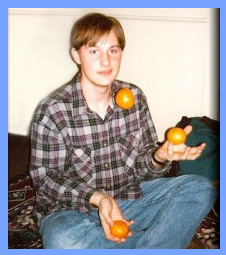
Dynamic Range and Speckle Analysis of Lyot Project/AEOS data

Sasha Hinkley, Columbia University



Collaborators:

Ben R Oppenheimer, Remi Soummer, Anand Sivaramakrishnan (AMNH), Lewis Roberts (Boeing), Jeff Kuhn (IfA), Russell Makidon (STSci), Marshall Perrin (Berkeley), James Lloyd (Cornell), Kaitlin Kratter (Toronto), Doug Brenner (AMNH)

Hinkley et al., ApJ, 654, 633 (2007)

The Lyot Project

•Optimized, diffraction limited classical Lyot Coronagraph.

•Deployed at 3.63m AEOS alt-az telescope on Heleakala. 941 actuator, Shack-Hartmann AO system.

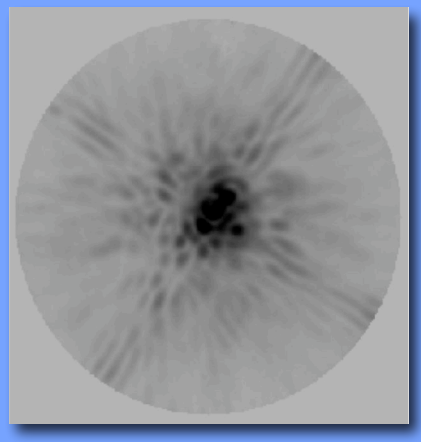
•Survey in J, H, and K_s bands. Dual-channel imaging polarimetric observations to access Q,U, and V stokes images.

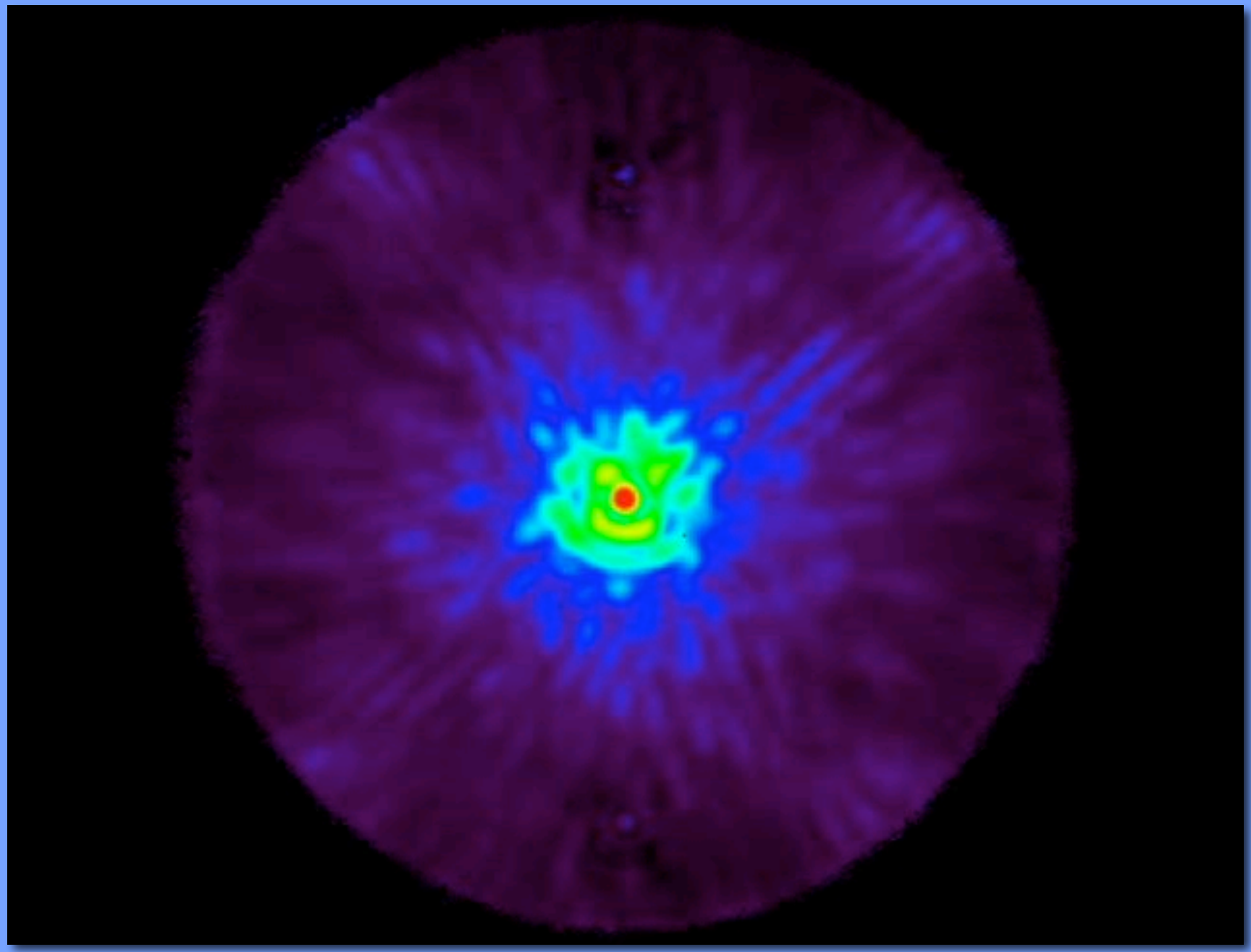
Data set of interest:

•284 coronagraphically occulted, AO-corrected 8s H-band images of Vega taken on 2005 May 14.

•AO loop fully closed, occulted with 4.9 λ/D mask in place.

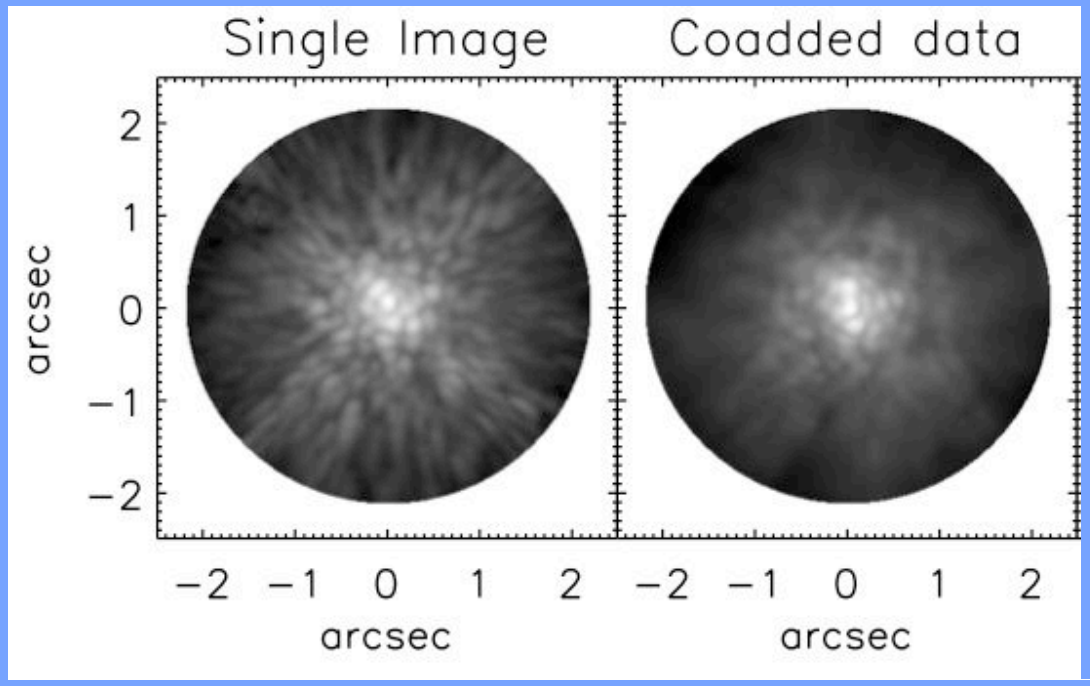
•Images recorded with Kermit IR Camera.

