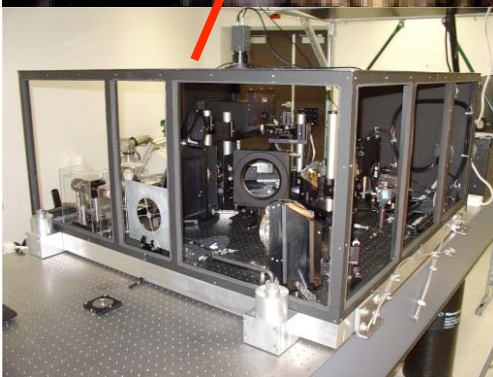


# *The Lyot Project*

## *Status and Results*



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*NSF Center for Adaptive Optics*  
*Stony Brook University*

941-channel AO on 3.6m AEOS telescope

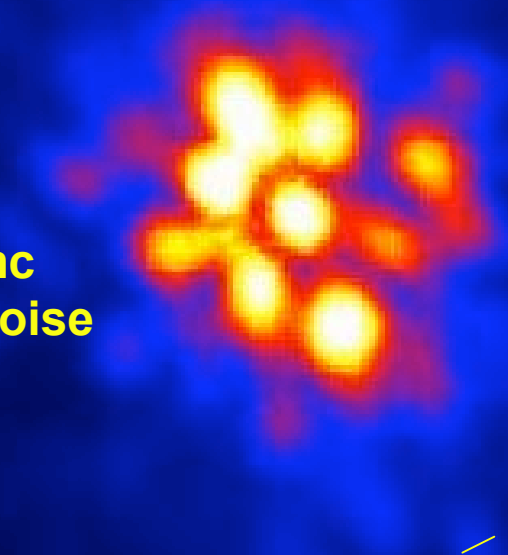
FPM **0.35"** in H-band (**4  $\lambda$ /D**)

First light: AEOS March 2004

Second AEOS DM: December 2006

**Coronagraphic image of 55 Cnc**  
**Residual speckles dominate noise**

- Speckle pinning
- Speckle amplification, statistics
- Aberration leak
- Symmetric halo speckle
- Apodized pupil coronagraph
- Chromaticity of speckles - IFU
- Scintillation, amplitude errors
- Spider suppression
- Astrometry & photometry
- Customized ADI speckle suppression methods
- Simultaneous dual polarization coronagraphy



TEAM

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Neil Zimmerman

Mike Simon

Jeff Kuhn

Paul Kalas\*

Mike Shara

Laura Newburgh

Kathryn Whitman

Observing \*Here

# FPM & Lyot masks

Reflective focal plane masks  
Guiding done behind hole



Reflective Lyot stop masks  
Pupil monitored continuously



Microscope Image by Jacob Mey,  
Charlie Mandeville  
(AMNH EPS Microprobe Lab)

- PalAO coronagraphic data: Oppenheimer et al. (SPIE 2000)
- AO coronagraphy theory: Sivaramakrishnan et al. (ApJ 2001)
- Numerical optimization: Makidon et al. (SPIE 2000)
- Early design: Lloyd et al. (SPIE 2001)
- Science case: Oppenheimer et al. (in Future of Small Telescopes 2003)
- Instrument design & construction: Oppenheimer et al. (SPIE 2004)
- PSF modelling with data: Makidon et al. (2005 PASP)
- New coronagraph designs Soummer (ApJL 2005)

# Companion discovery

## Lyot Project Common Proper Motion Companion

H-Band 15 minute exposure

$10^{-4.0}$

47 AU

5"

