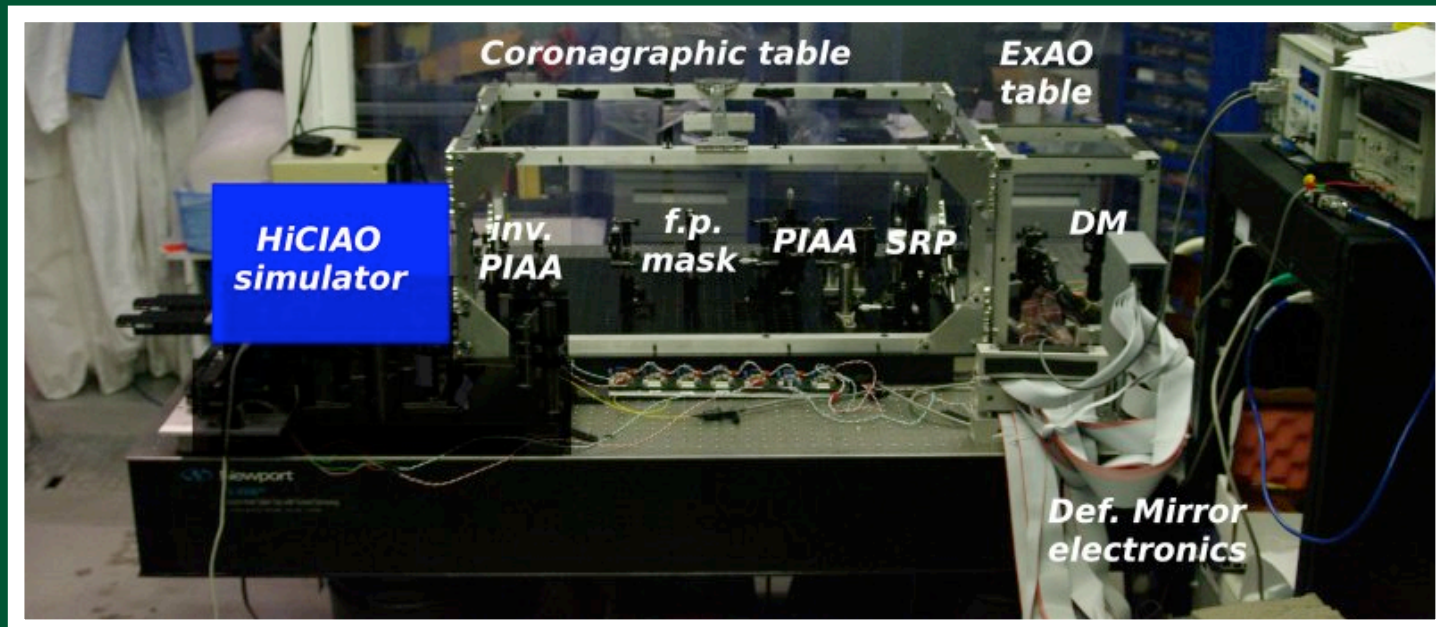


The Subaru Coronagraphic Extreme AO Project

August 5, 2009



Frantz Martinache
CEAO Research Fellow

*Acknowledgement: Olivier Guyon,
Vincent Garrel, Gaetano Sivo, Frédéric Vogt,
Tyler Groff, Yosef Razin, Elizabeth Jensen,
Julien Lozi, Michael McElwain, Ryuji Suzuki,
Yoshi Doi, Steve Colley, Brian Elms*



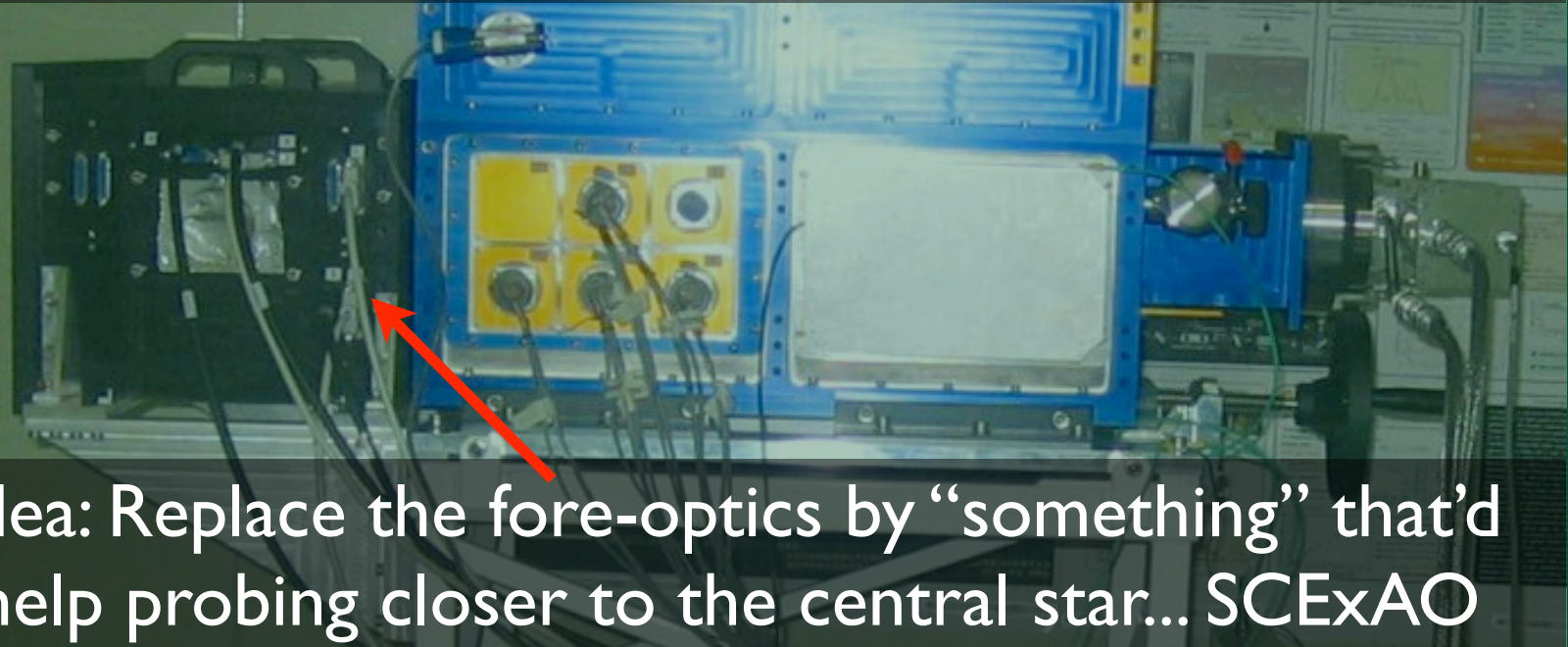
SCExAO and



S E E D S

HiCIAO: coronagraphic imager for Subaru (AO188)
SEEDS: a 120-night survey for exoplanets and disks

Like other comparable surveys, inner working angle
limited to 0.5" ($\Delta H=9.5$) or 1" ($\Delta H=12$)



idea: Replace the fore-optics by “something” that’d
help probing closer to the central star... SCExAO