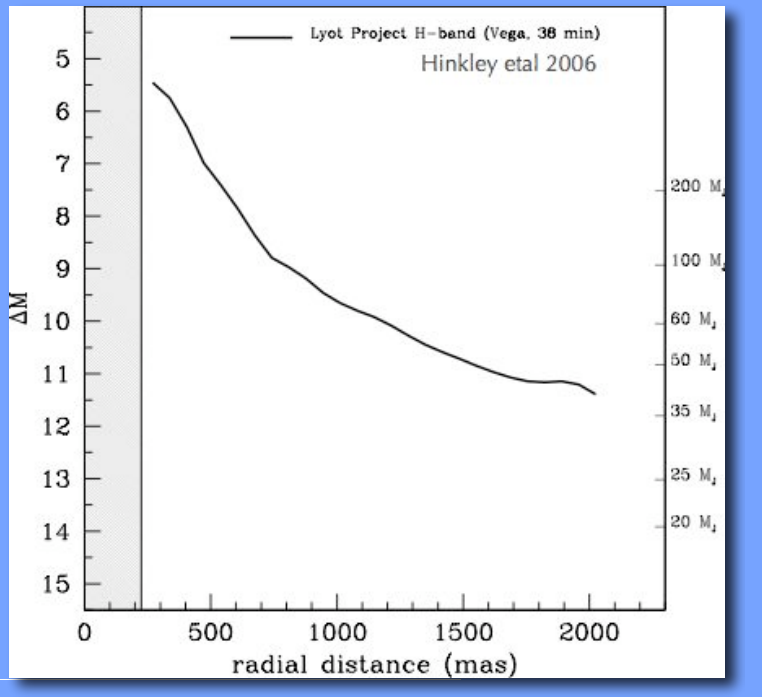




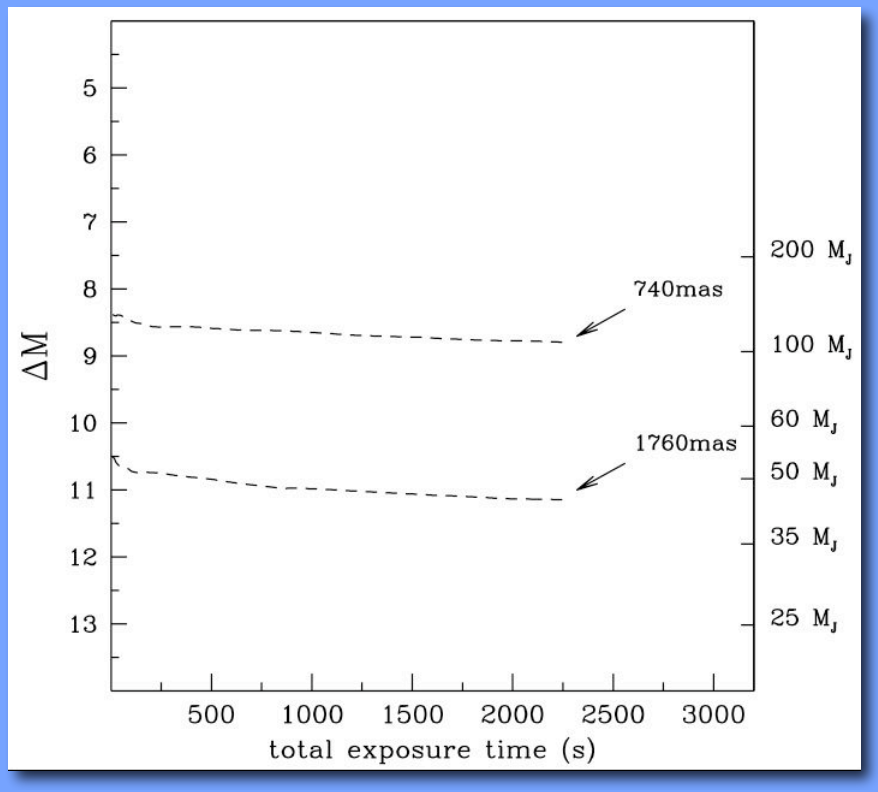
Dynamic Range Estimation

•Made a sequence of sequential co-added images. N^{th} coadded image was the mean of first n individual images.
•Evaluated dynamic range on each image: faintest companion detectable at a location at the 5σ level.
•Measured the σ in a 0.28" diameter box at each point in the image.