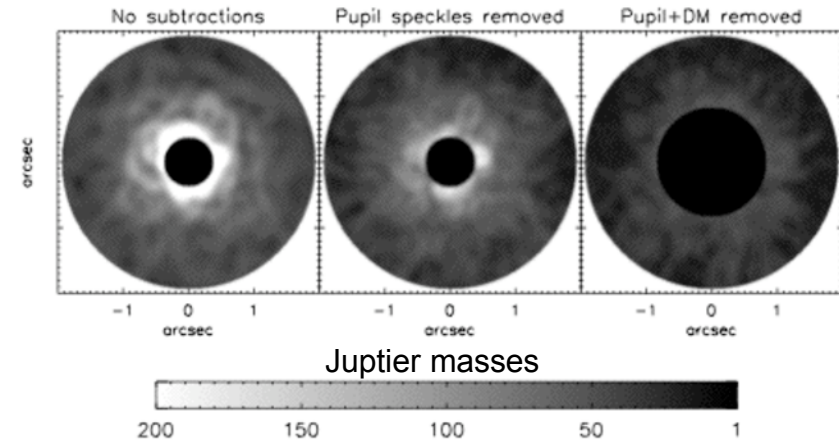
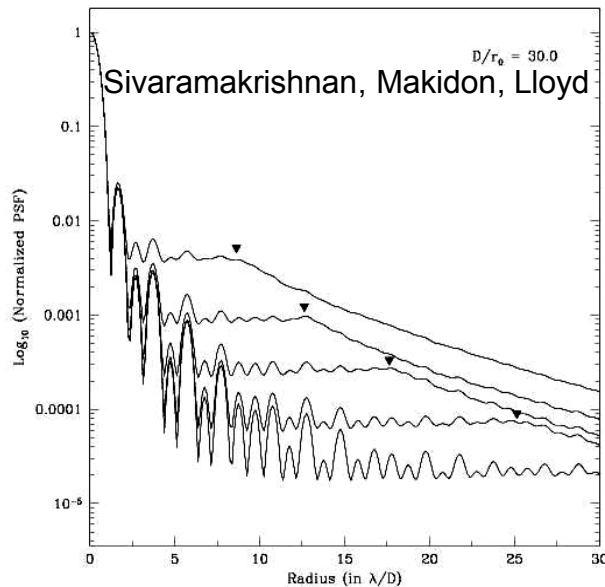
A3V,  $M_H = 1.39^m$ , Companion:  $M_H = 11.4$

Simultaneous dual channel polarization result to be submitted soon - also a very useful technique for speckle suppression of polarized sources (e.g. disks). Calibration on Alt-Az has been hard.

Oppenheimer et al. ( in prep. 2007)



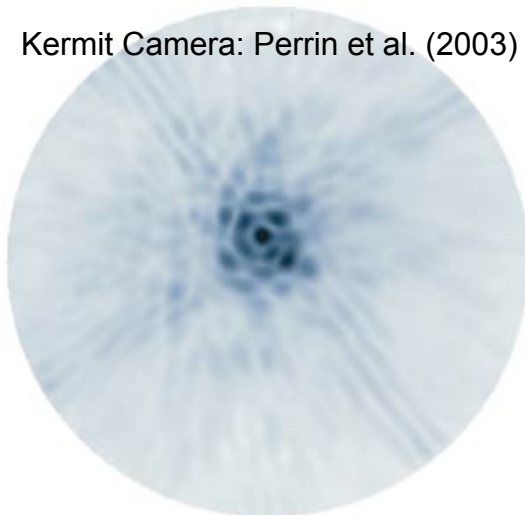
# Dynamic range (old DM)