“in house” techno developments

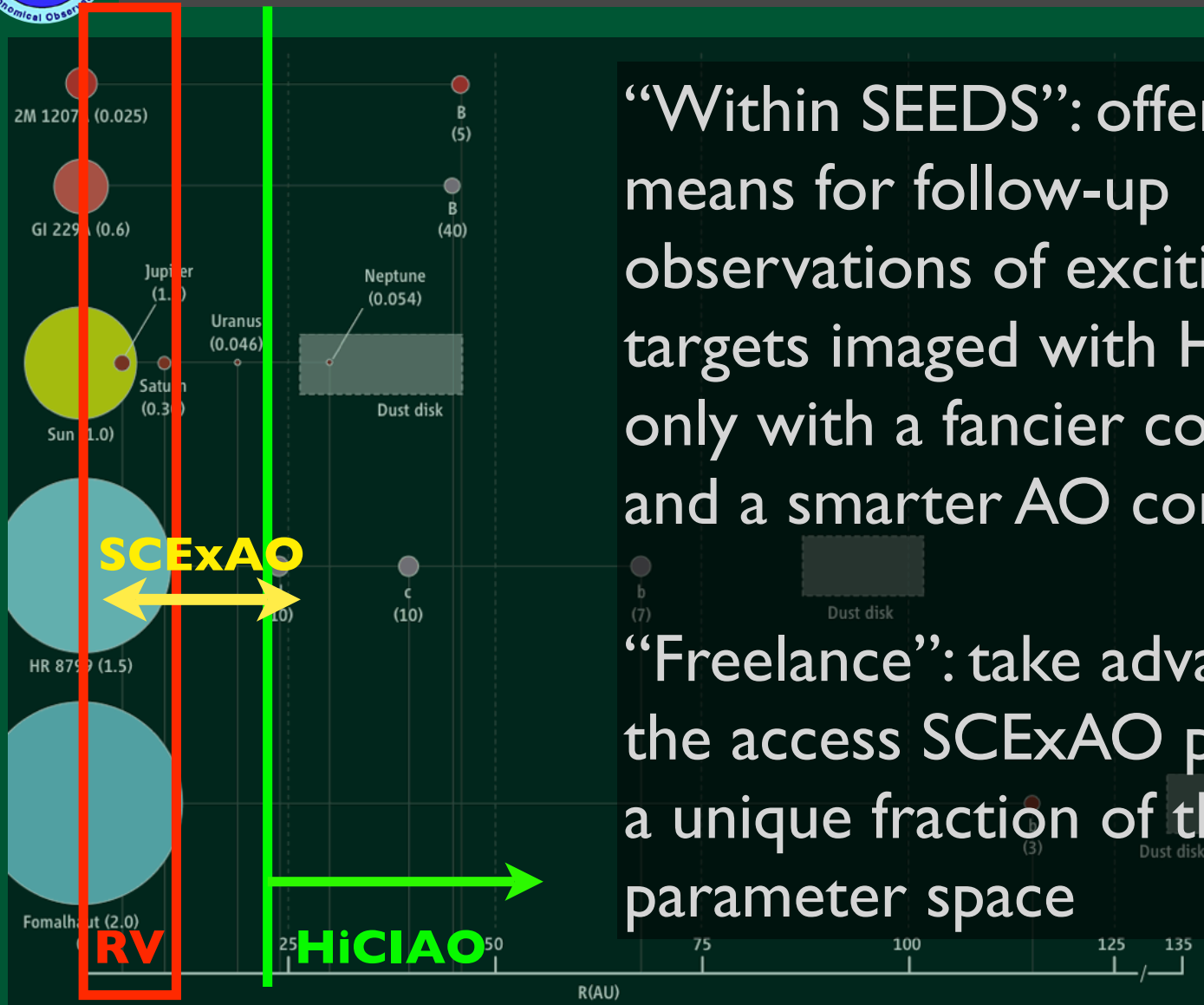
Take advantage of recent developments, some (most) of which were made at Subaru

These techniques are now mature:

- PIAA coronagraph
- Spider Removal Plate
- Aperture Masking Interferometry
- Coronagraphic Low Order Wavefront Sensor
- Advanced WFS sensing techniques
- maybe your technique also?



Project objectives



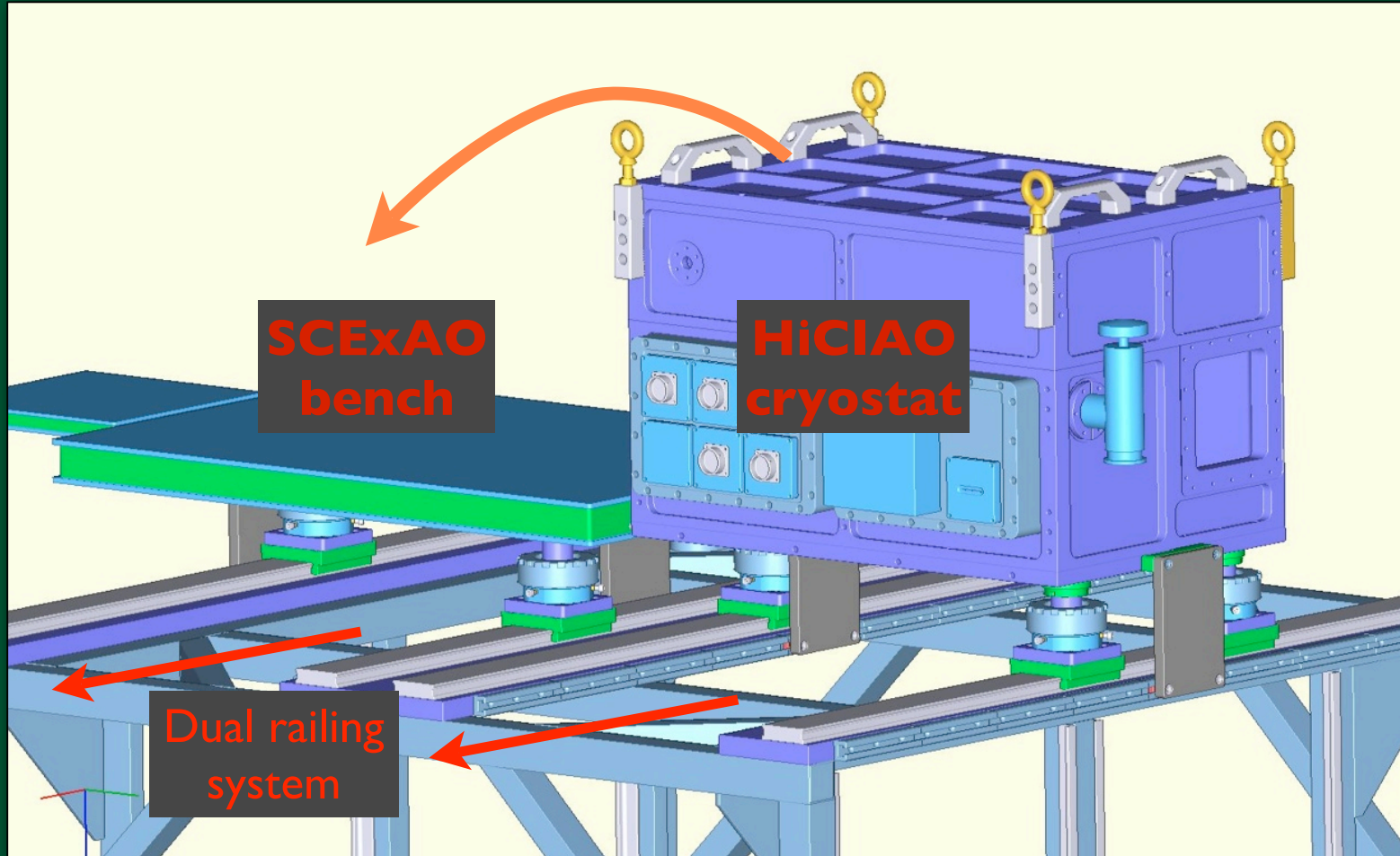
“Within SEEDS”: offer the means for follow-up observations of exciting SEEDS targets imaged with HiCIAO only with a fancier coronagraph and a smarter AO correction.