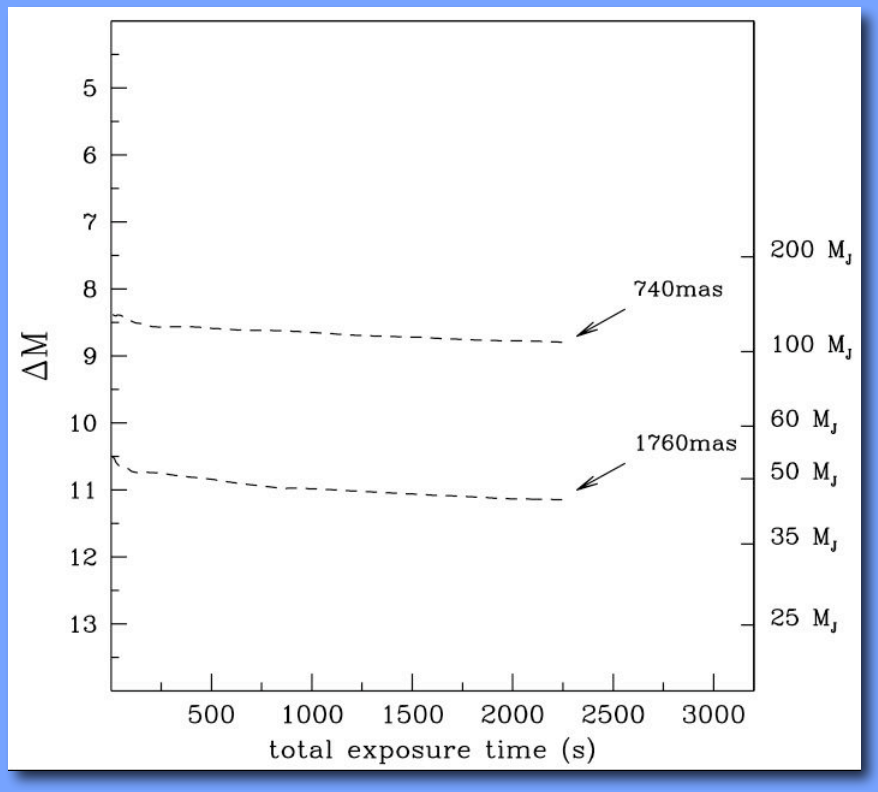


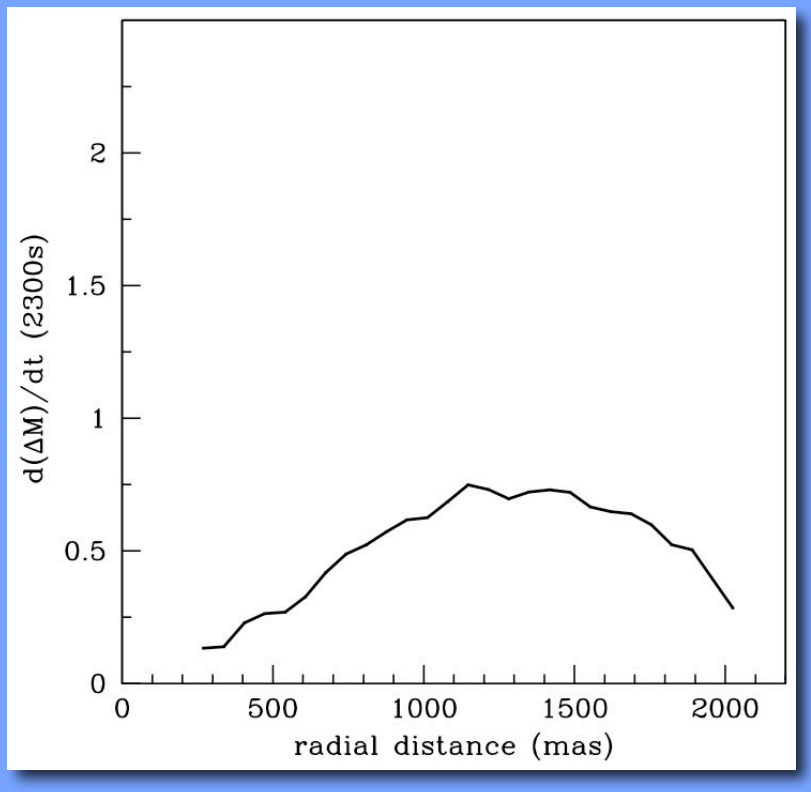


Dynamic Range Evolution

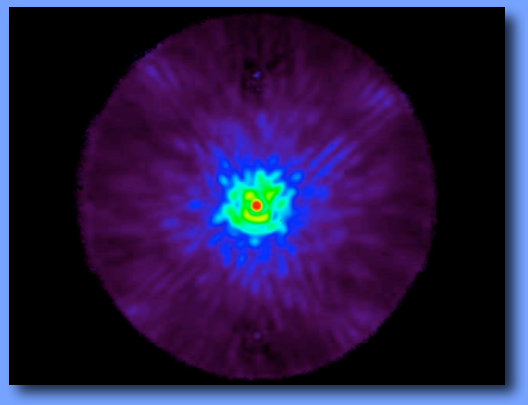


Dynamic Range Evolution



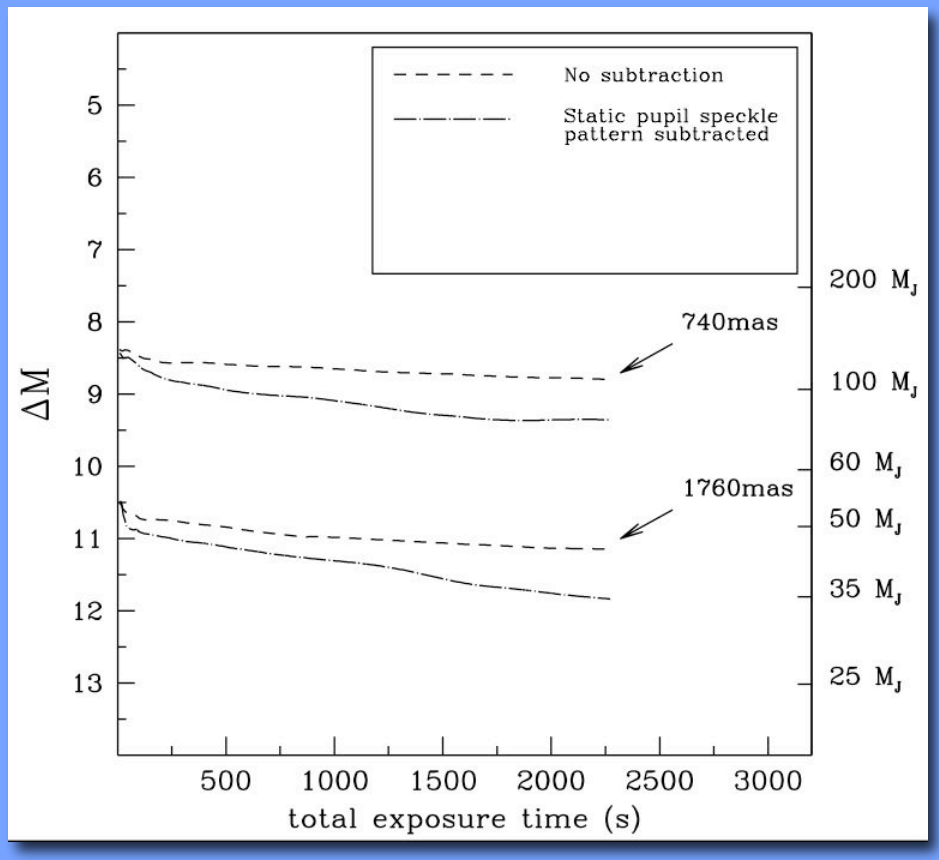


Static Speckle Subtraction



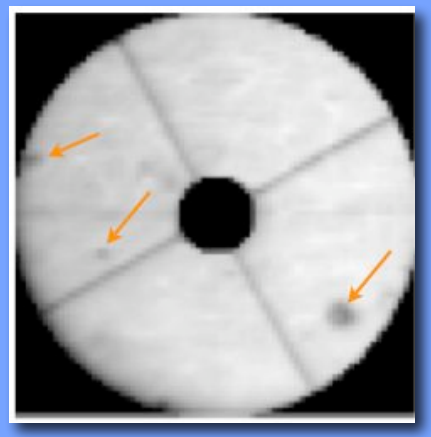
- Subtraction of purely static, rotating spider speckles in telescope pupil frame gives significant improvement.

- Similar to Marois (2006)

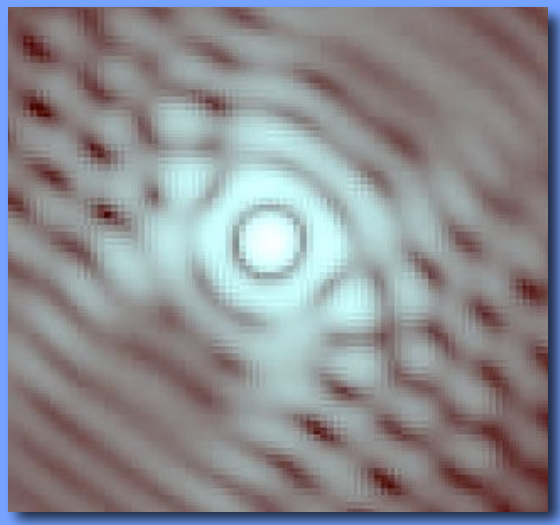


Dead Actuators on DM

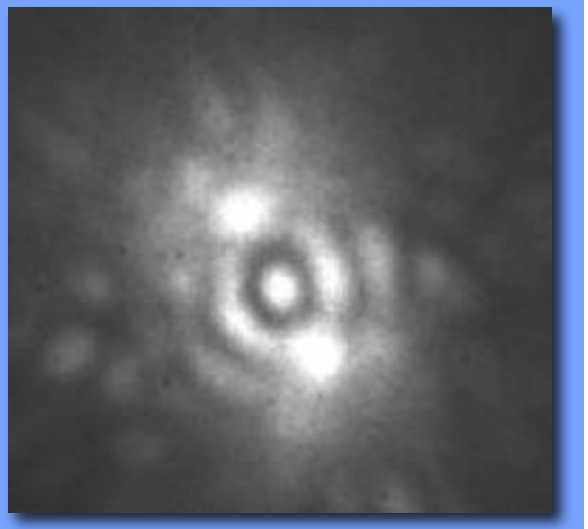
- Pinned actuator in DM introduces significant phase error.
- DM frame rotates at a different rate than pupil frame



Pupil image

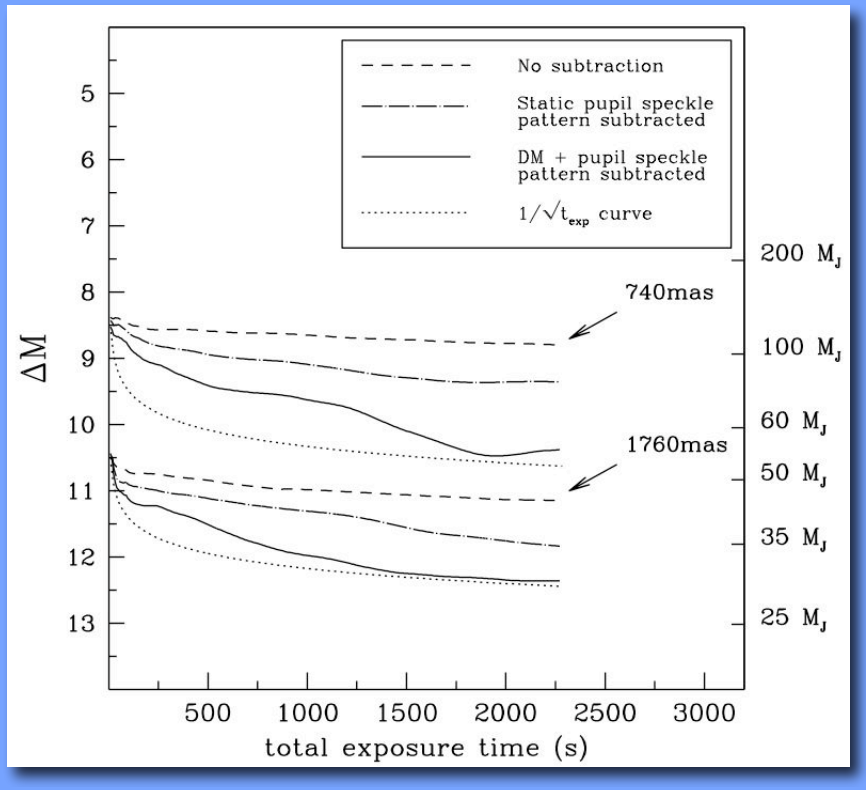


Simulations
(Sivaramakrishnan et al. 2006)