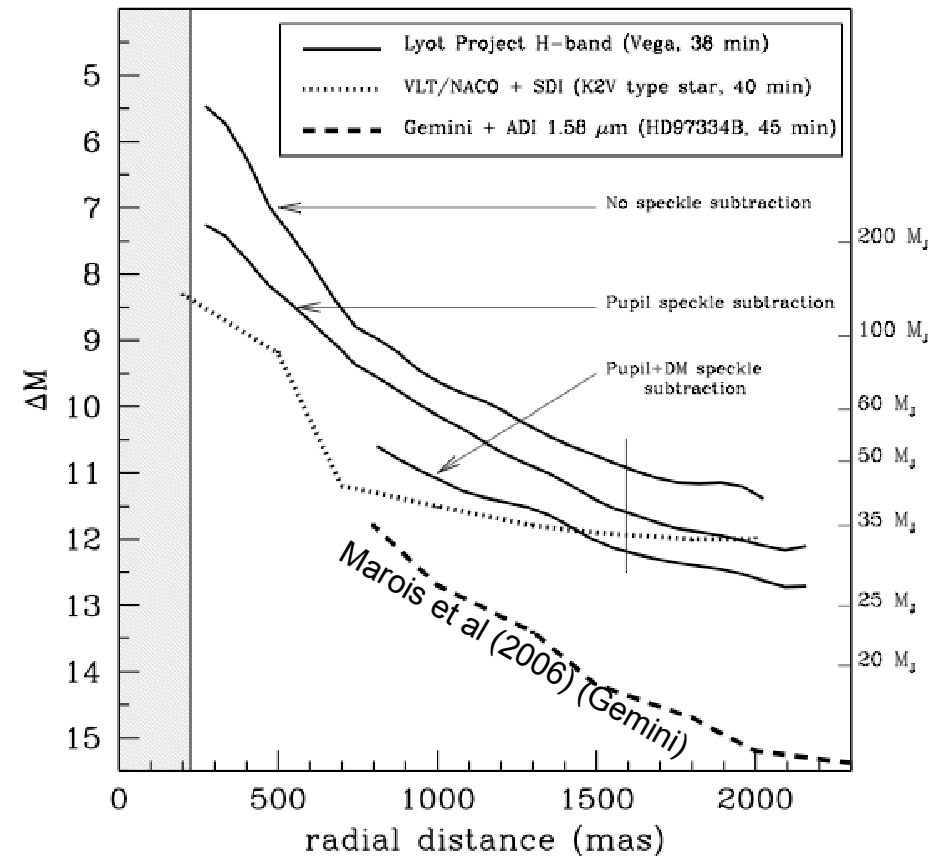
Performance != prediction

- Broken Actuators
- Half-voltage operation of DM
- No Spatial Filter in WFS
- Simple data reduction (no ADI)

Kermit Camera: Perrin et al. (2003)

