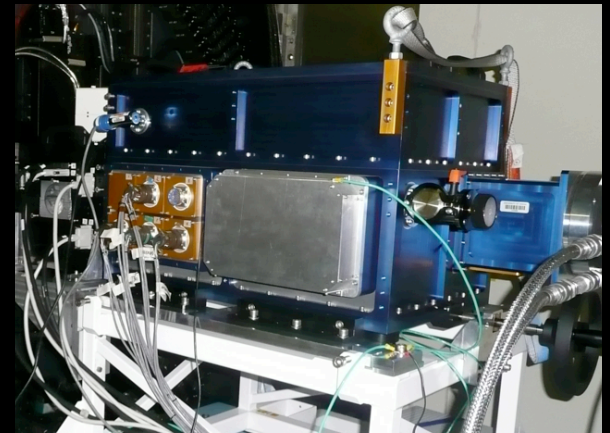
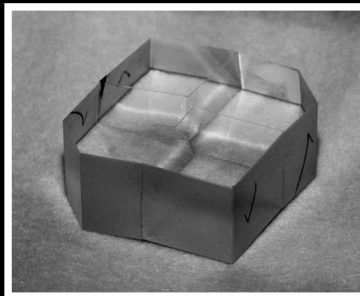
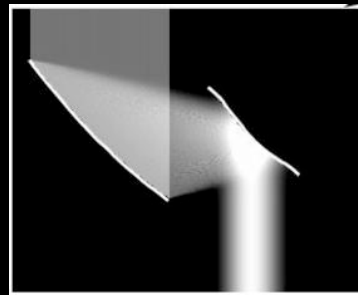
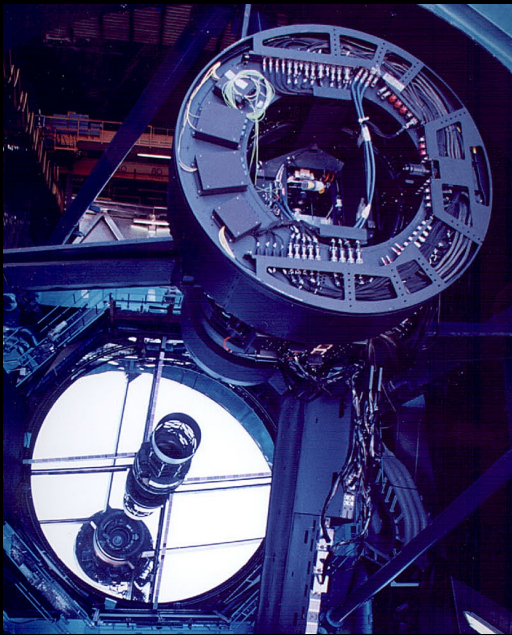


# The Subaru Coronagraphic Extreme AO Project (SCEExAO)



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**CEAO Research Fellow**

*Acknowledgement: Olivier Guyon  
Julien Lozi  
Vincent Garrel  
Célia Blain*



# Why this project?

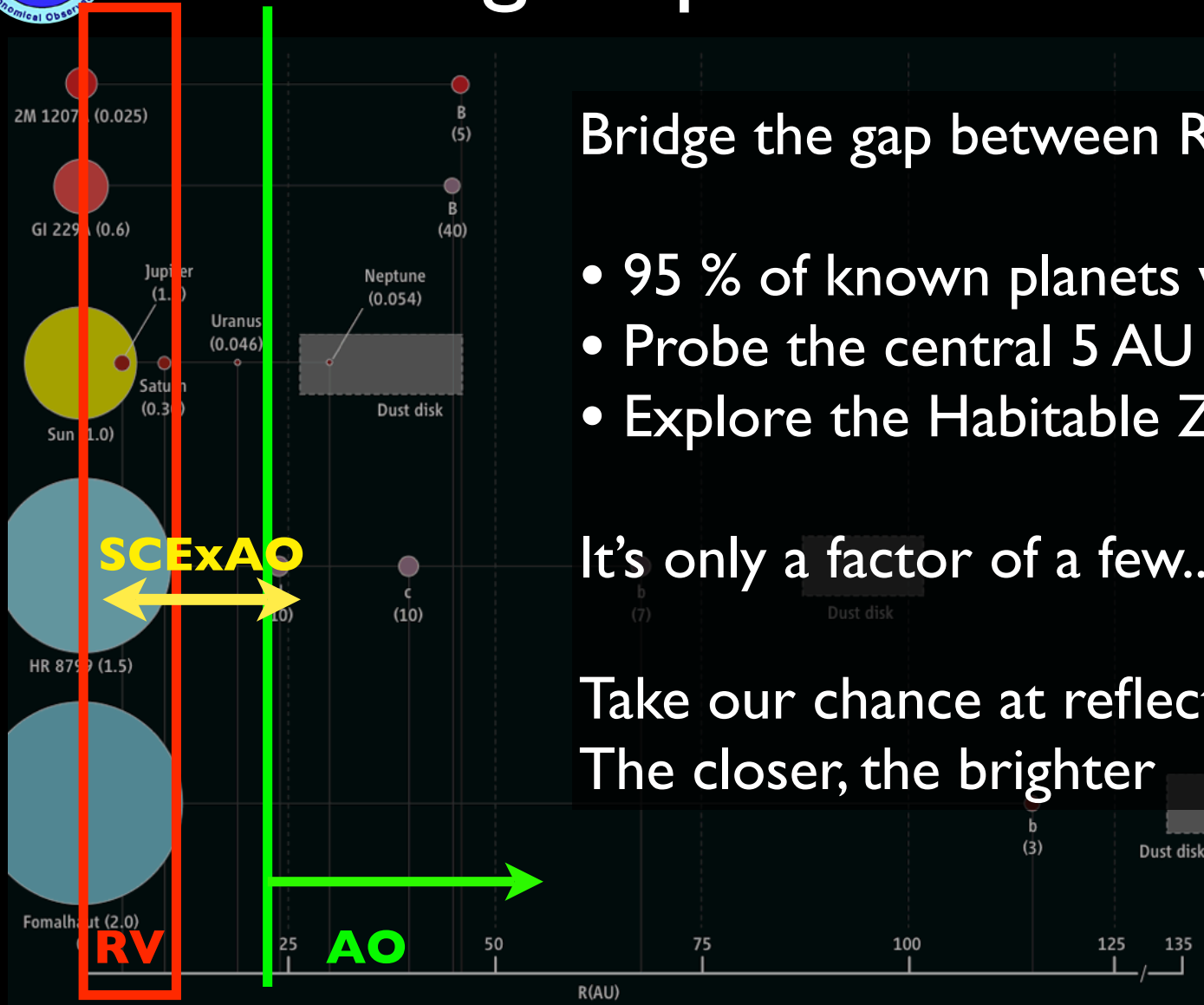
Logical conclusion of a sustained effort that started in 2003