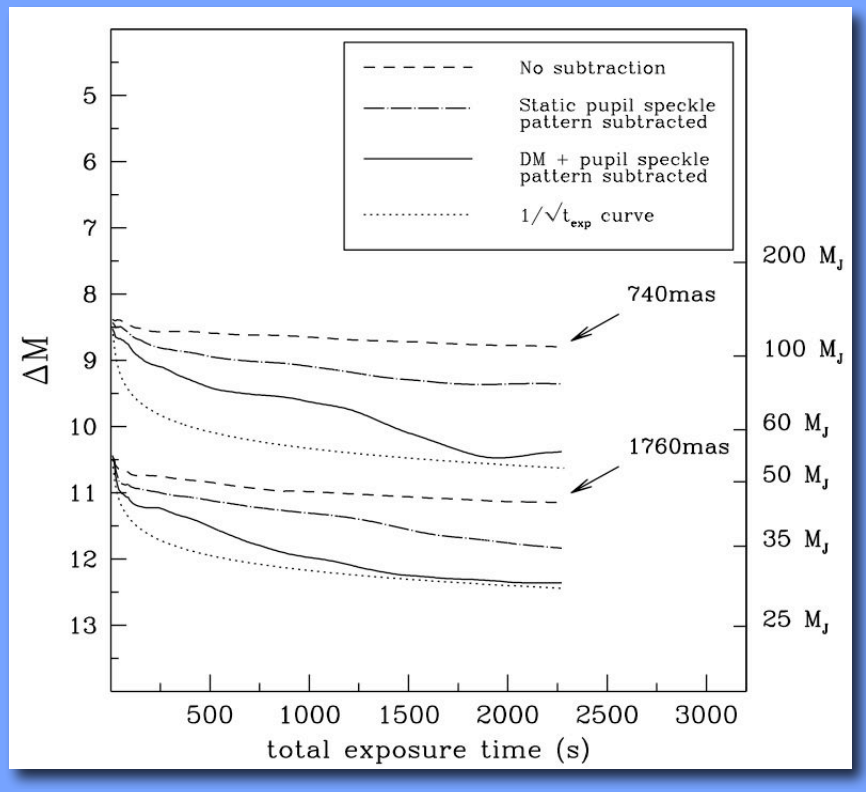
Data

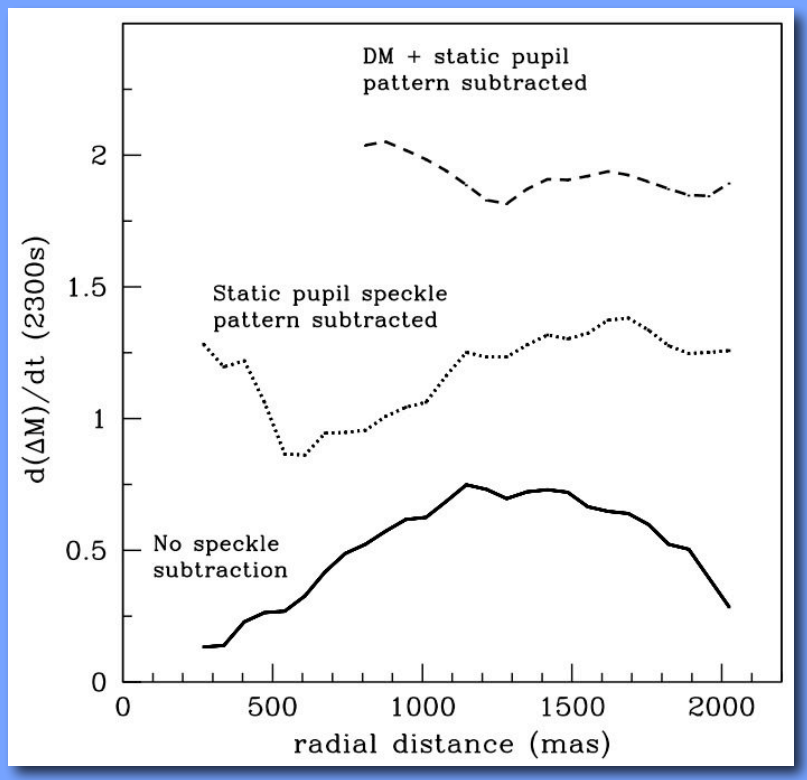
Pupil + AO system speckle subtraction



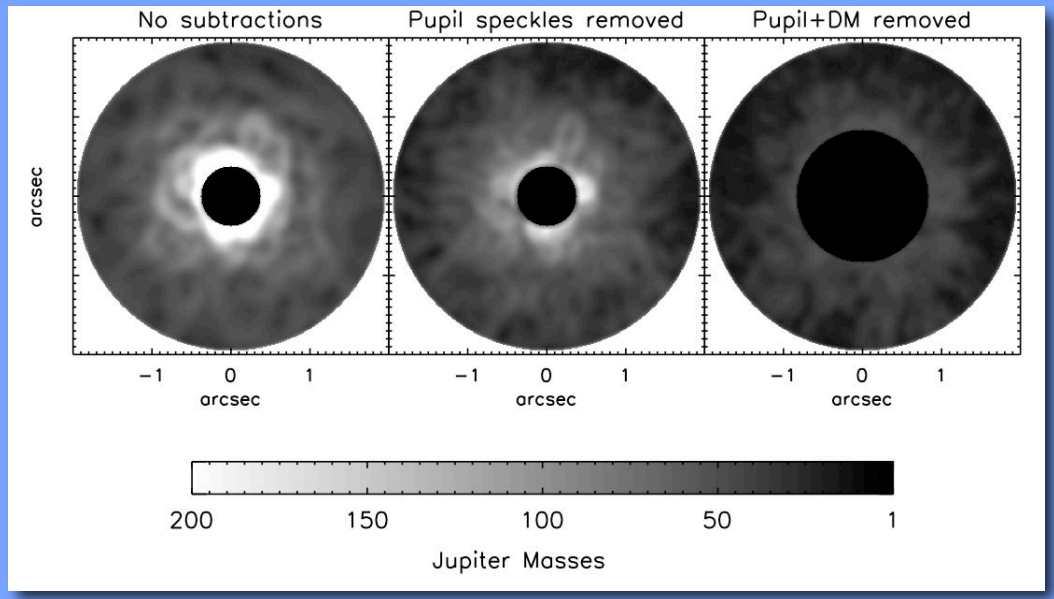
Subsequent subtraction of speckle pattern due to DM and AO optics gives even more improvement.