“Freelance”: take advantage of the access SCEXAO provides to a unique fraction of the parameter space

(fig. from Marley, Sci. Exp, 10/13/2008)



Reconfigurable frame

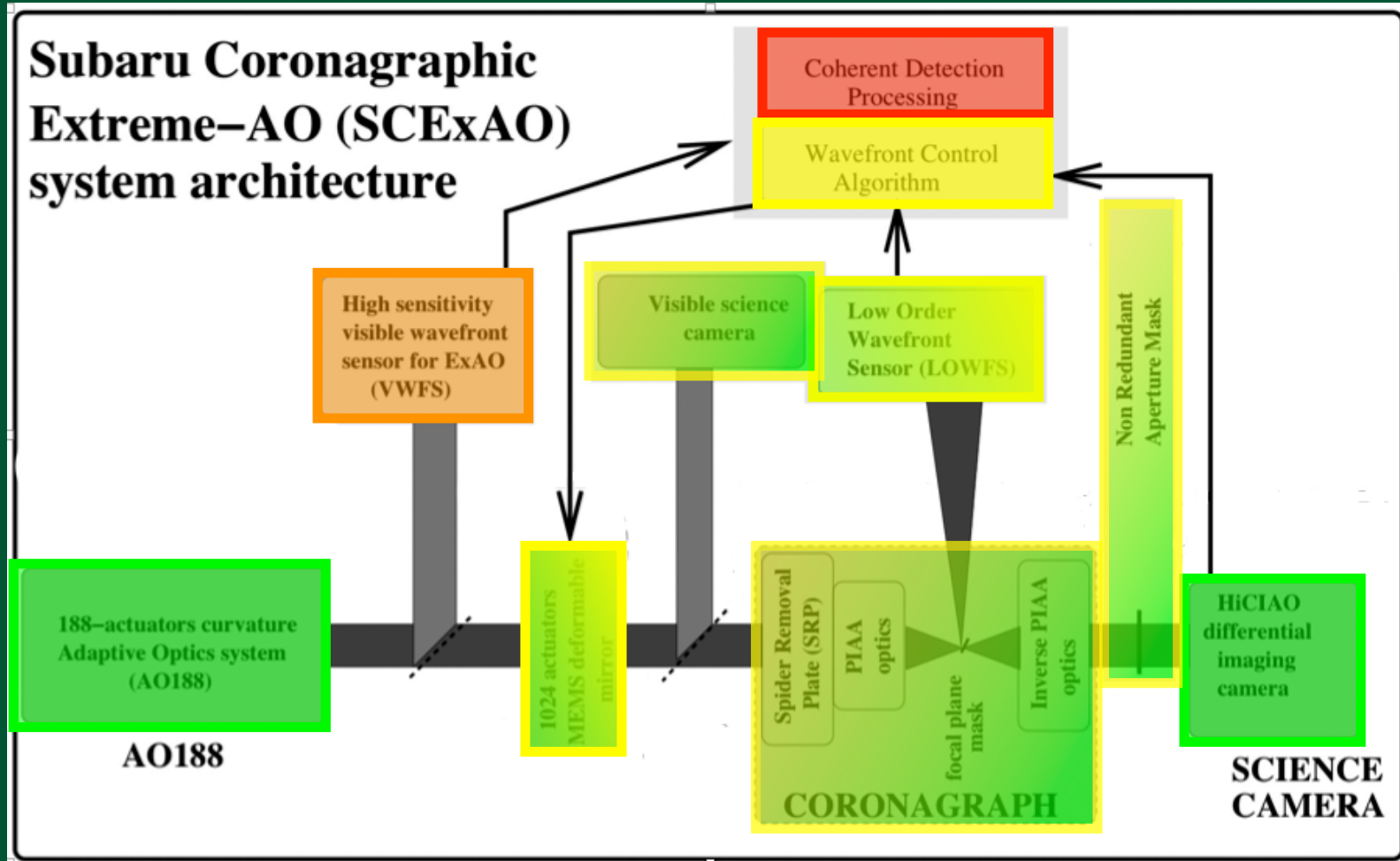


Manufacturing of the frame is financed
Delivery @ Nasmyth platform 01/2010
Frame can host guest instruments

(CAD drawing by Yoshi Doi)