Key technologies have been developed and tested:

- PIAA coronagraph
- Spider Removal Plate
- Aperture Masking Interferometry
- Coronagraphic Low Order Wavefront Sensor
- Other advanced WF sensing techniques



# Driving requirement: IWA



Bridge the gap between RV and AO:

- 95 % of known planets within 10 AU
- Probe the central 5 AU
- Explore the Habitable Zone

It's only a factor of a few...

Take our chance at reflected light:  
The closer, the brighter

*Marley, Sci. Exp, 10/13/2008*



# The context is ideal...

- 188-actuator curvature AO system
- coronagraphic diff. imaging camera HiCIAO
- Nasmyth platform
- 120 Subaru nights allocated to the completion of the SEEDS program

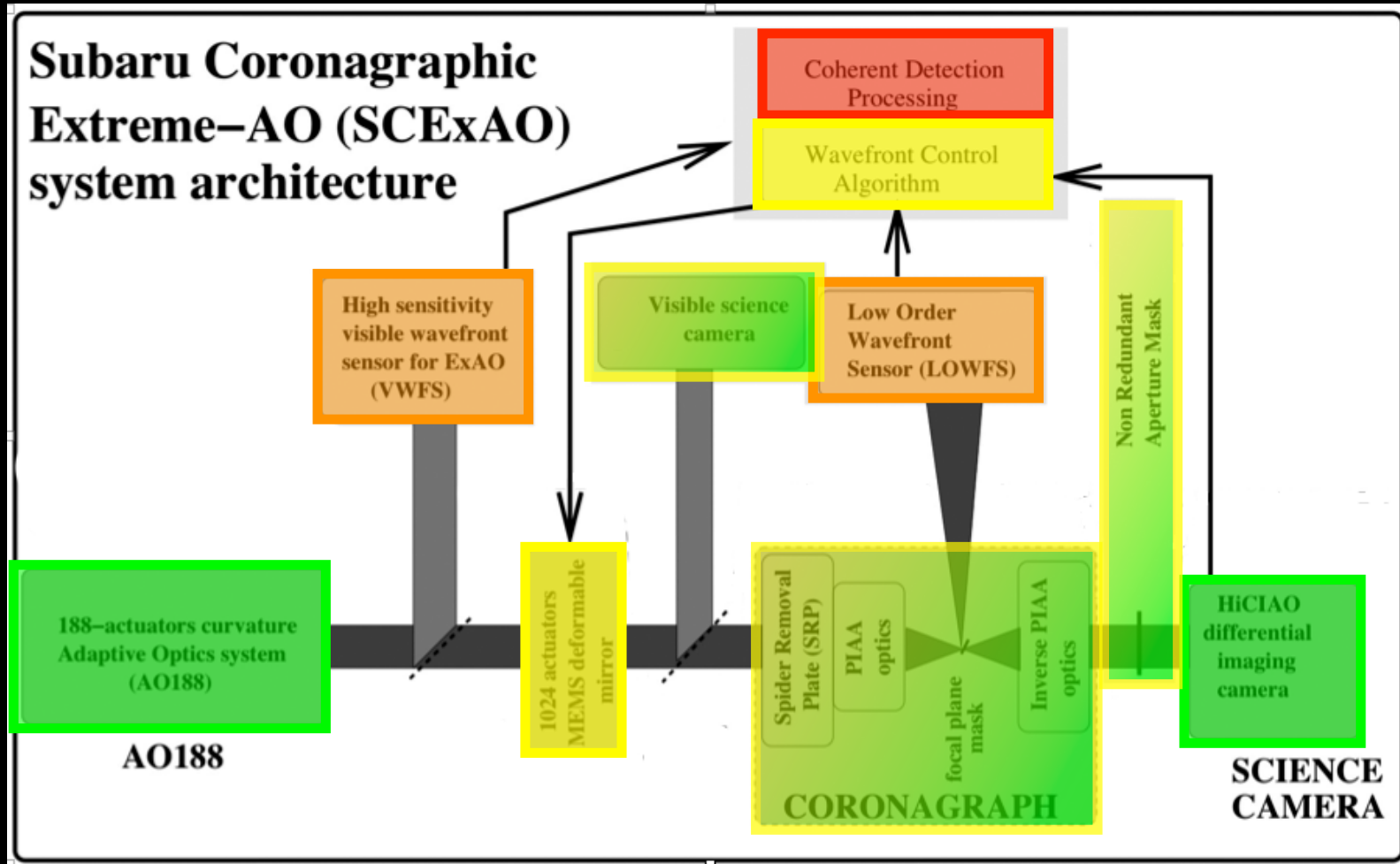
The SCExAO: an upgrade of the current Lyot coronagraph in front of HiCIAO