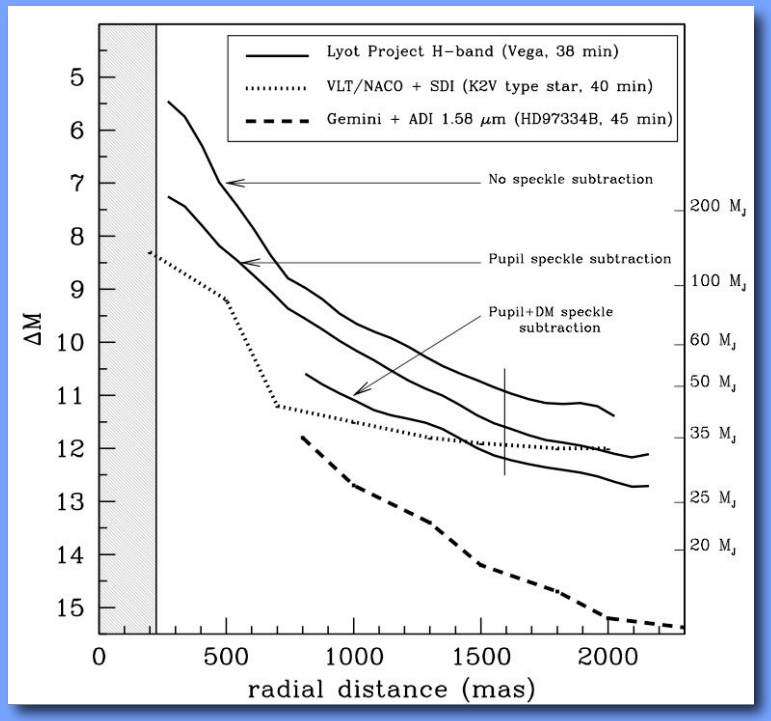
Pupil + AO system speckle subtraction





Dynamic Range Improvement

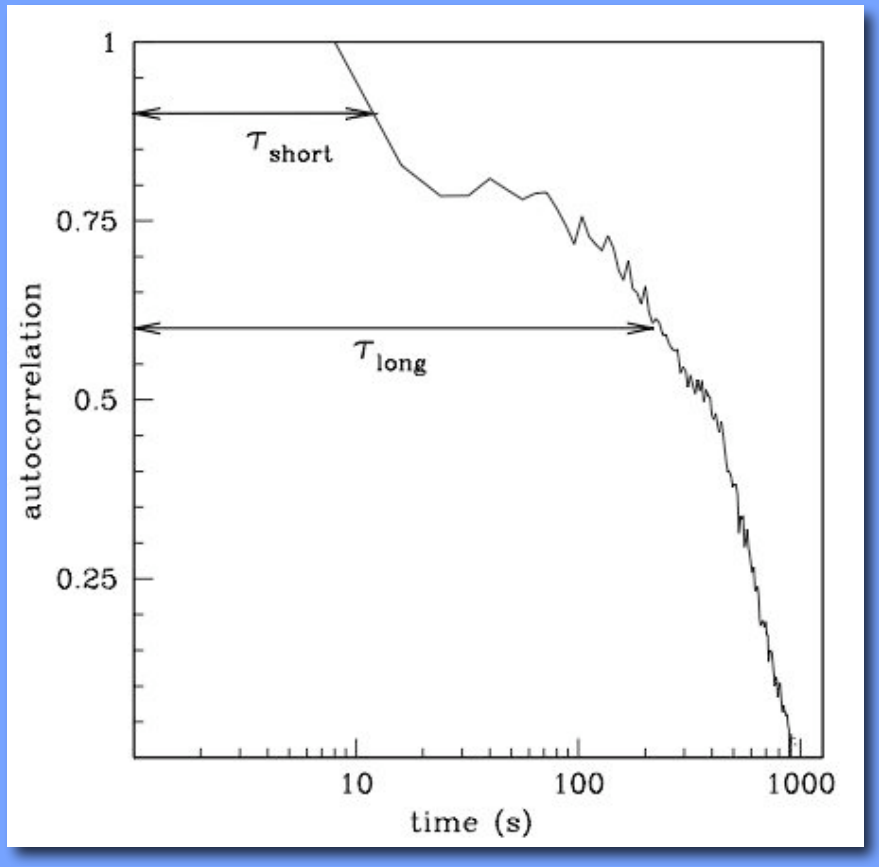




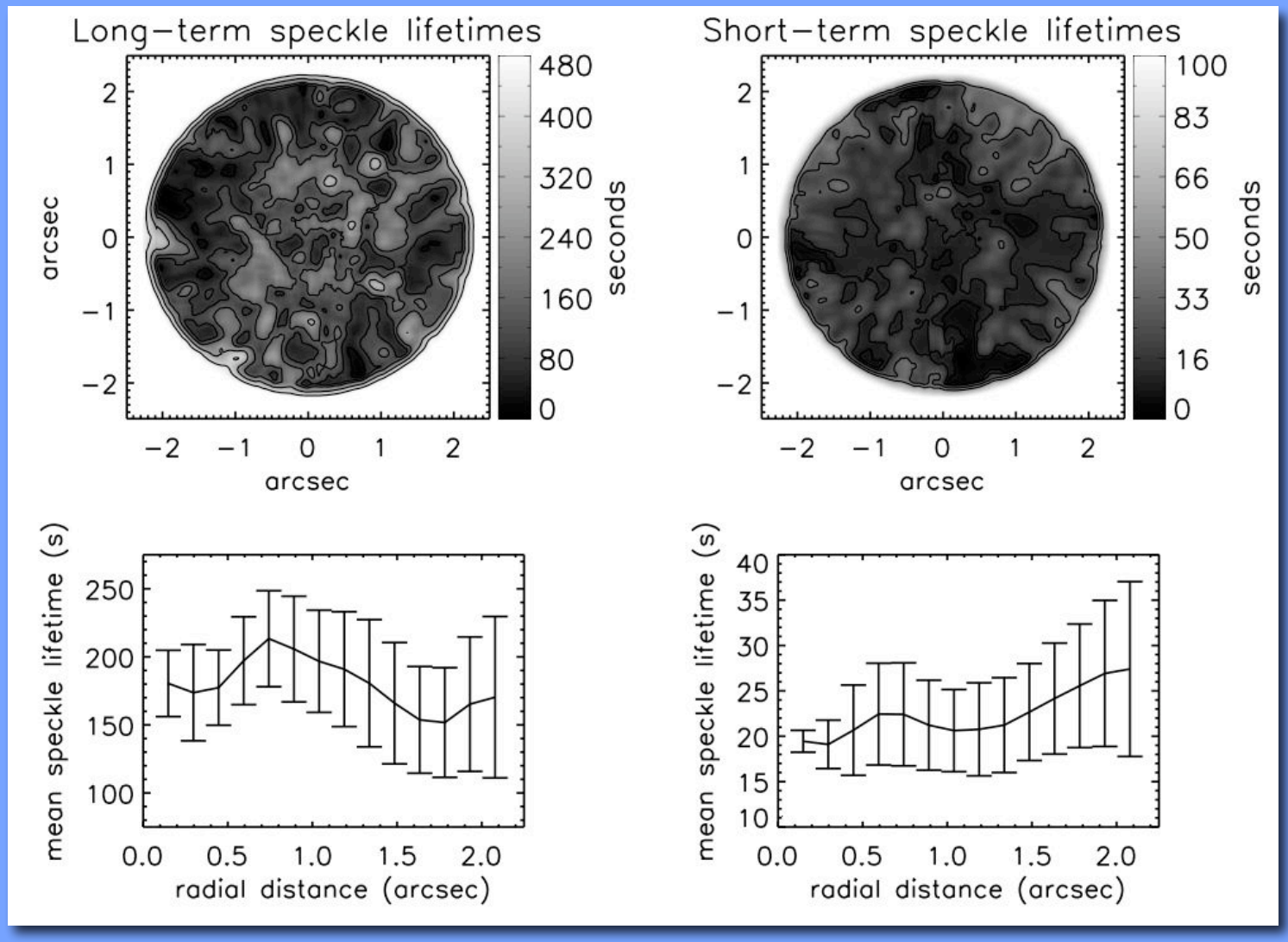
Hinkley et al., ApJ, 654, 633 (2007)

Autocorrelation lifetime analysis

- After static (spider) speckle pattern was removed, temporal autocorrelation was calculated for each pixel. Similar to Fitzgerald & Graham (2006)
- Two distinct timescales evident, defined by the half-widths of two regions separated by "knee" near 20s.
- τ_{short} corresponds to rapid decorrelation of speckles, slight increase in dynamic range.
- τ_{long} corresponds gives a measure of quasi-static speckle lifetimes



Speckle Lifetimes



Hinkley et al., ApJ, 654, 633 (2007)

Limits on Vega's companion

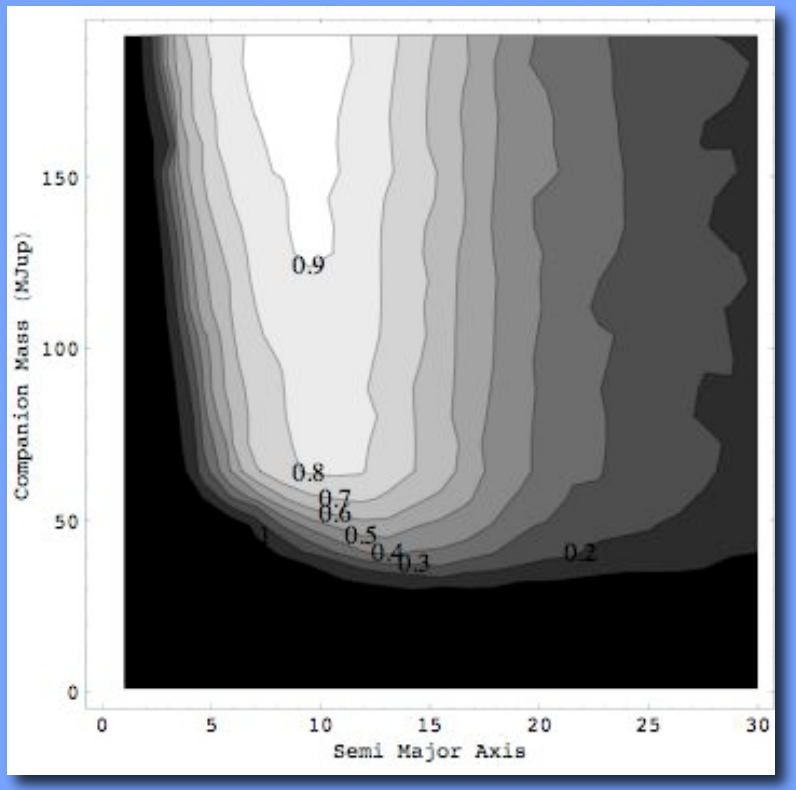
TABLE 1

SENSITIVITY LIMITS FOR IMAGING STUDIES OF VEGA

Work	Wavelength	Telescope, Technique	0.5″	1″	2″	4″	7″	10″
Macintosh et al. (2003)	*K*	Keck, AO	...	...	...	...	10	8
Metchev et al. (2003)	*H*	Palomar, AO	...	...	...	30	15–20	~12
Marois et al. (2006)	1.58 μm	Gemini, ADI	...	...	...	5	4	3
Hinz et al. (2006)	*M*	MMT, AO	...	...	26	7	7	7
Itoh et al. (2006)	*H*	Subaru, AO + coron.	...	...	120	7	5–10	...
This work	*H*	AEOS, AO + coron.	135	43	27	...	...	...

NOTE.—Sensitivity limits (in Jupiter masses) at different angular separations for several selected prior imaging studies of Vega.

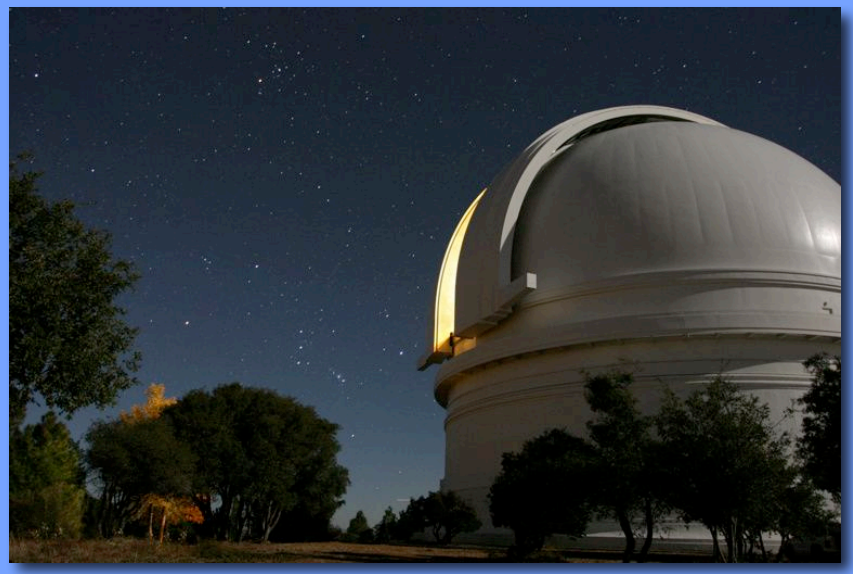
Hinkley et al., ApJ, 654, 633 (2007)