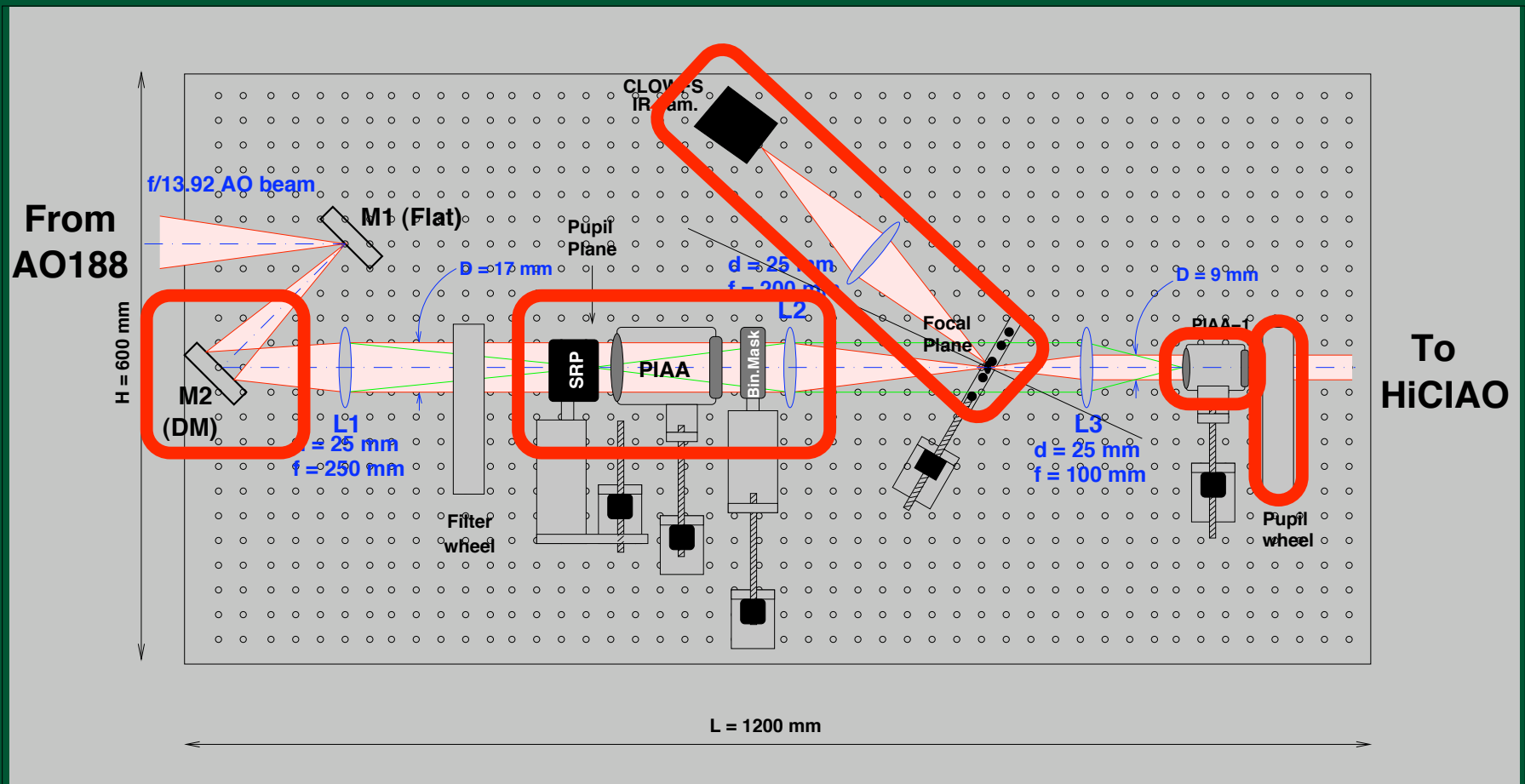
System architecture



Designed as a flexible, evolvable platform

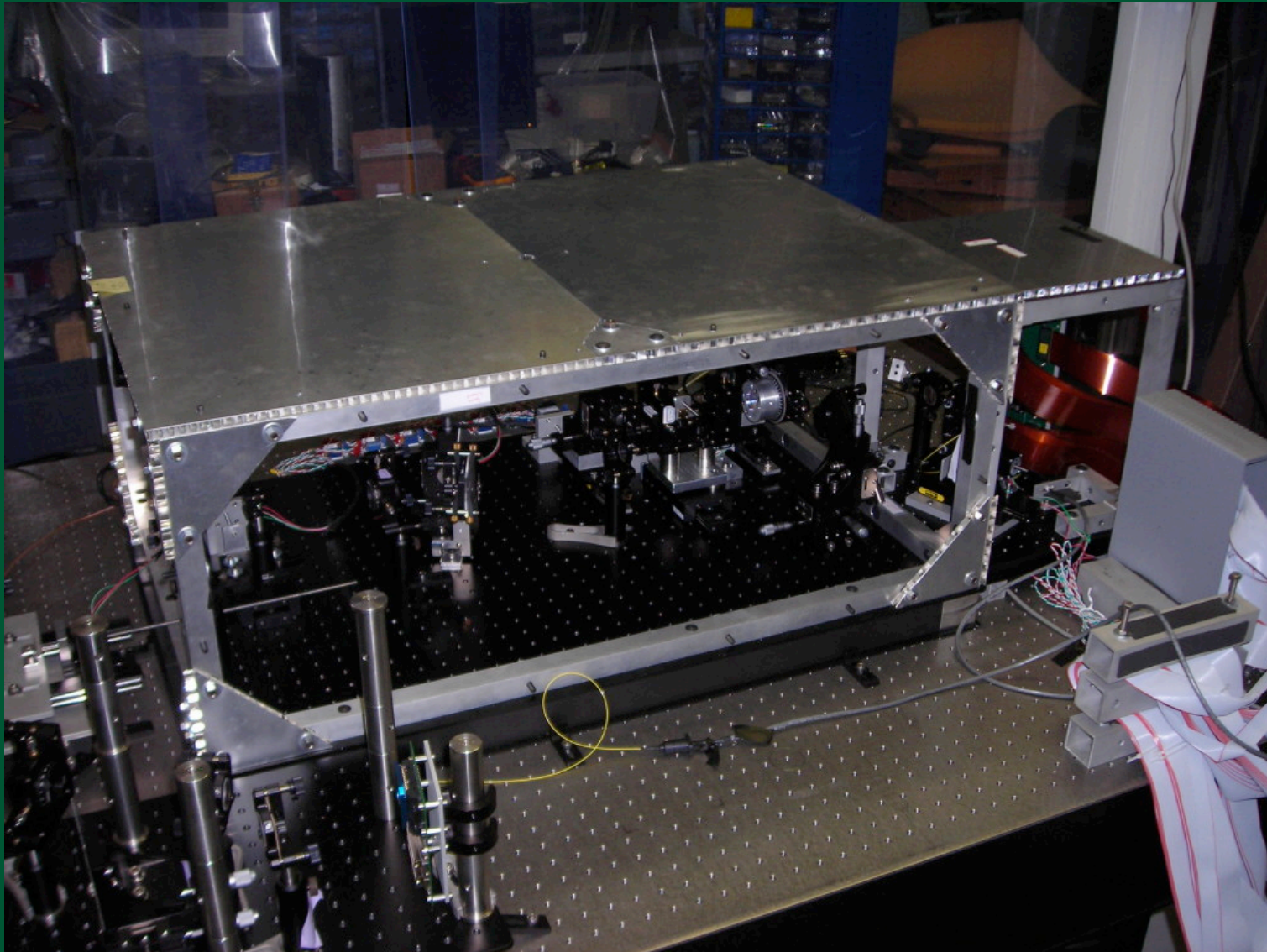


First optical design



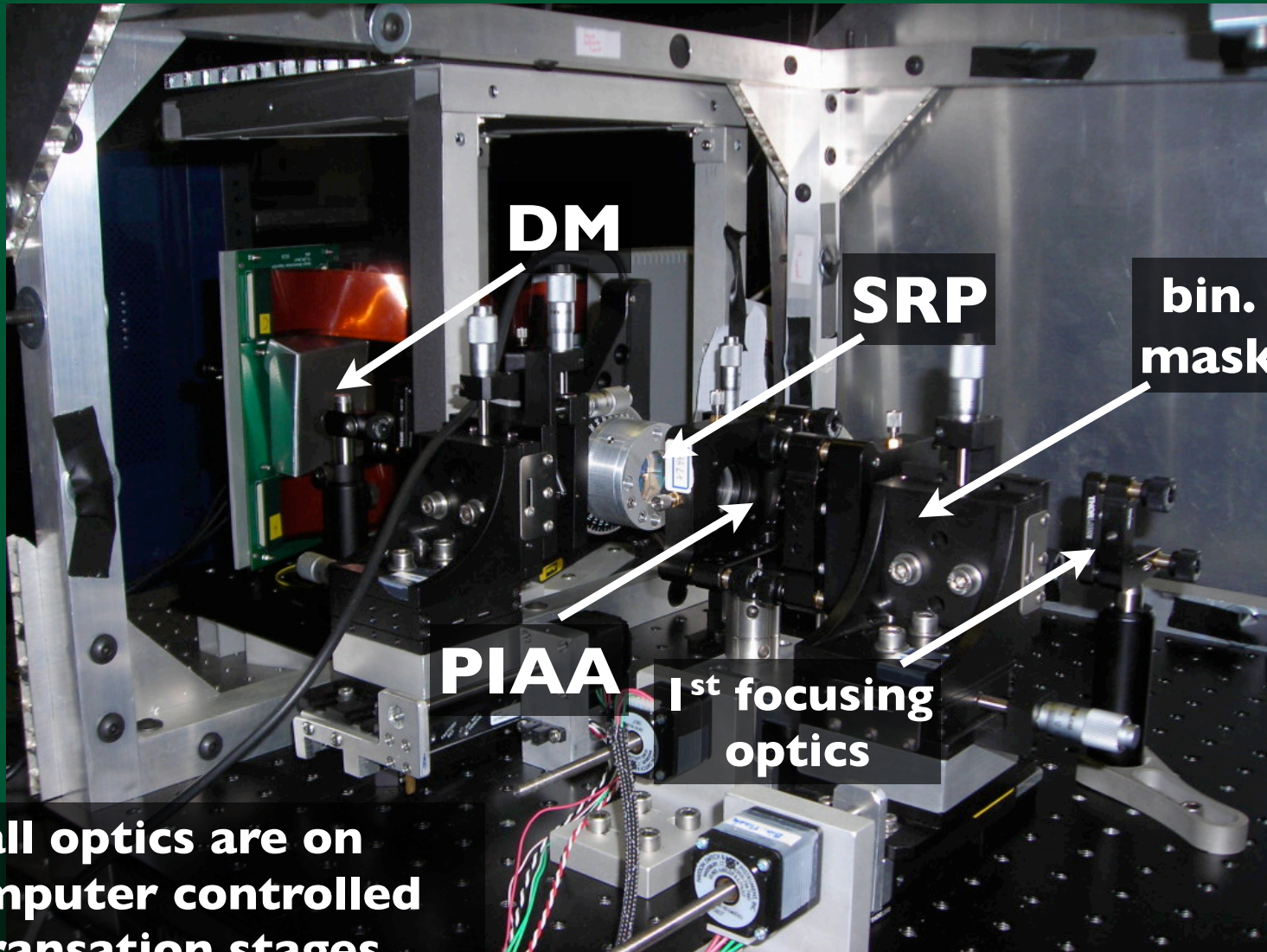


work in progress





compact beam forming module



**all optics are on
computer controlled
translation stages**