Open platform design for new concepts tests

Delivered at the telescope: end of 2009



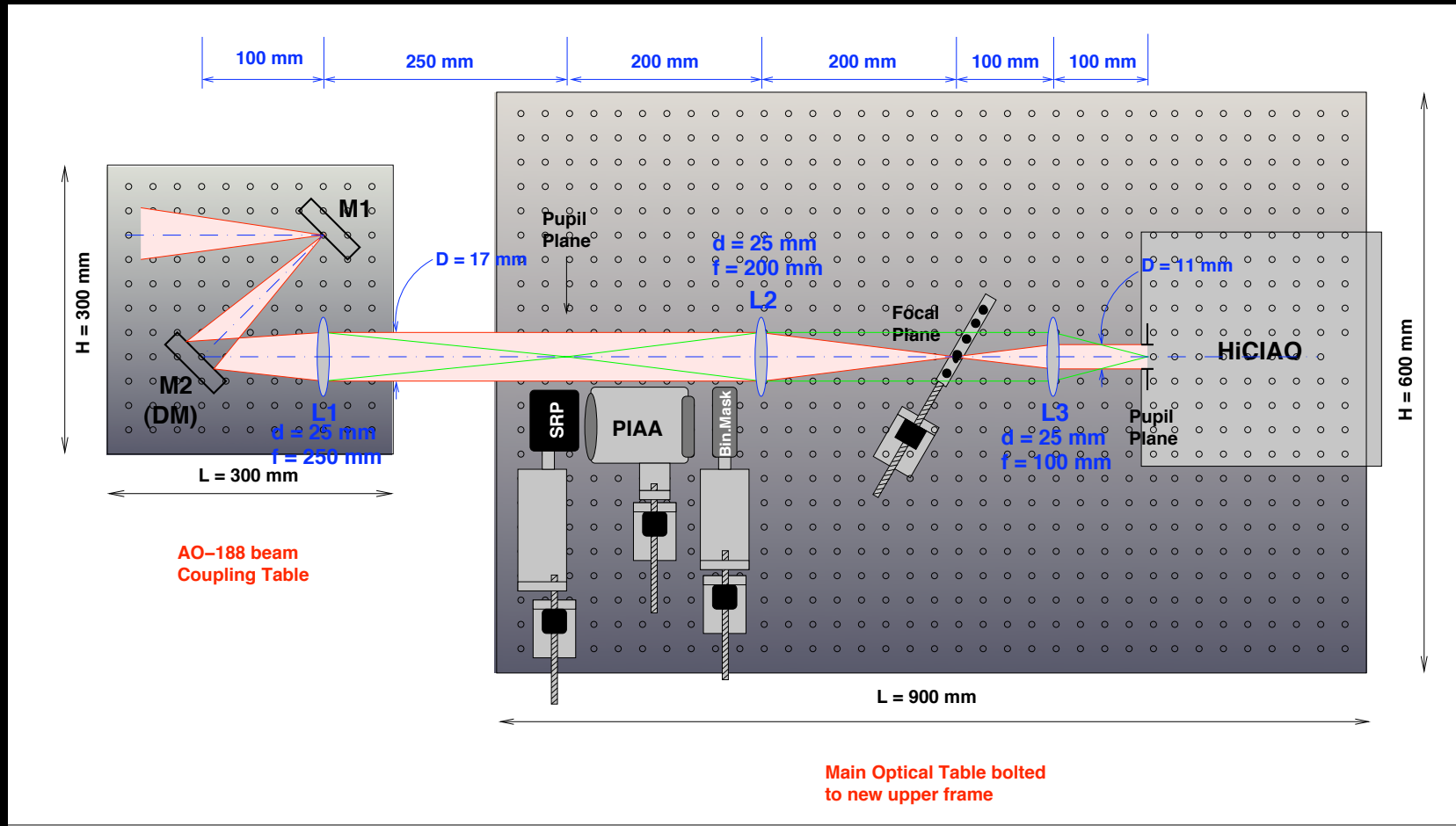
# System architecture



Designed as a flexible, evolvable platform



# Our first objective



Make some room, but maintain HiCIAO's primary observing mode. Only then ...