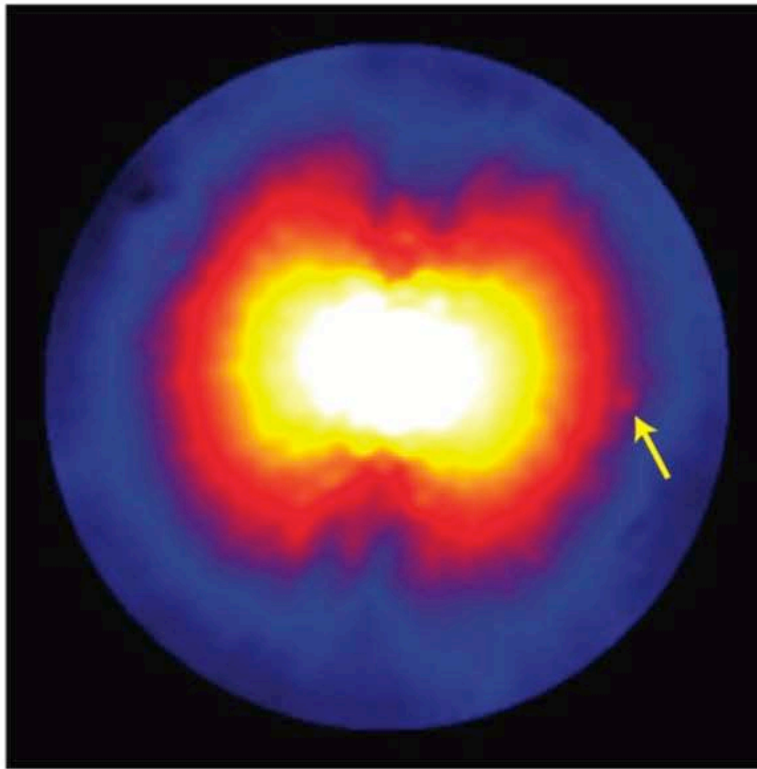


Hinkley et al (ApJ 2007)  
Sky rotation ADI  
DM rotation ADI

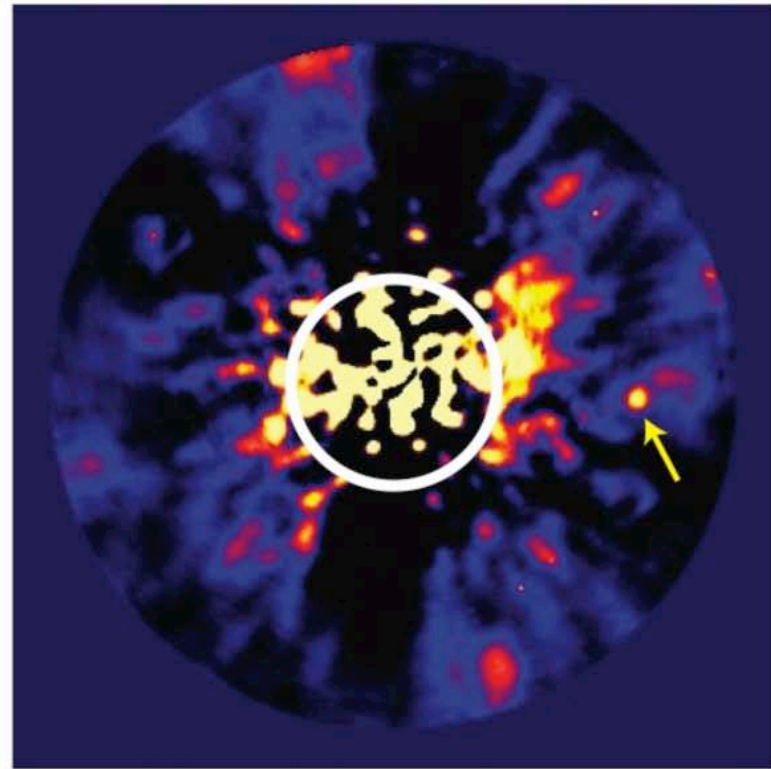


# Revised data reduction

see poster by Jeremy Leconte et al.



Average, no ADI: source is 3 sigma  
9.9 mag difference

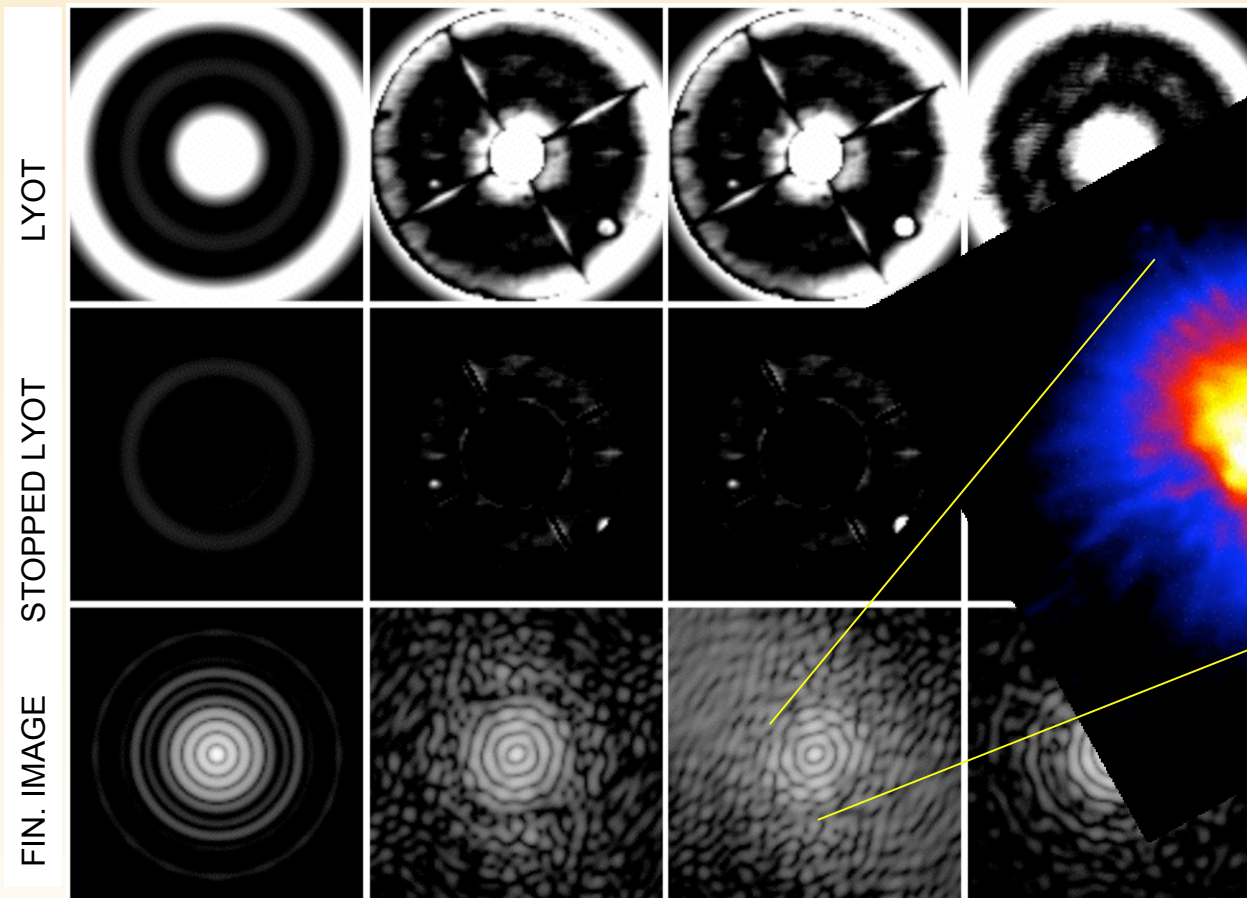


With ADI: source is 9 sigma  
1 mag improvement  
If confirmed, 70 Jupiter mass object