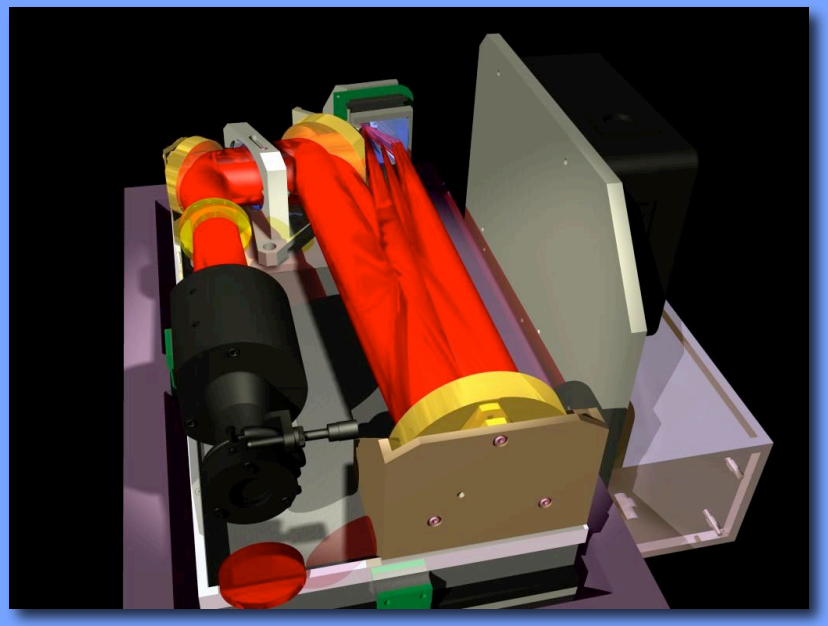


- Can constrain masses within 2" (16 AU) of Vega system, radii not previously probed at these sensitivities.

- Complements monte carlo simulations of expected detectable fractions.

Project 1640: A New Integral Field Spectrograph for Exoplanetary Science



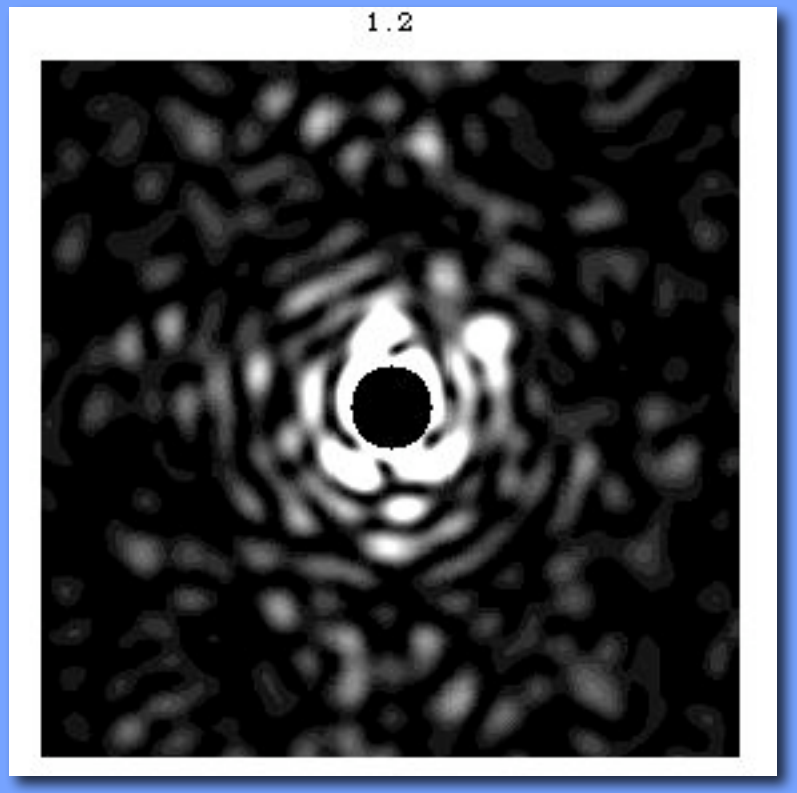


THE LYOT PROJECT

AMERICAN MUSEUM of NATURAL HISTORY

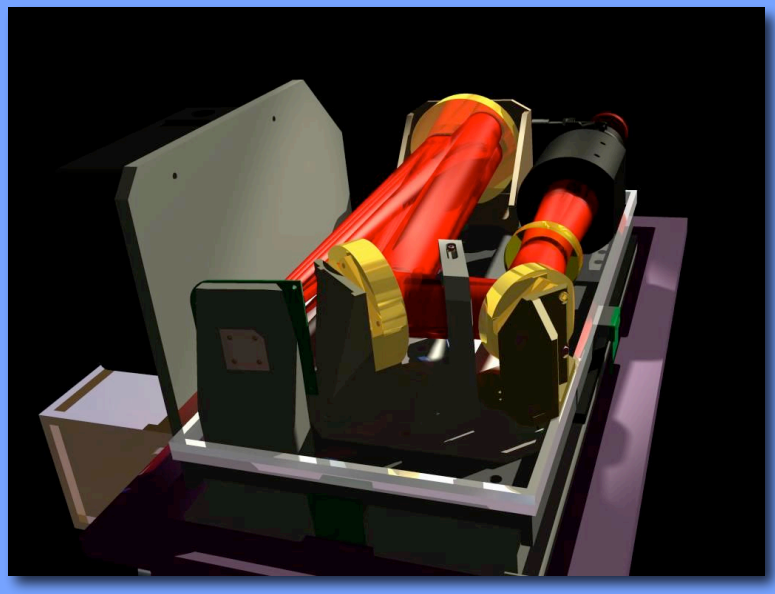
IoA UNIVERSITY OF CAMBRIDGE

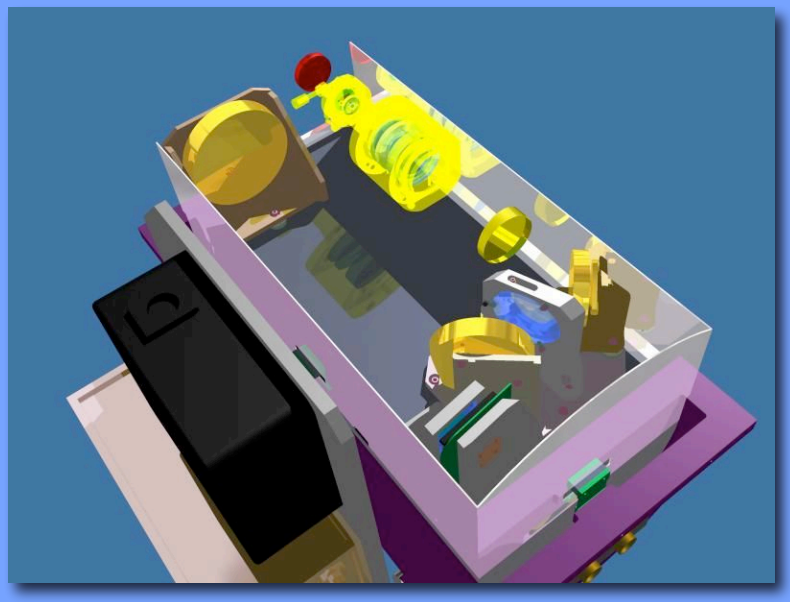
Utilize spectral nature of speckles



Also, spectra!!

Instrument Layout



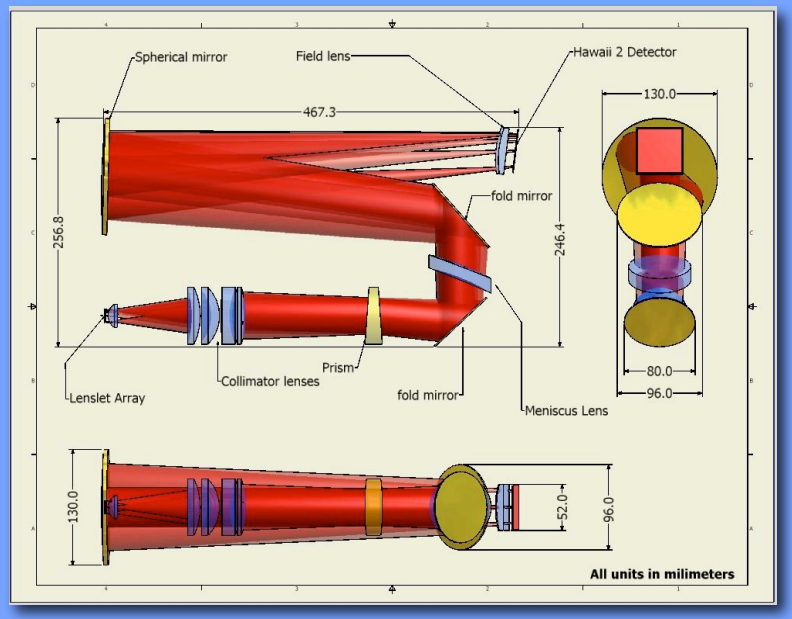


•Full system will include high-order AO System, Lyot coronagraph, and IFU operating in J through H bands (1.0 - 1.8 microns) with R ~ 30.