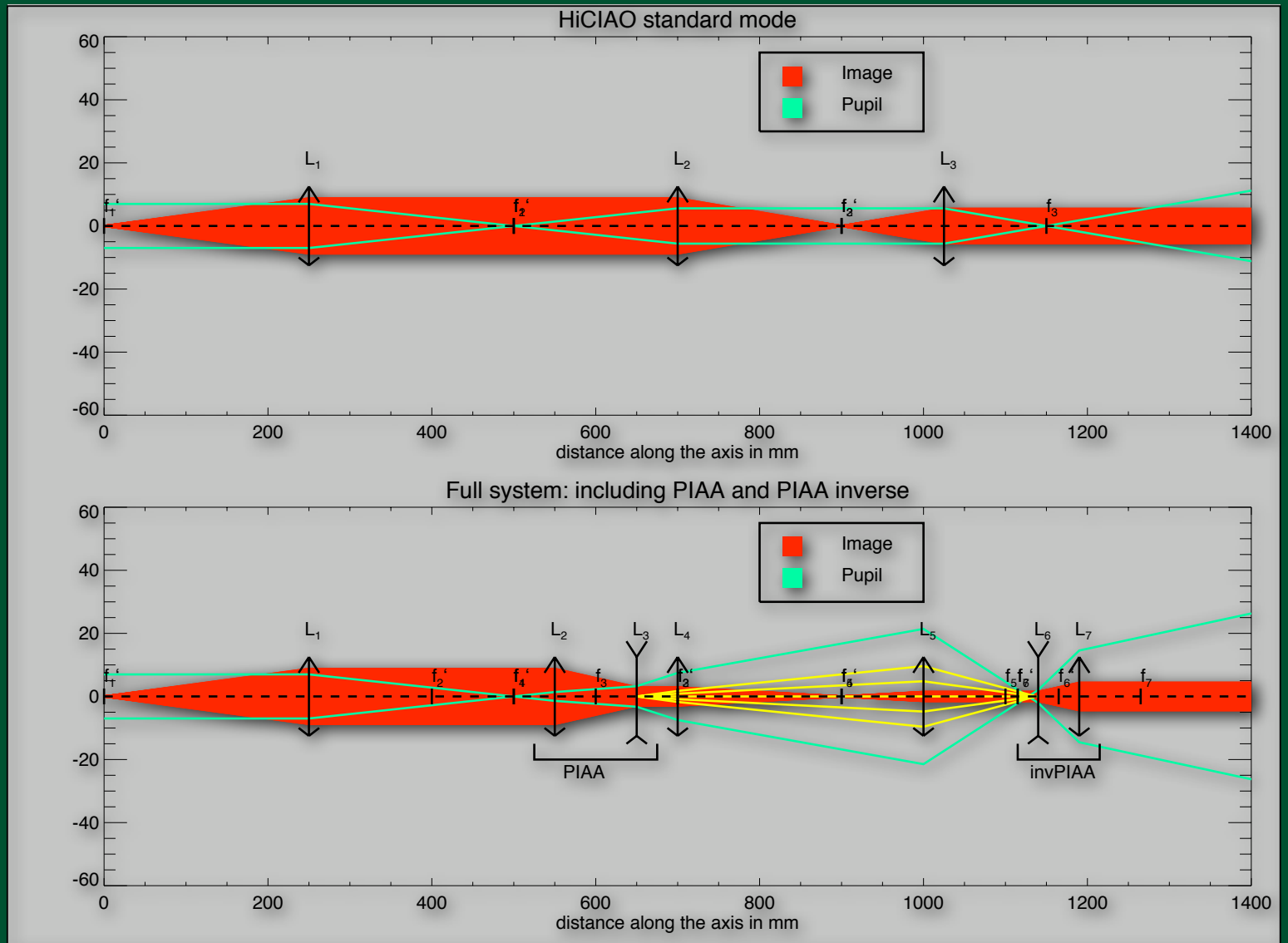


Optical configurations

emulate the
current
HiCIAO
fore-optics

or

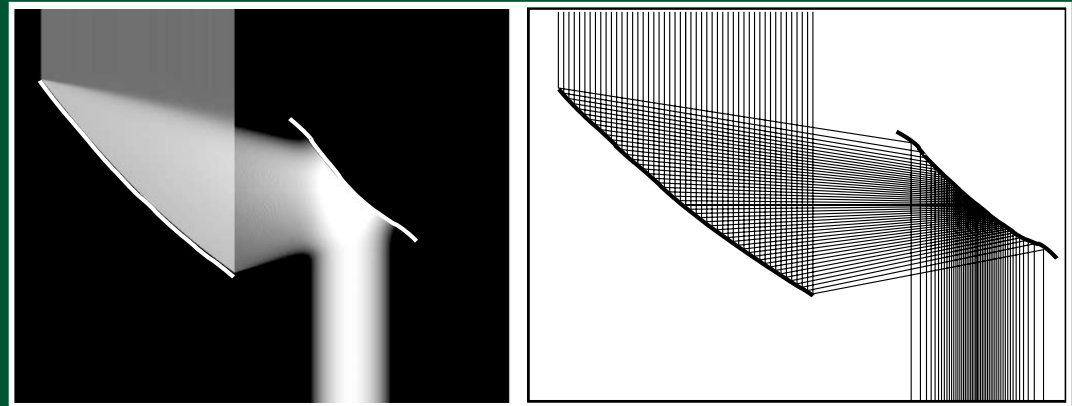
go for the
whole
shebang





Phase Induced Apodization

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,

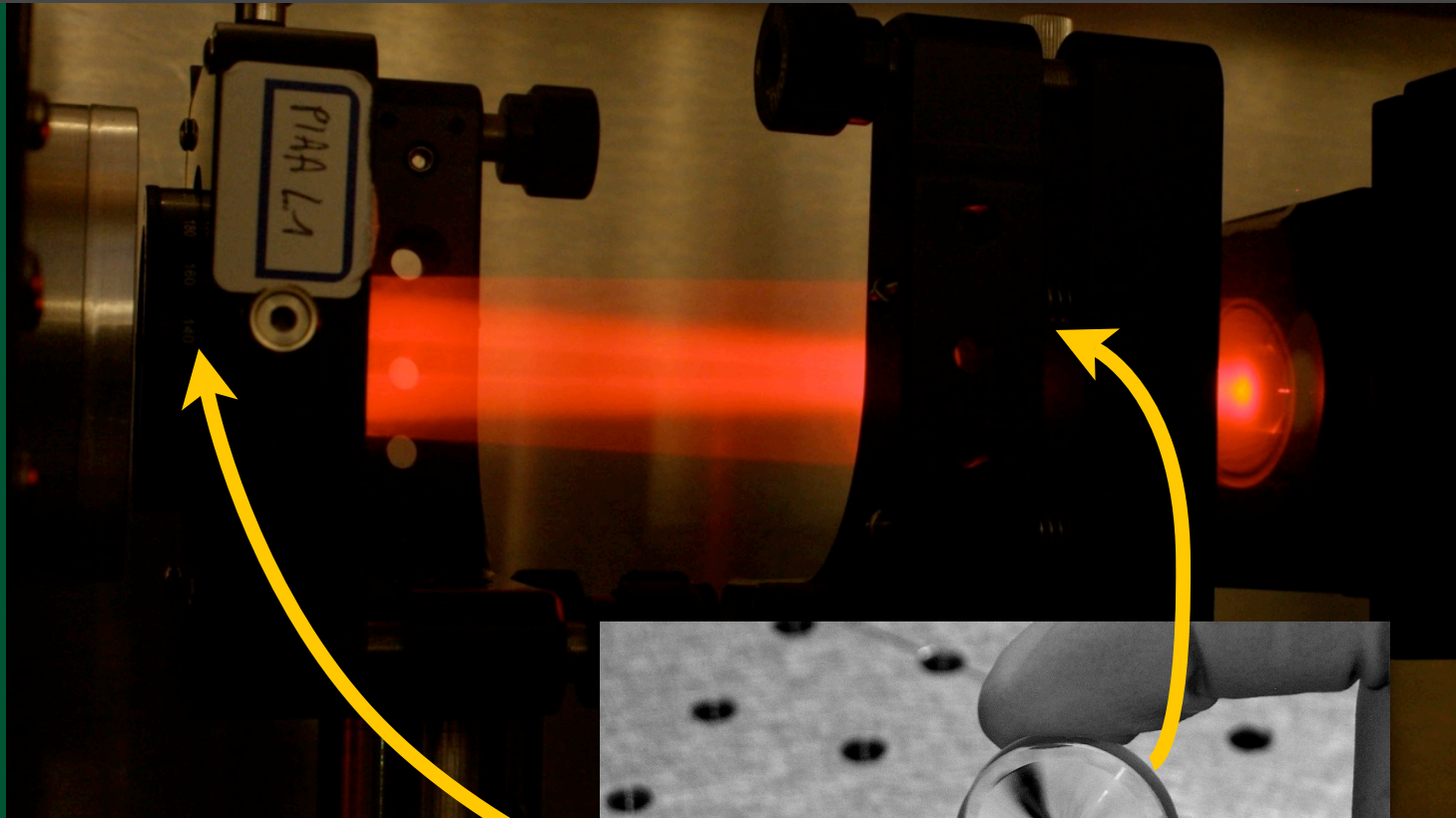
Guyon et al, 2005, ApJ, 622, 744