Sivaramakrishnan et al. AMOS 2003, 2004  
 Roberts et al. AMOS 2004  
 Sivaramakrishnan et al IAUC (2005)  
 Makidon et al. IAUC (2005)  
 Oppenheimer et al. AMOS 2005

# Pupil illumination



perfect

amplitude  
only

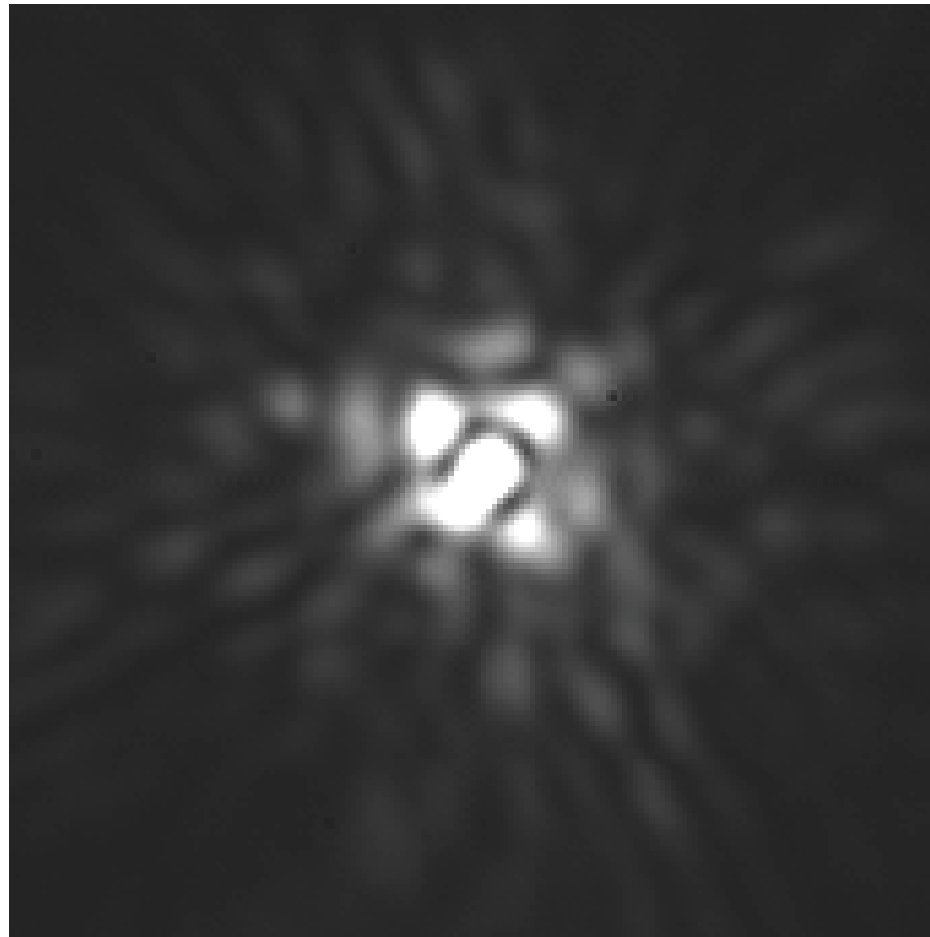
amplitude  
& phase

atmospheric  
amplitude

The phase bump on the DM causes significant 'speckle noise' - far more than atmospheric scintillation estimates from optical data.



# AO coronagraphic data



AEOS 941 channel AO system on Maui (USAF)  
Lyot Project coronagraph (Oppenheimer et al.)  
Kermit Camera: Perrin et al. (2003)