# Integration

HiCIAO

pupil wheel

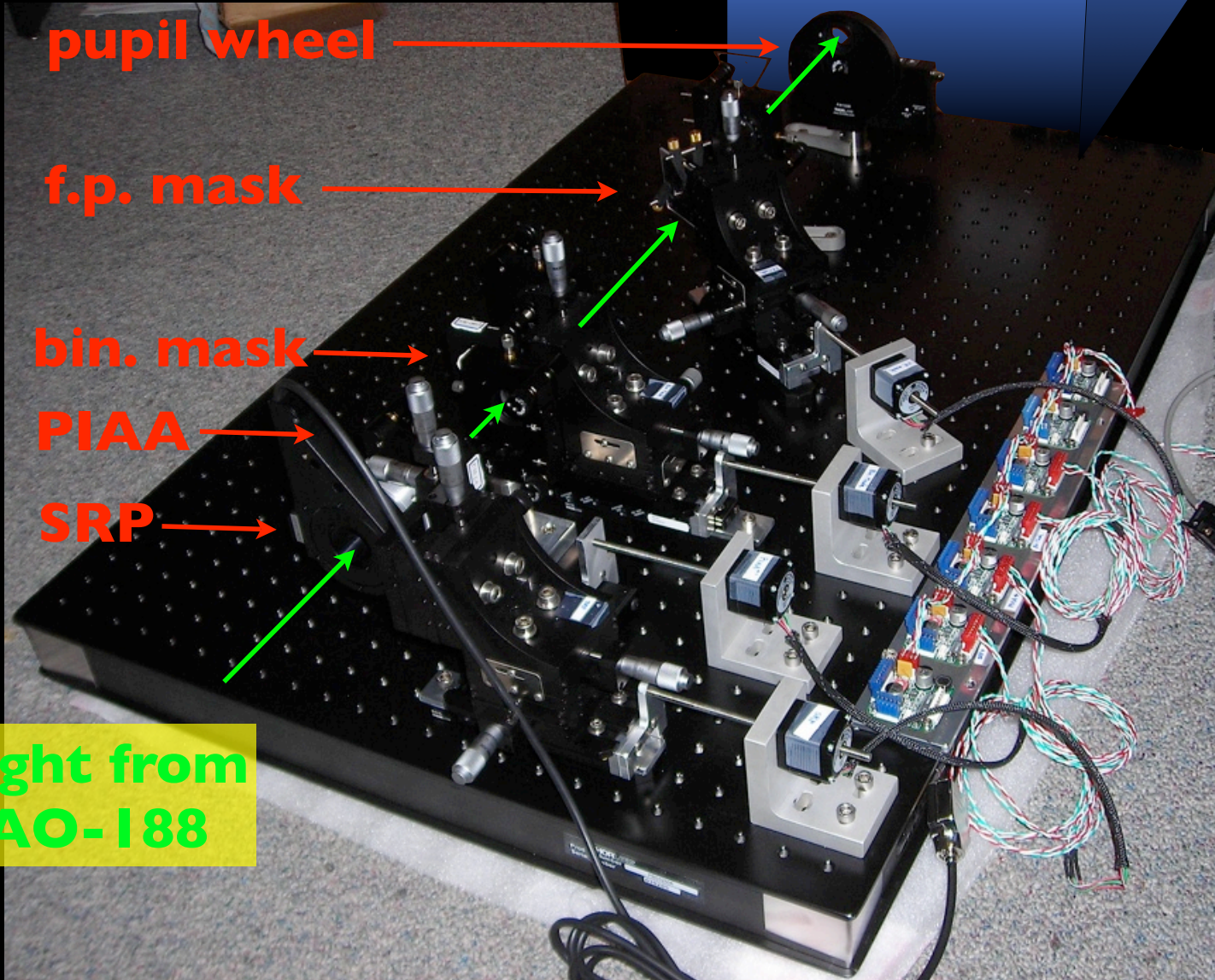
f.p. mask

bin. mask

PIAA

SRP

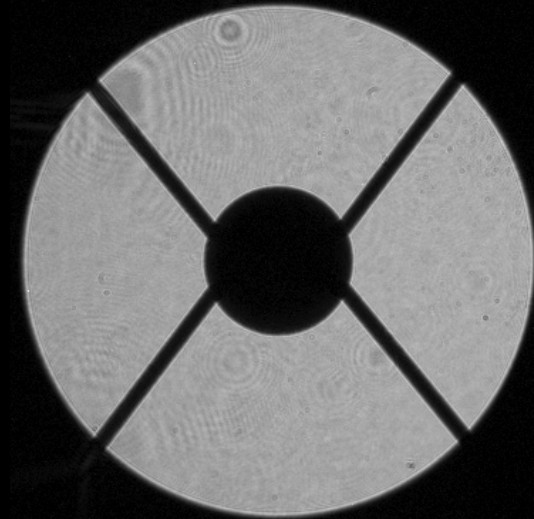
Light from  
AO-188





# Let's massage the Beam!

The Subaru pupil is not fitted for High Angular Resolution



*simulated PSF*

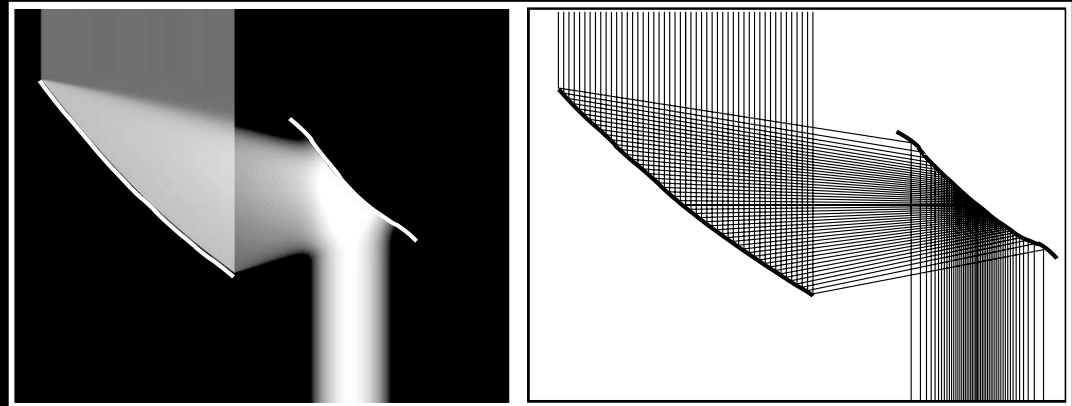
But cures exist!

- Apodization gets rid of rings
- SRP gets rid of the spikes



# Apodization with a PIAA

Two aspheric optics redistribute the light and keep things clean...



- 100 % throughput (well, almost)
- angular resolution is preserved
- high contrast demonstrated @  $1.1 \lambda/D$  (40 mas in H)
- geometric optics  $\rightarrow$  fairly achromatic