Martinache et al, 2006, ApJ, 639, 1129

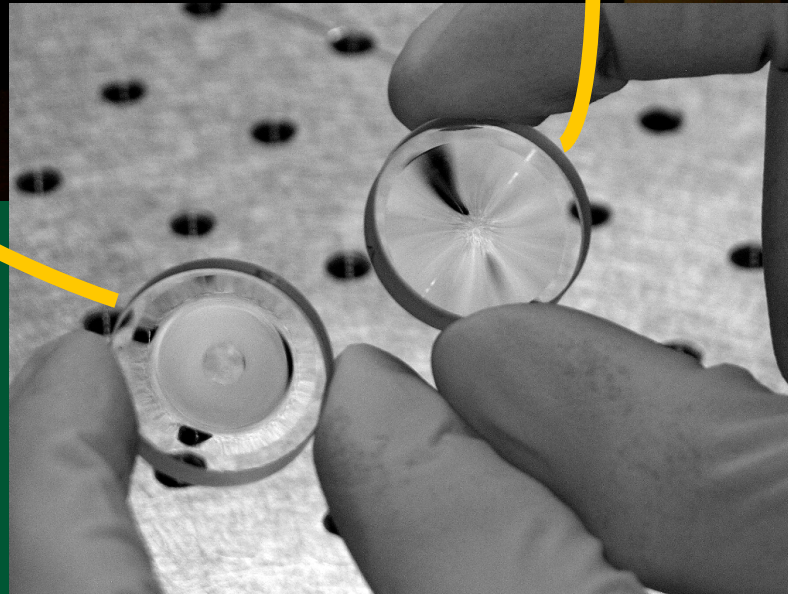
Pluzhnik et al, 2006, ApJ, 644, 1246



3rd generation PIAA optics



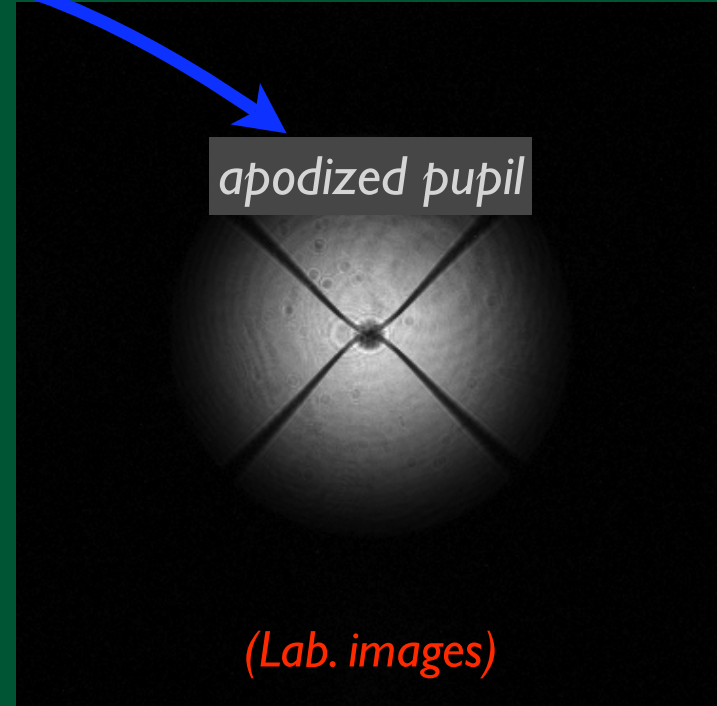
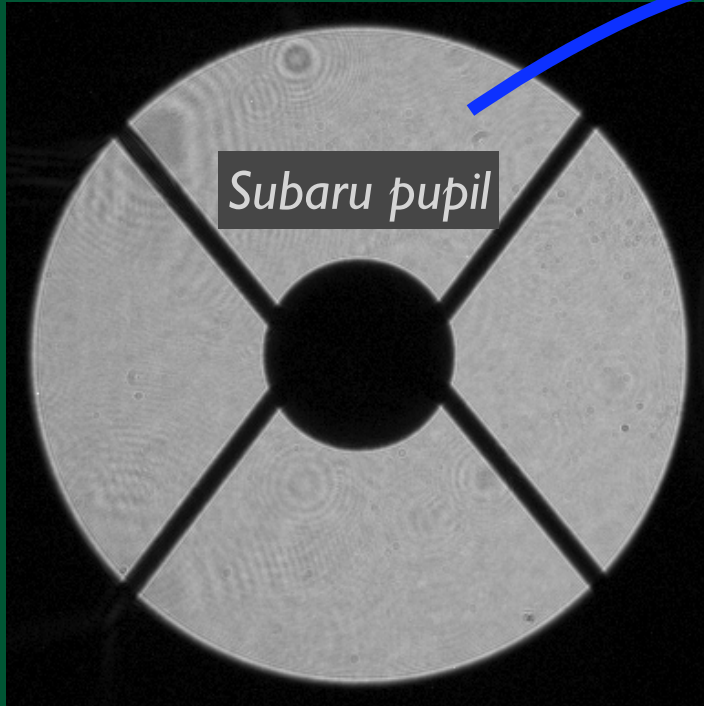
- On-axis lenses
- Lenses are 96 mm apart
- Apodize the beam
- Remove the central obscuration



Optics tested, and good to go!