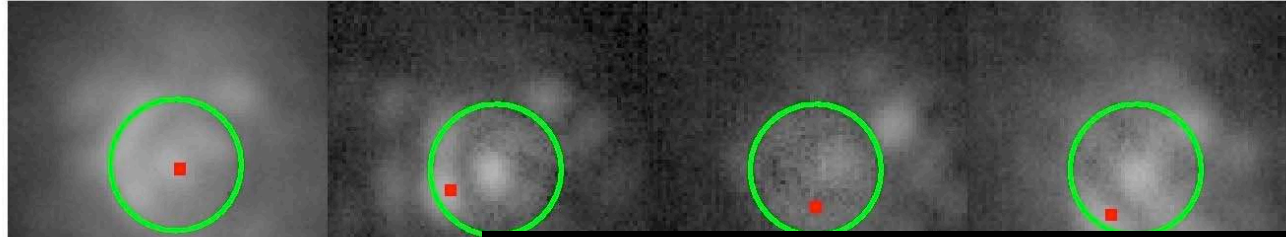




# Tip-tilt, astrometry, photometry

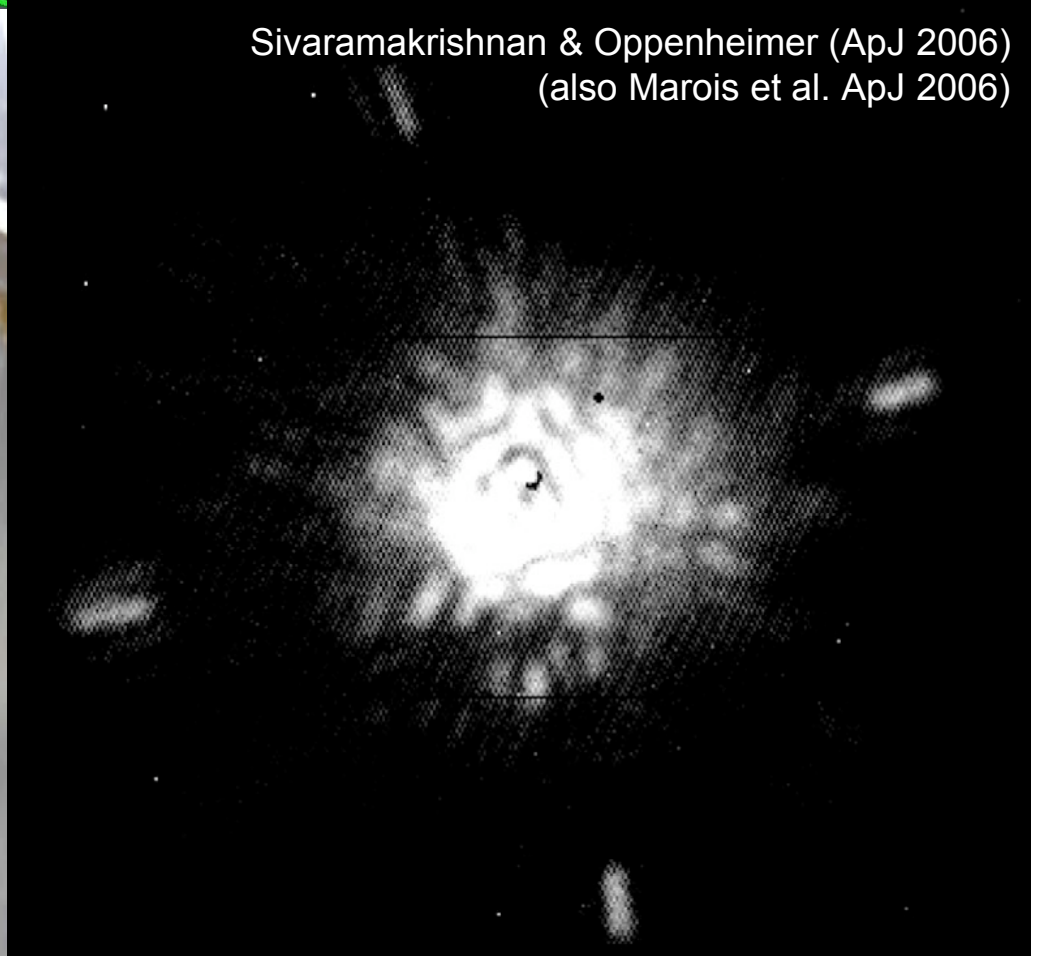
Better astrometry - more science per /\$ or /year

Digby et al. (ApJ 2006)