•Three basic optical components: collimator, prism, and camera.Three gold plated aluminum mirrors: one sphere, two folds.

•Rockwell Hawaii 2 array configured at IoA. Detector system is a copy of DAZLE system.

•All contained in a cryogenic dewar based on PHARO design.



Collaborative effort. . .

AMNH (headquarters):

-Optimized Coronagraph for Palomar 5m

-Integral Field Spectrograph as Science Camera

JPL:

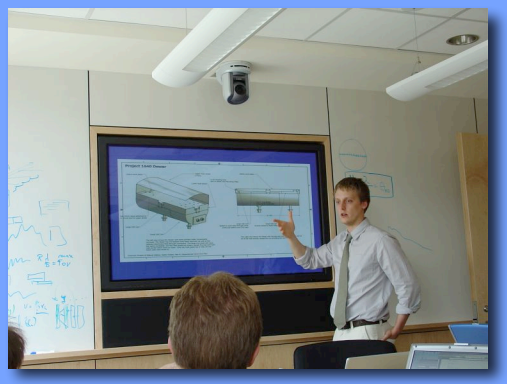
-Interferometric wave front calibration system.

Caltech:

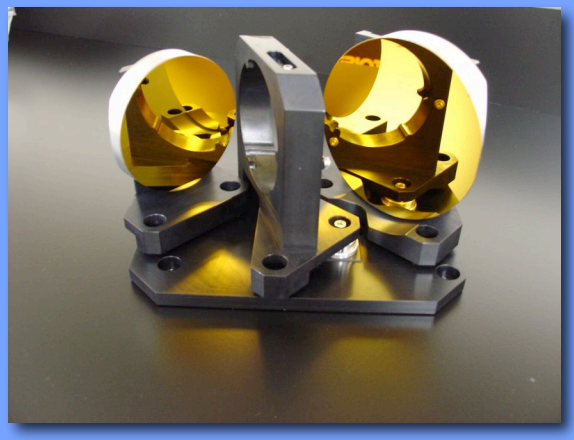
-5m telescope

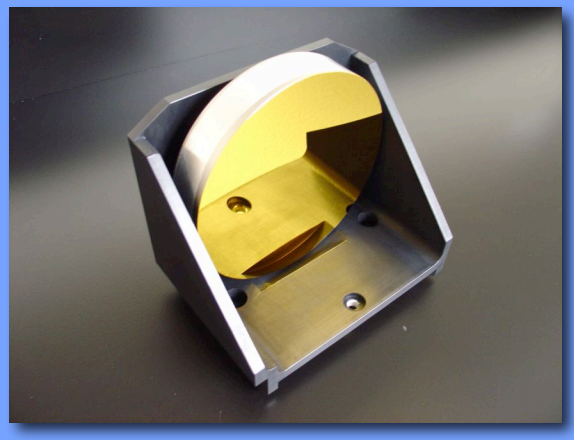
-PALAO => PALM3K (3000 Actuator AO system)