*Guyon, 2003, A&A,*

*Guyon et al, 2005, ApJ, 622, 744*

*Martinache et al, 2006, ApJ, 639, 1129*

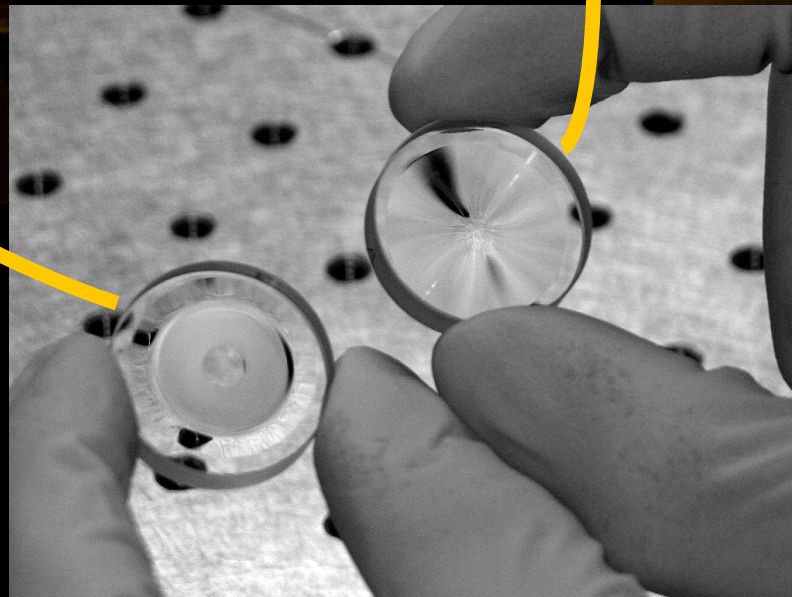
*Pluzhnik et al, 2006, ApJ, 644, 1246*



# 3<sup>rd</sup> generation PIAA optics

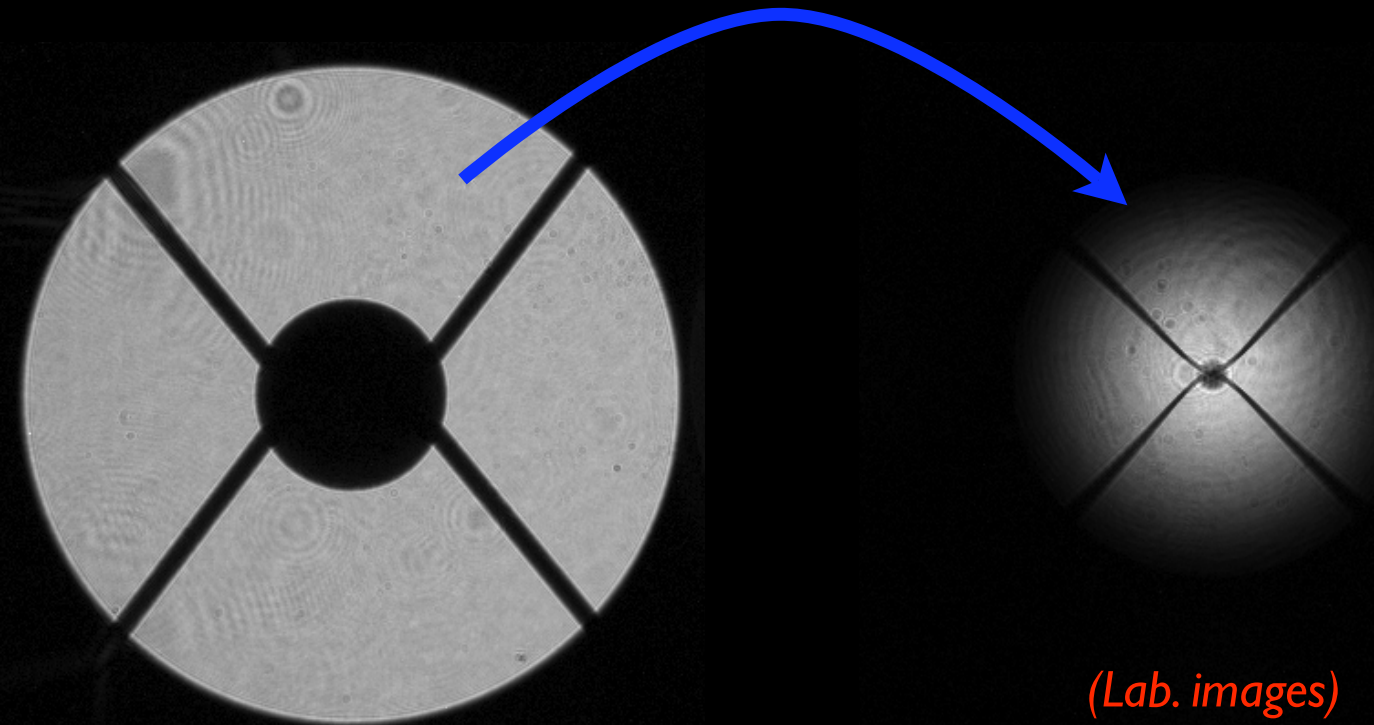
- On-axis lenses
- Lenses are 96 mm apart
- Apodize the beam
- Remove the central obscuration

Optics tested, and good to go!





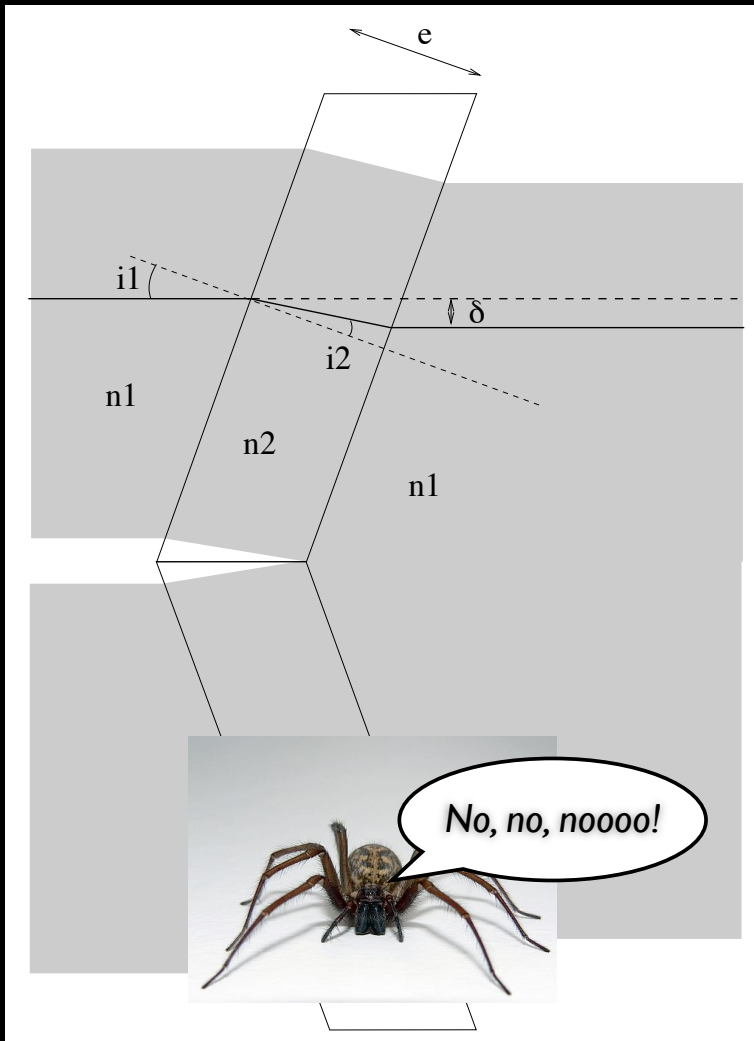
# Apodized beam



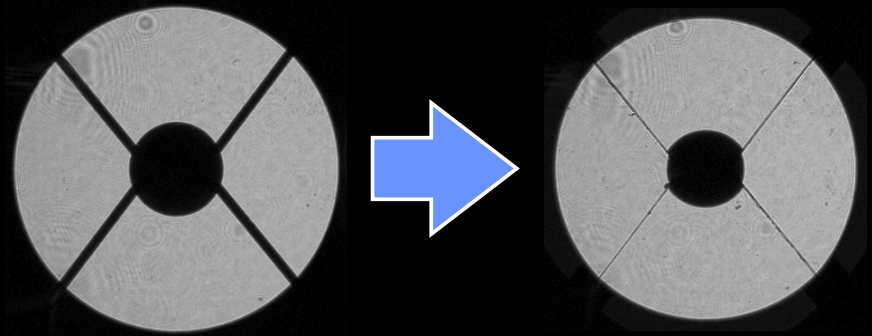
The PIAA does its job but spider vanes remain...