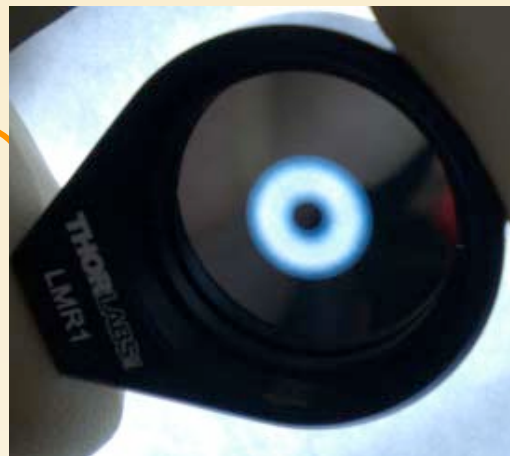
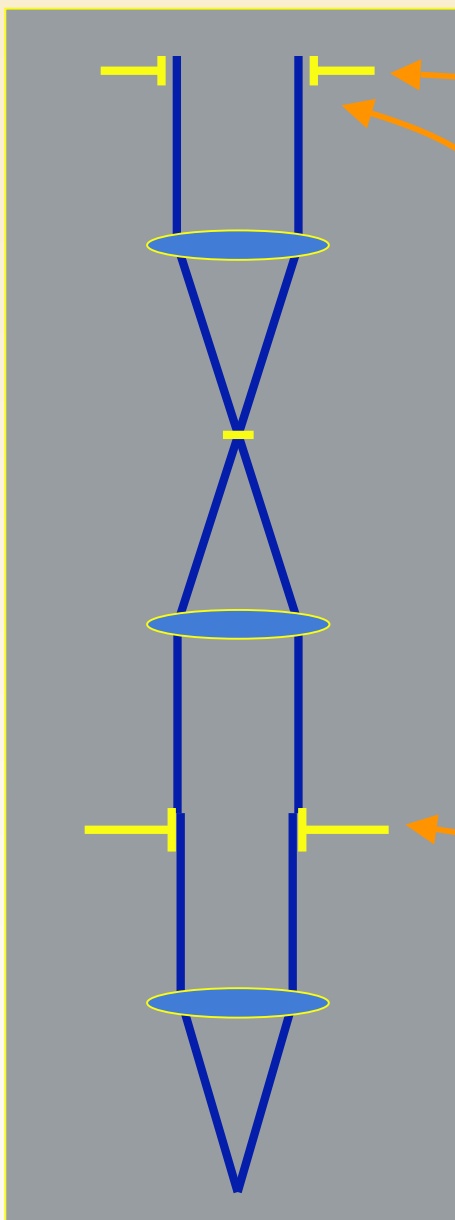


Dragoslav Scepanovic

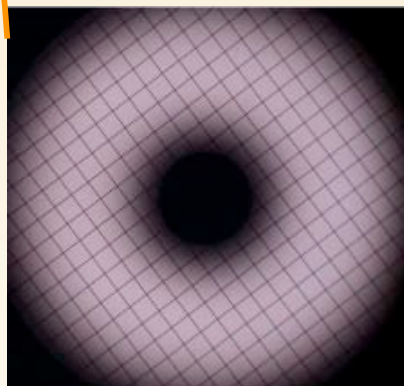
Sivaramakrishnan & Oppenheimer (ApJ 2006)  
(also Marois et al. ApJ 2006)