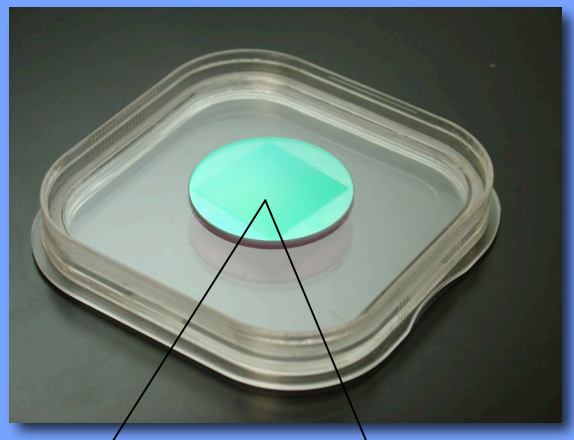
Design Review: July 13th, 2006

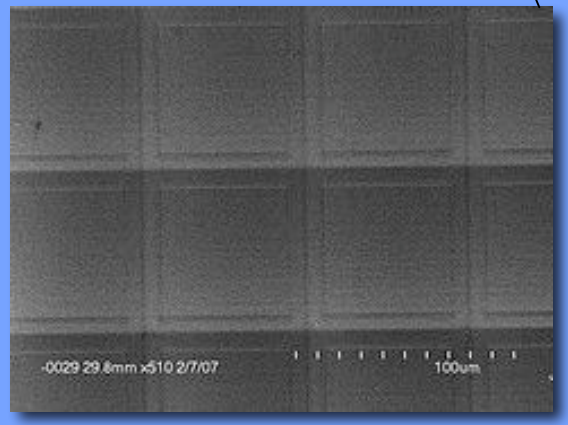


Project 1640 Hardware in House

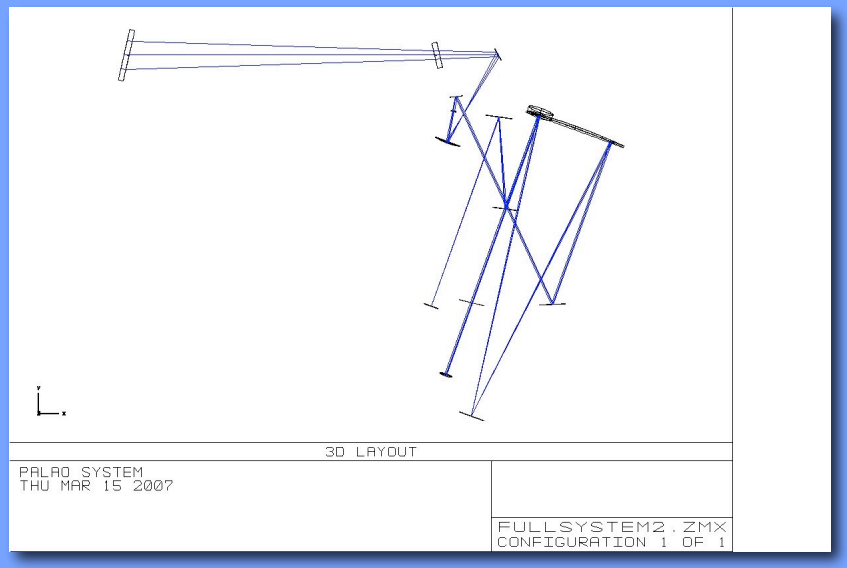


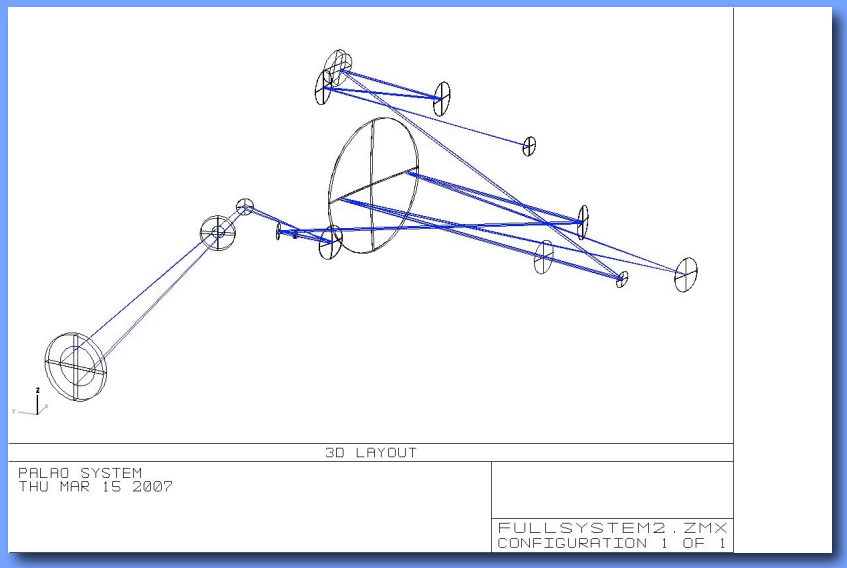






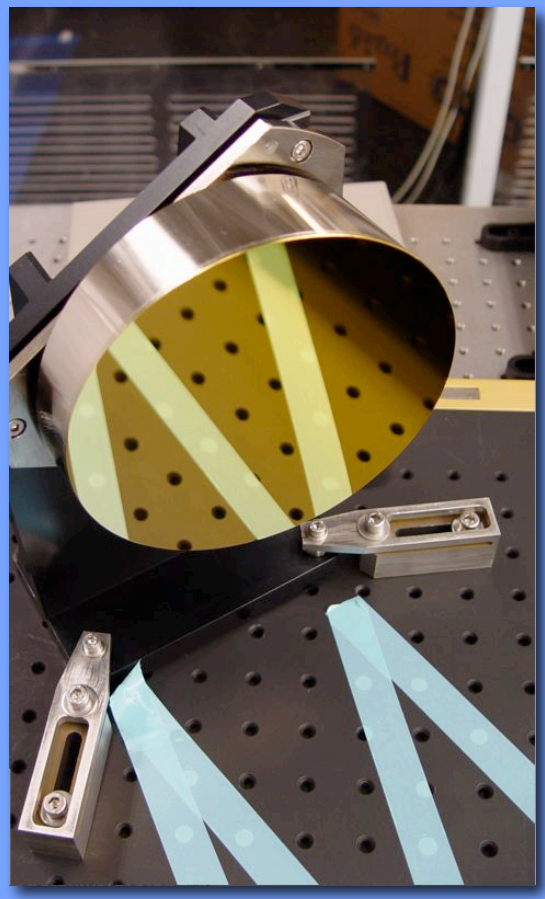
Coronagraph Designs

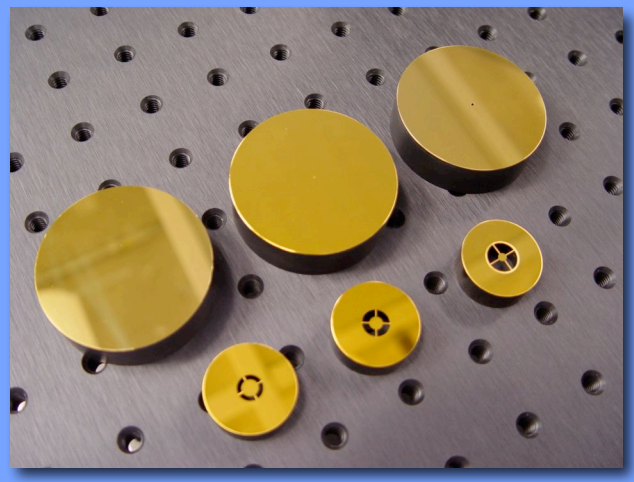


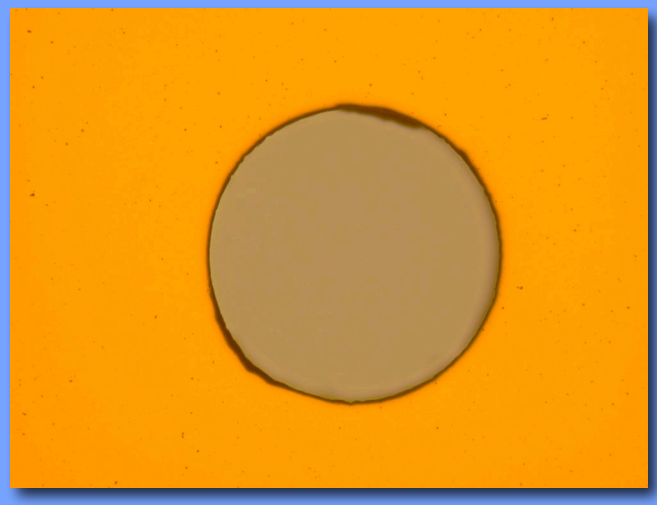


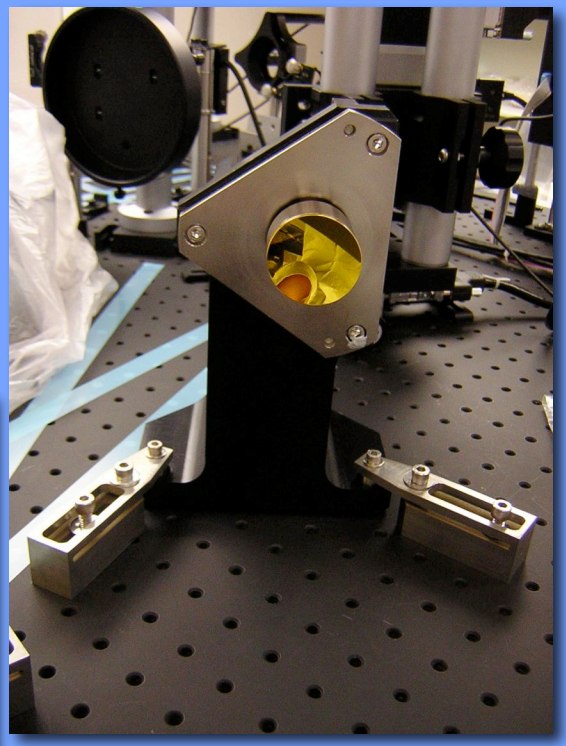
- Significant recycling of existing Lyot Project optics to save cost.
- F/153 beam needed on the P1640 lenslet array
- Order of optics: fold, OAP, fast-steering mirror, parabolic mirror, calibration system beamsplitter, OAP, two more folds.

Coronagraphic Optics

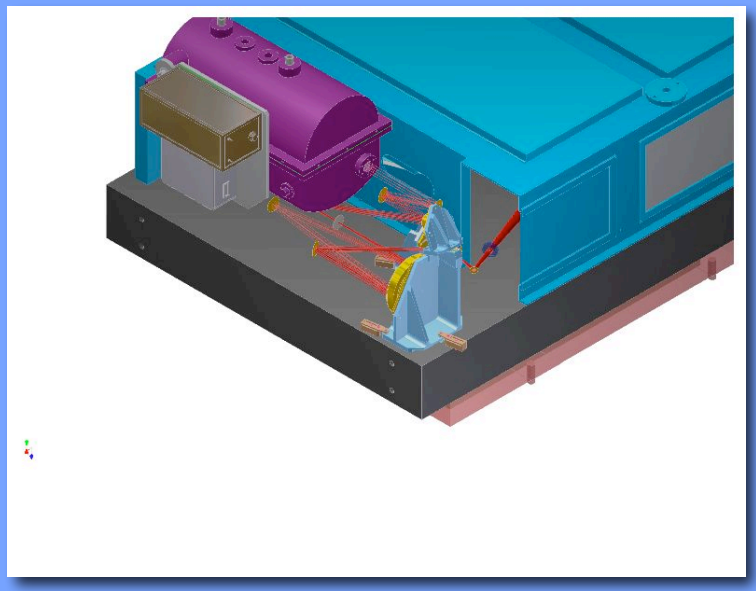


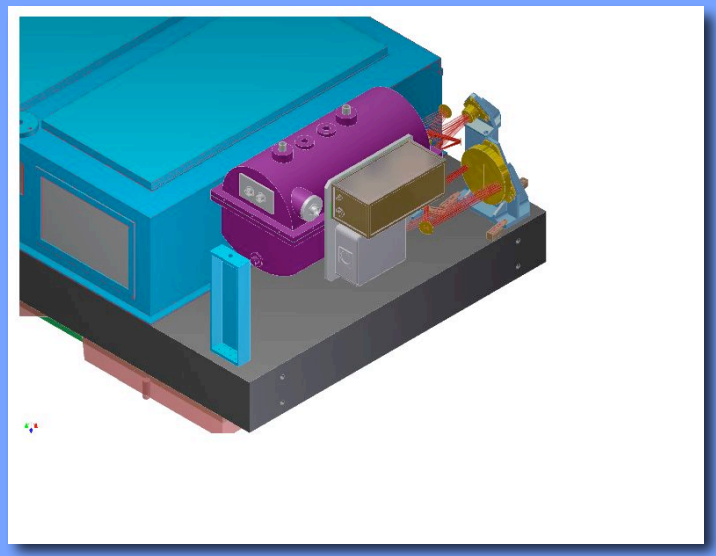




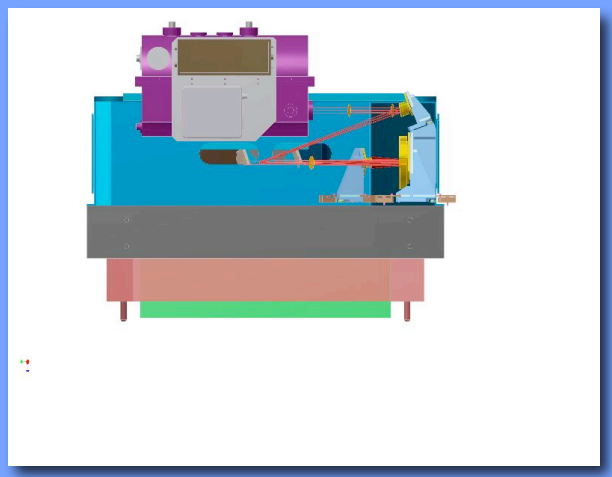


Coronagraph/IFU PALAO interface





- Roughly a 25x18x5 inch volume for the calibration unit.
- One piece of BaF2 to counter SSM1 dispersion.
- Still needed: ADC, tip/tilt optical path
- Calibration unit optics not shown



Project 1640 Calendar

6/2007: Initial IFU operations at AMNH. Decommissioning of Lyot Project coronagraph. Cal system design and construction begins at JPL.

10/2007: IFU and coronagraph integrated at AMNH; testing begins.

3/2008: Shipping of P1640 to Palomar, integration with AO system.

Palomar 08B, 09A: Semesters for initial observations with 241 actuator AO system; Proof of chromatic speckle suppression; observations of disks, young and evolved stars.

8/2009: AO system removed from operation for PALM-3000 upgrade. P1640 moves to JPL for cal system integration.

6/2010: Approximate first-light operation of PALM-3000 system. Integration with P1640 proceeds as above.

Palomar 10B-12B: Initiation and execution of the exoplanet survey.