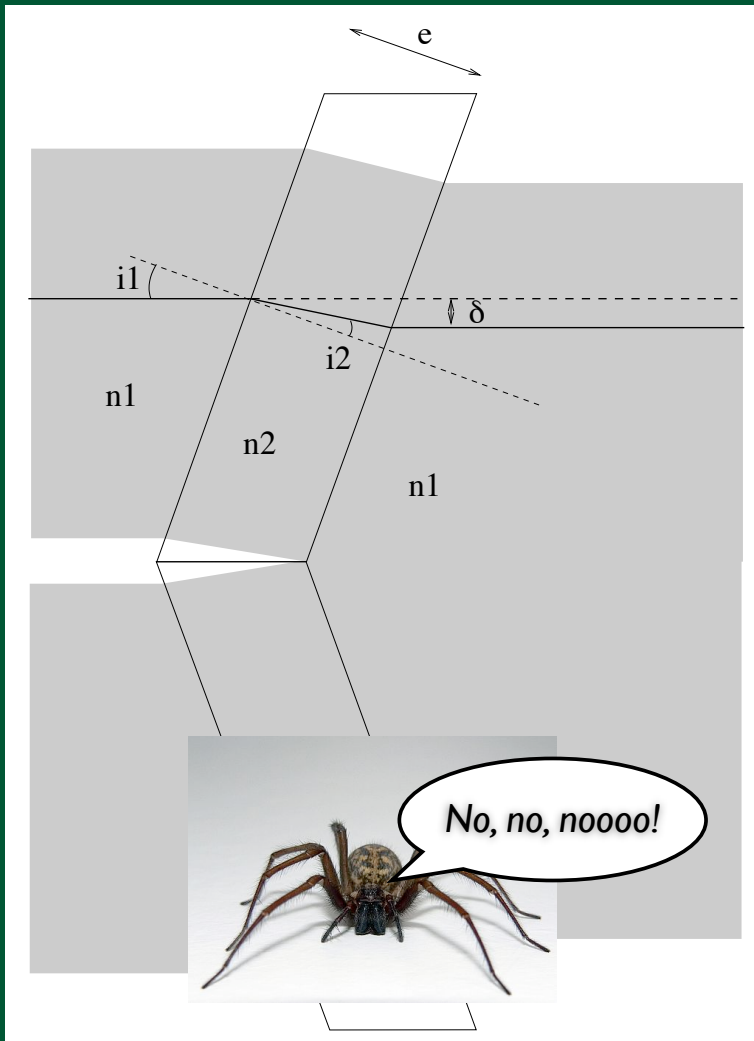
Beam Apodization



- Pupil apodized
- Central obscuration pretty much gone
- Spiders still there...

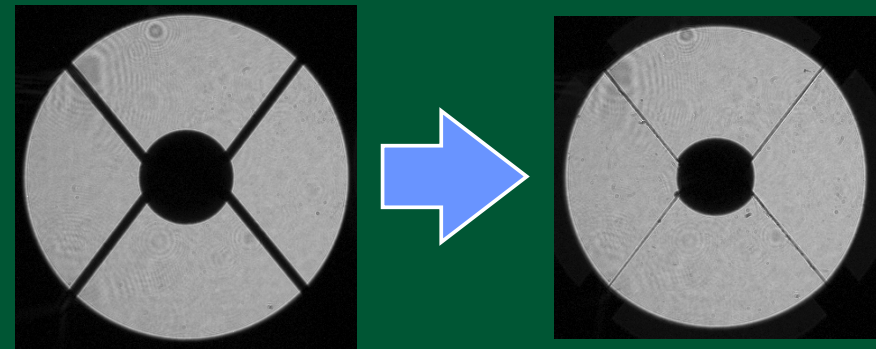


Spider Removal Plate



Lozi et al, 2009

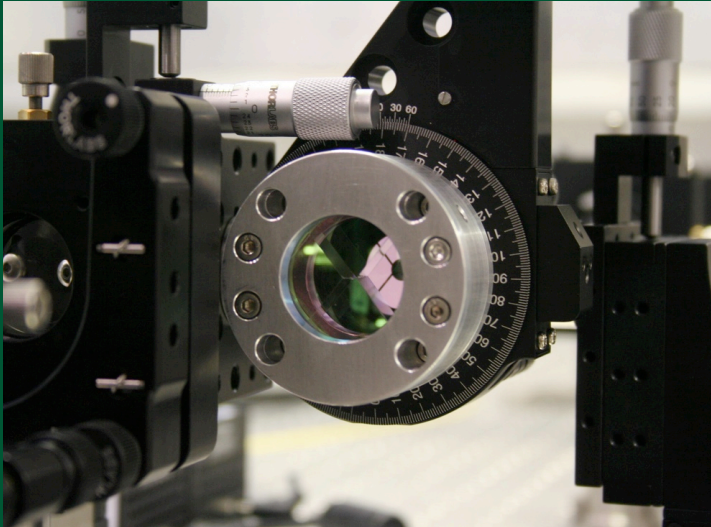
$$\sin i_1 = n \sin i_2$$
$$\delta = e \sin(i_1 - i_2) / \cos i_2$$
$$\text{OPD} \approx e(n - 1)(1 + i_1^2 / 2n)$$



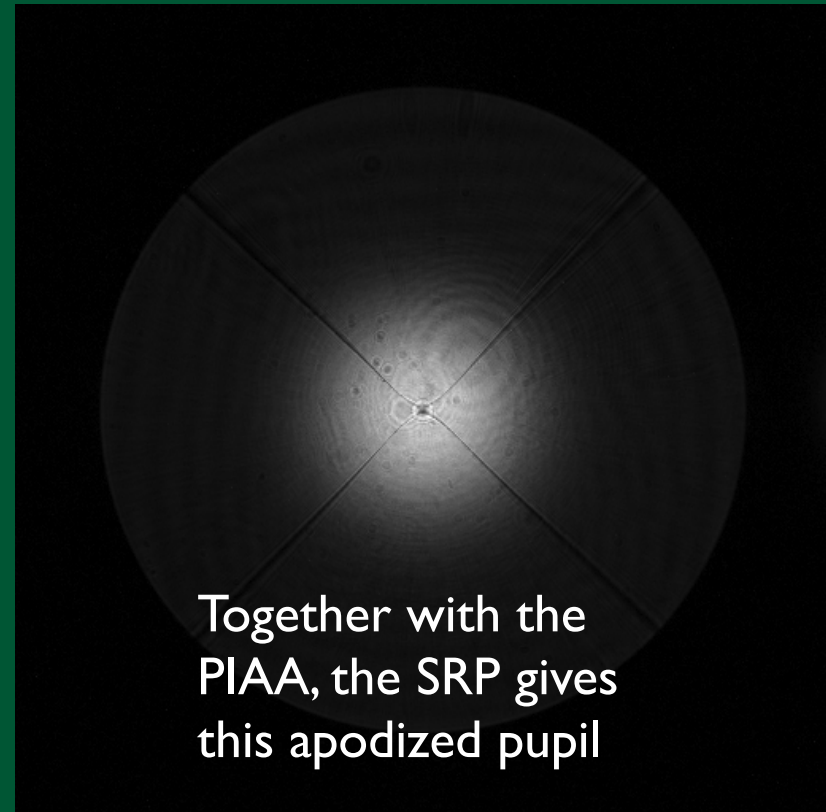
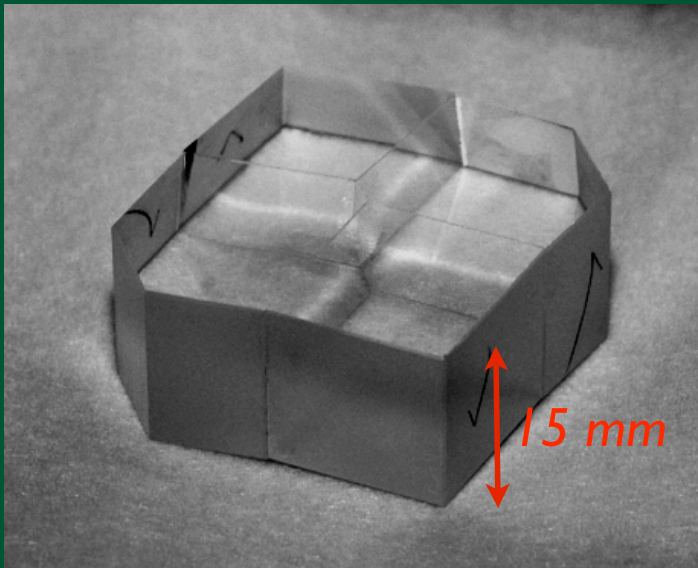
(Lab. images)



