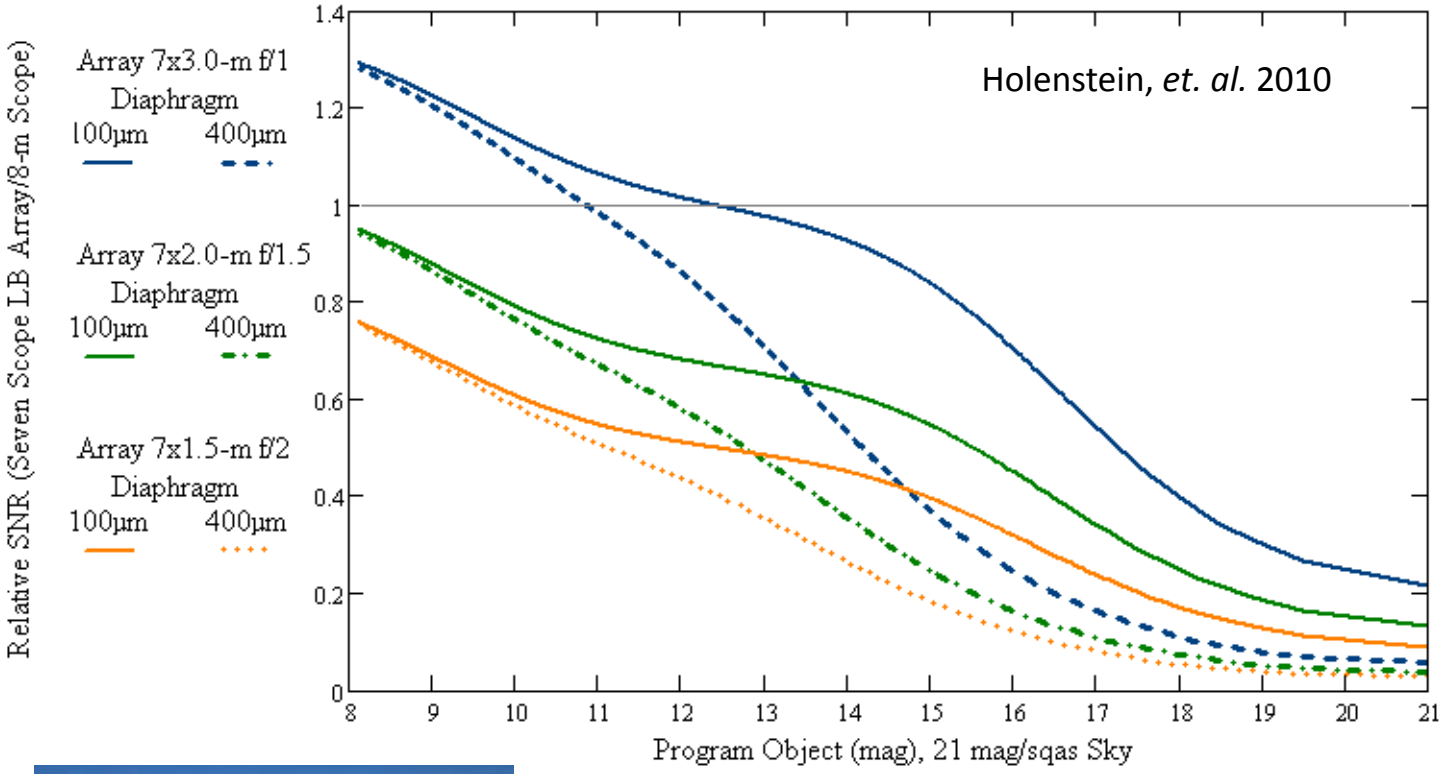
7-Element Arrays vs. Traditional

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

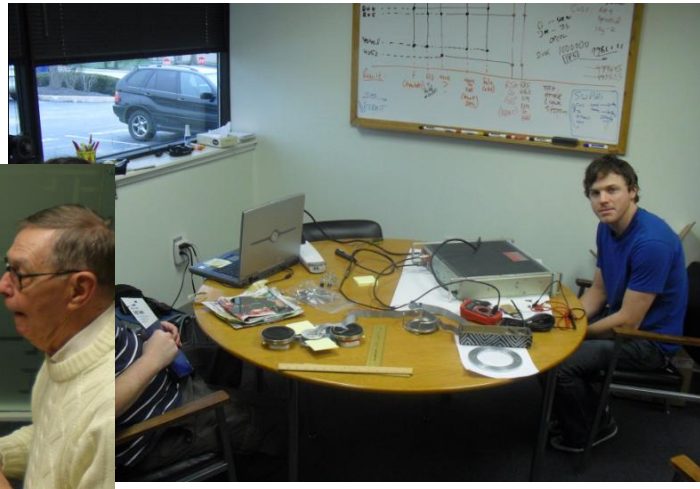
2 relative diaphragm diameters (400, 100 vs 40 micron on 8-m)

Scintillation at 3000-m,

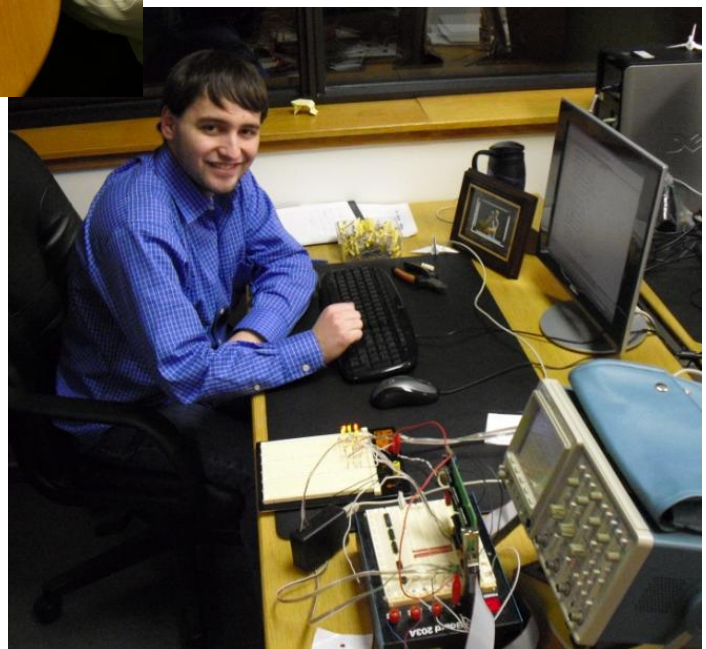
1.5 air-mass



Mentoring



RHK always had time for those just starting out.



Results of Koch's Mirror Work

- Built several medium-aperture, portable telescopes, more in progress
- Methods to characterize light bucket mirror quality - two book chapters & several talks
- Gravic – we built an electro optics lab, authors active in astronomy again
- Plans to build a 7-element array of 1.5-m scopes
- Students mentored