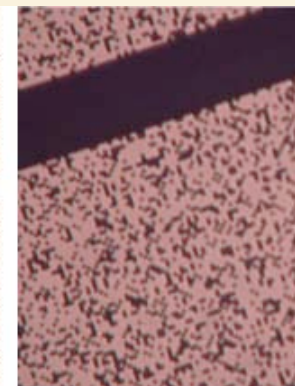
# Apodized pupil Lyot coronagraph



Iconel alloy deposition  
apodizer



Chromium microdot apodizer with astrometric grid

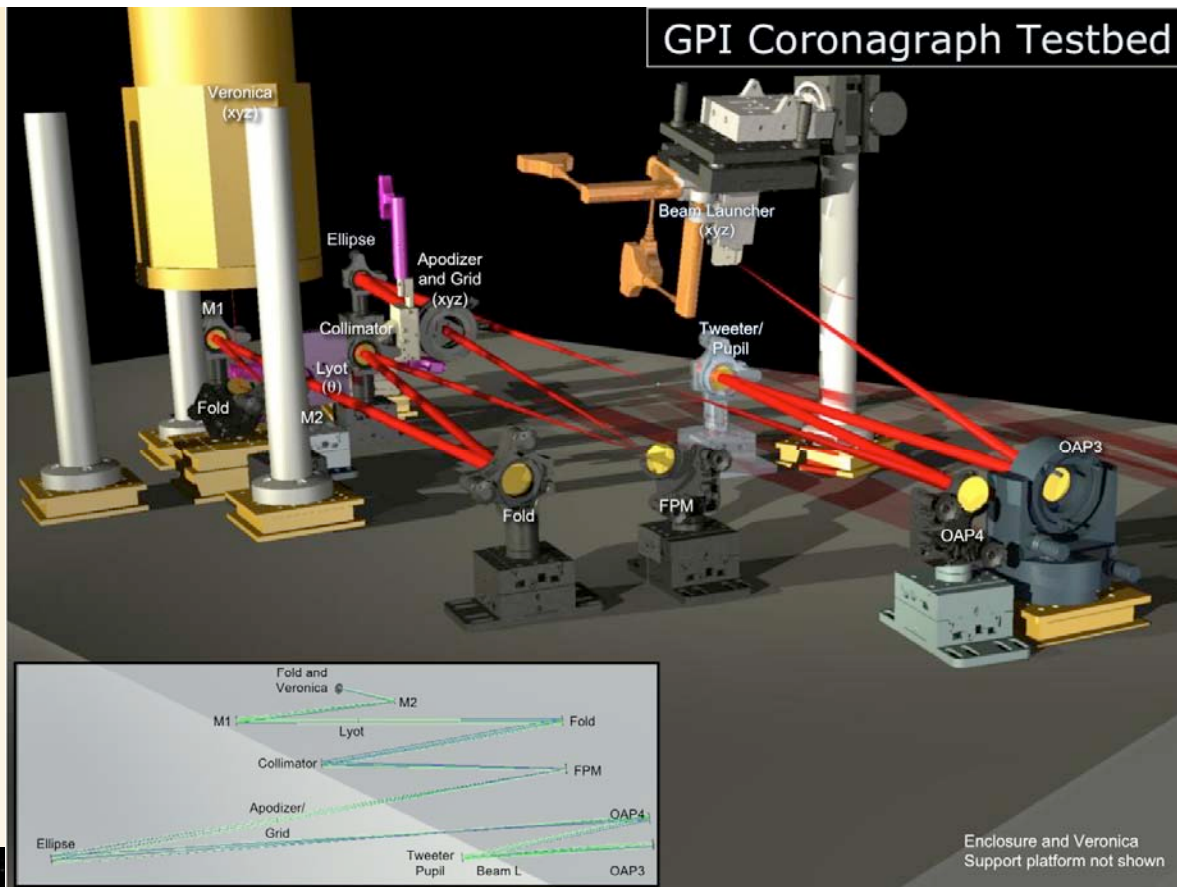
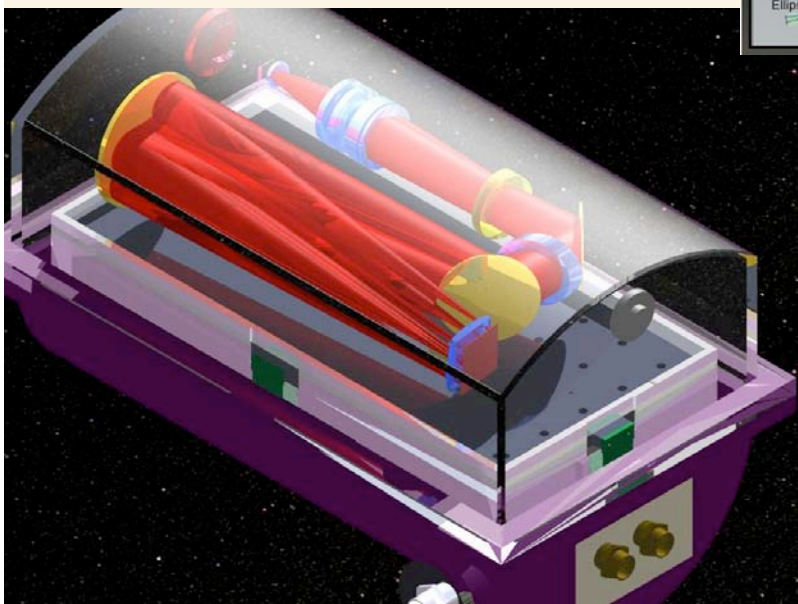


At Lyot pupil no under-sizing  
required. Increased throughput  
and resolution

Aime, Soummer, Ferrari (2001)  
Aime, Soummer, Ferrari (2002)  
Soummer, Aime & Falloon (2003)  
Soummer (2005)  
Soummer et al. 2007 (submitted)



“Project 1640” IFU behind PalAO 249-channel, also usable behind future AO upgrades. AEOS coronagraph decommissioned after this run, remade for P1640 and PalAO with Soummer’s APLC (to Palomar 2008)



At AMNH lab: Gemini near-IR coronagraph testbed for mask development and testing being built now. Bruce Macintosh will present GPI.