# Spiders beware!



$$\sin i_1 = n \sin i_2$$
$$\delta = e \sin(i_1 - i_2) / \cos i_2$$
$$\text{OPD} \approx e(n - 1)(1 + i_1^2 / 2n)$$

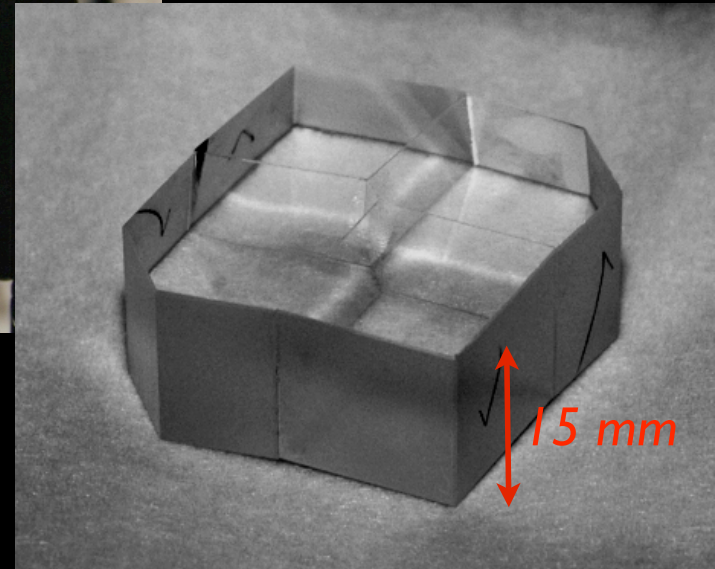
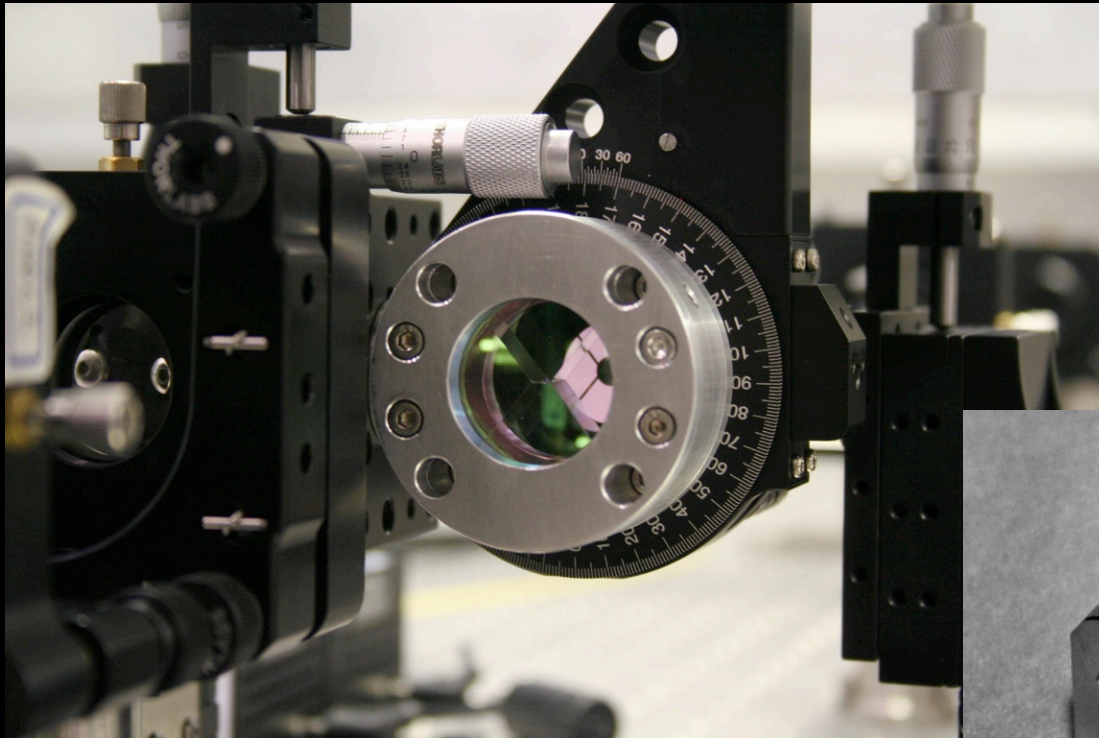


Lozi et al, 2009, in prep.

(Lab. images)



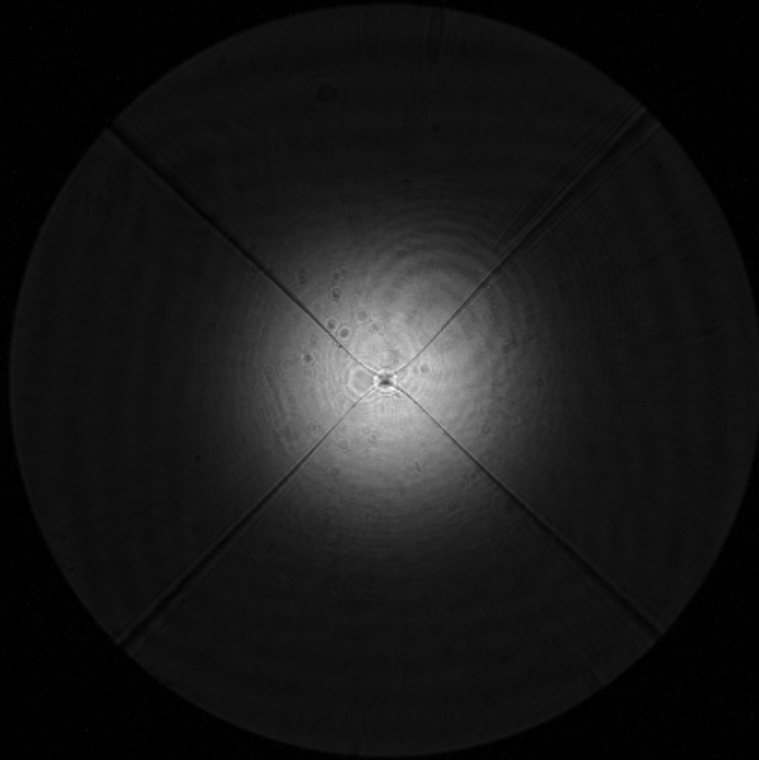
# Spider Removal Plate



- 15 mm thick precision window
- Fused Silica
- Tilt angle:  $5 \pm 0.02^\circ$  does the trick



# Putting things together: SRP+PIAA



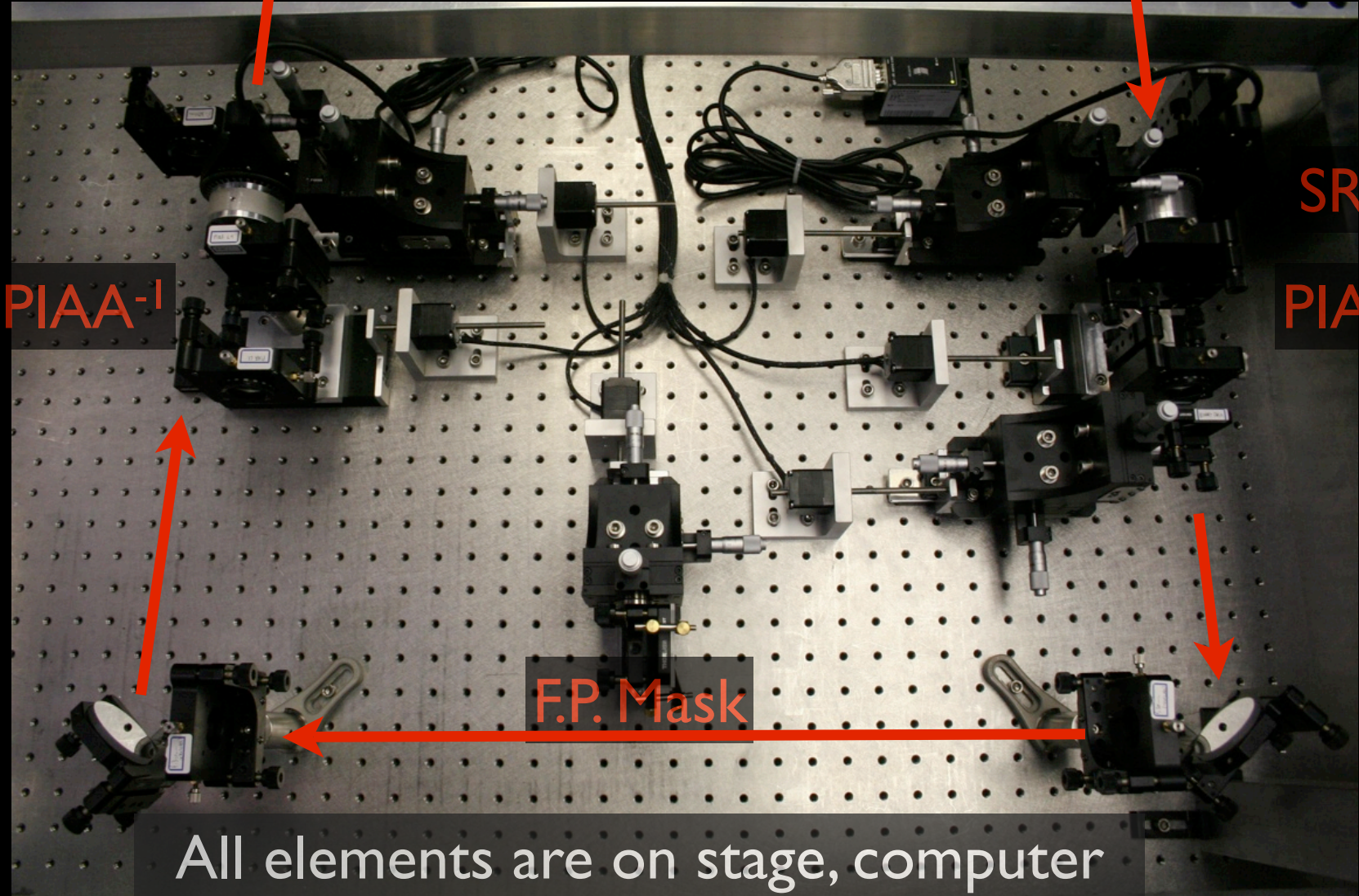
*(Lab. image)*

## Checklist:

- ✓ Spider vanes gone
- ✓ Cent. obscur. gone
- ✓ Pupil apodized



# Lab setup



PIAA-1

SRP

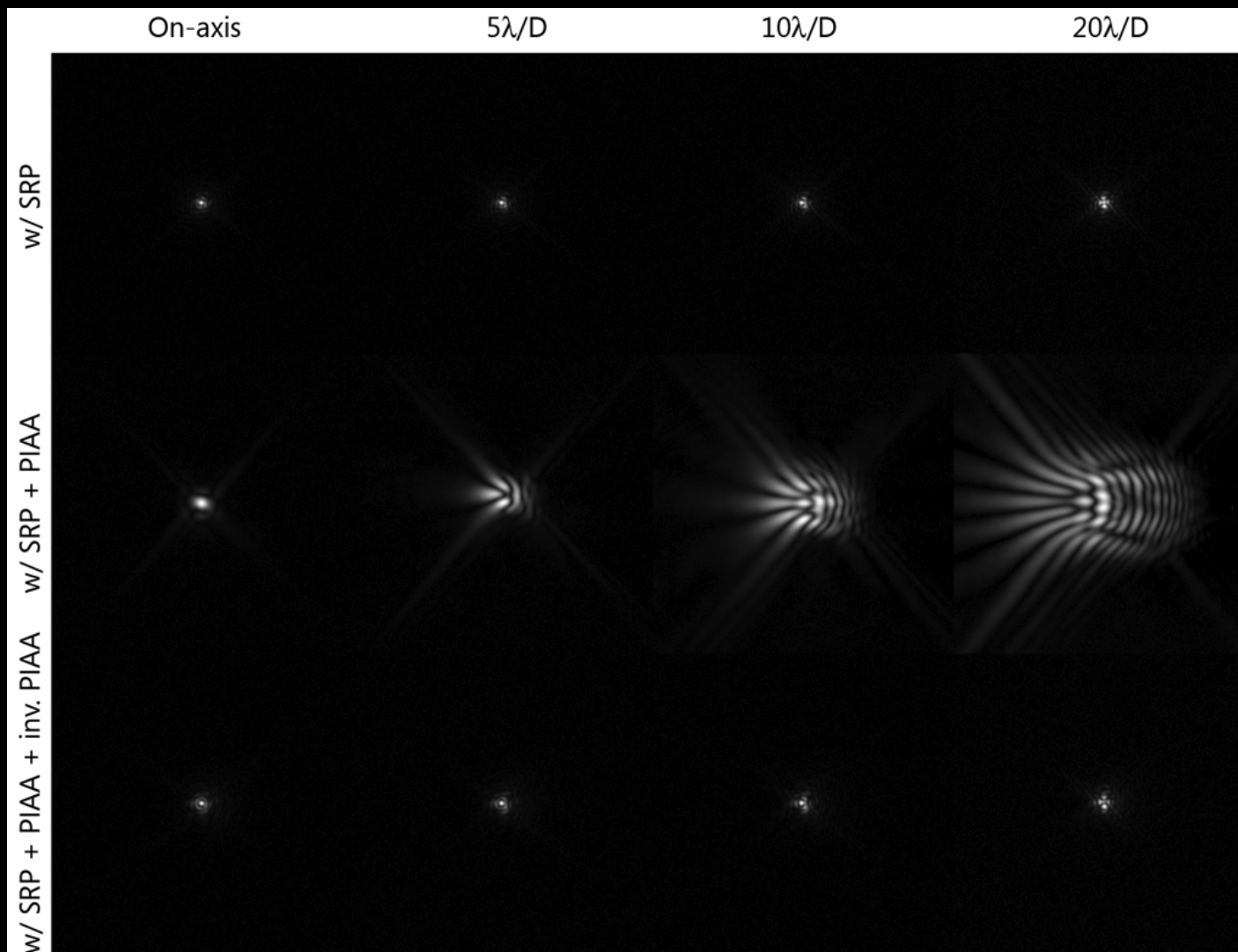
PIAA

F.P. Mask

All elements are on stage, computer controlled for quick diagnostic

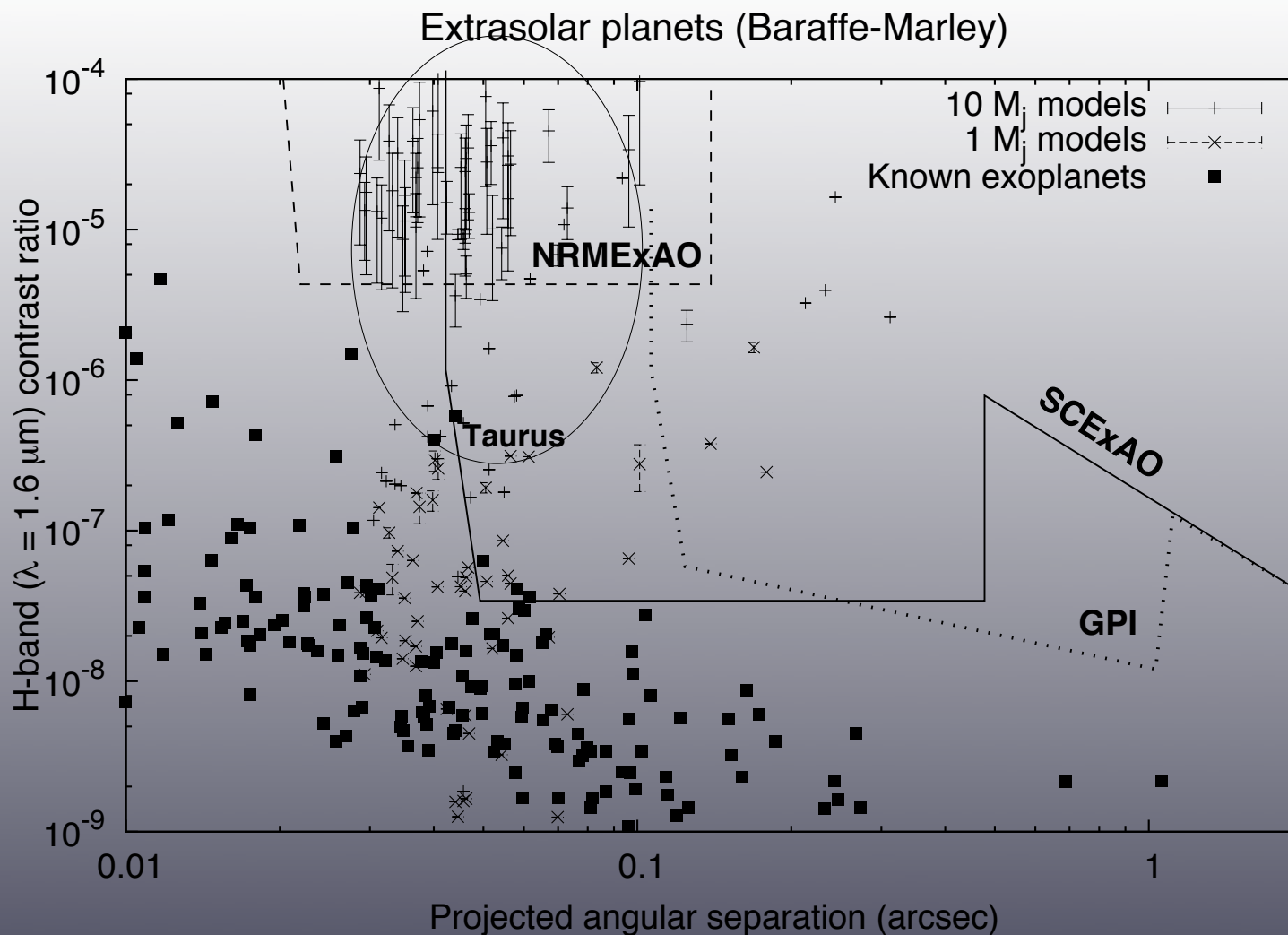


# Recover the Field of view





# Expected performance?





# Conclusion: project status

We're in pretty good shape:  
critical components (PIAA, Masks, SRP) crafted & tested  
WF control techniques being tested now  
All hardware has been purchased

TBD:

mechanical interface with Subaru's IR Nasmyth platform  
Wavefront control after AO-188  
Interface with Hi-CIAO camera

At the telescope by November 2009