Spider Removal Plate



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

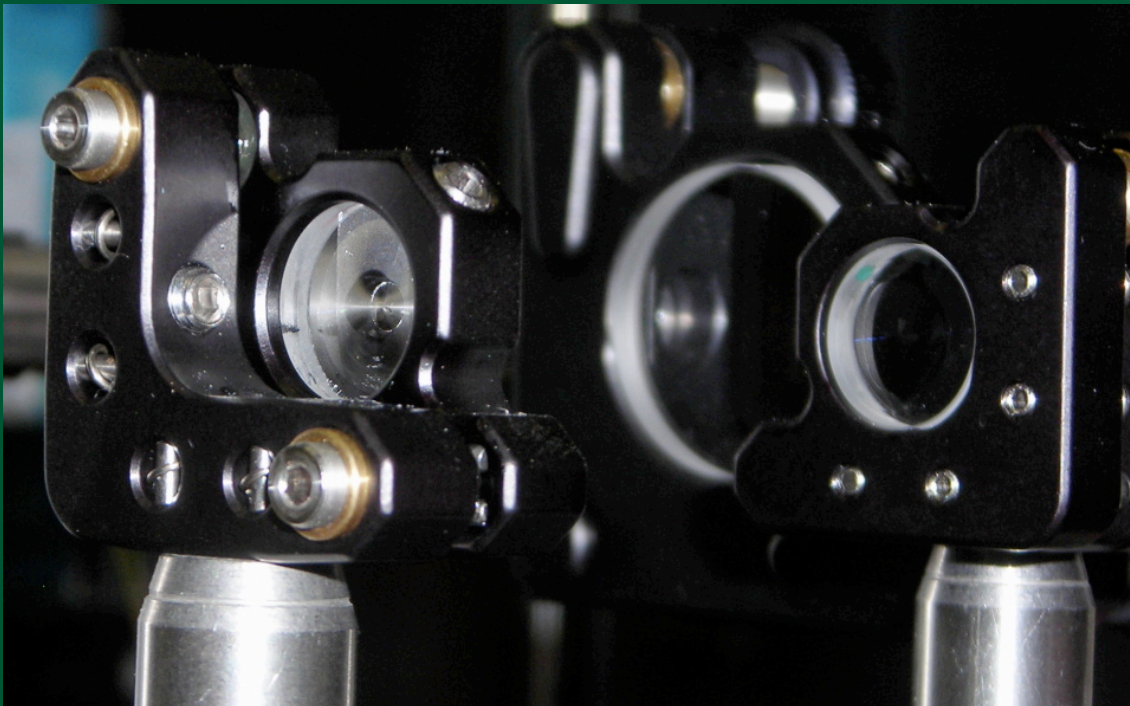


Together with the PIAA, the SRP gives this apodized pupil



PIAA⁻¹: principle

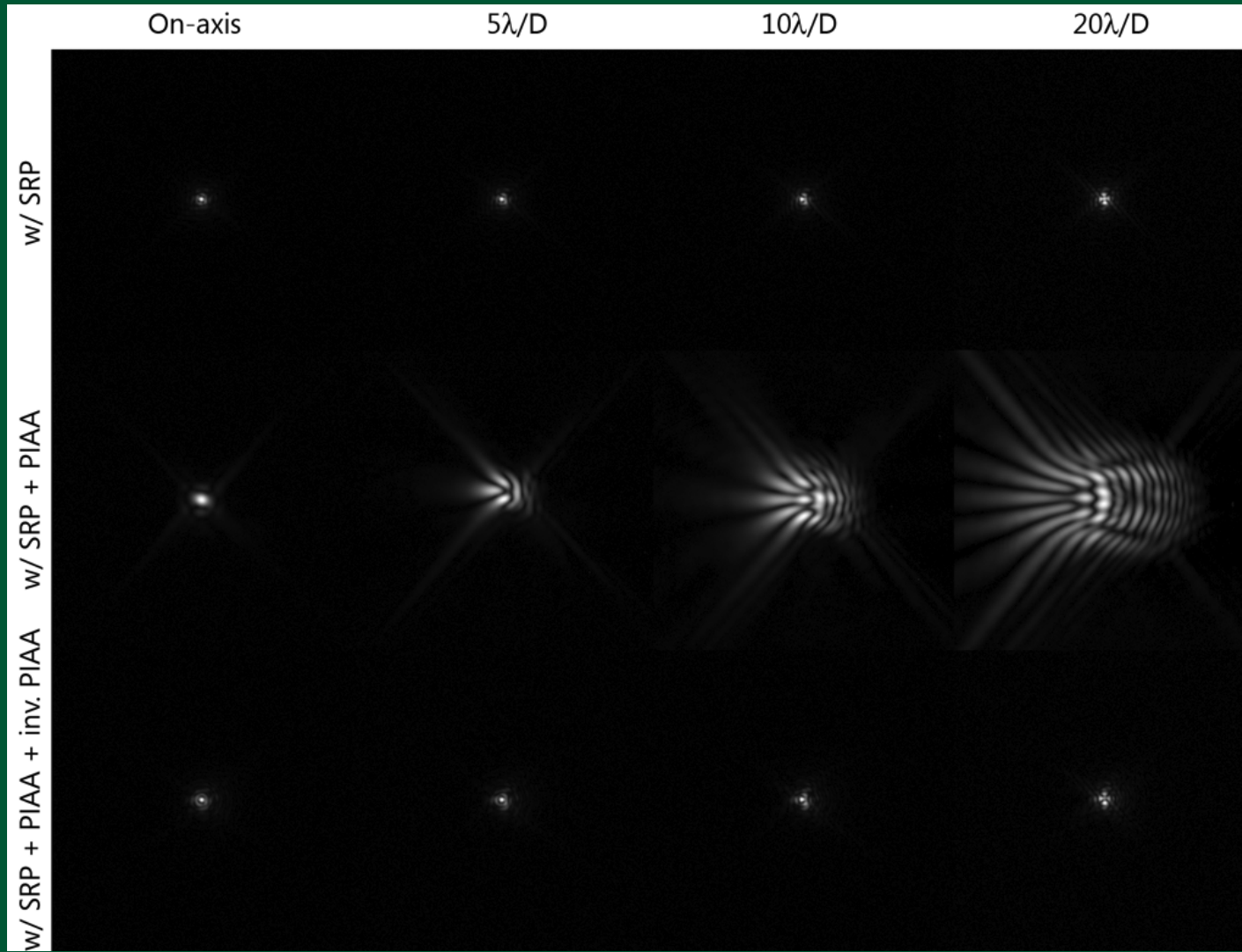
For some years, the idea of tweaking the pupil has been difficult to accept...



exact copy of the PIAA,
scaled down (factor 2)
(48 mm long)
solves the Rubik's cube



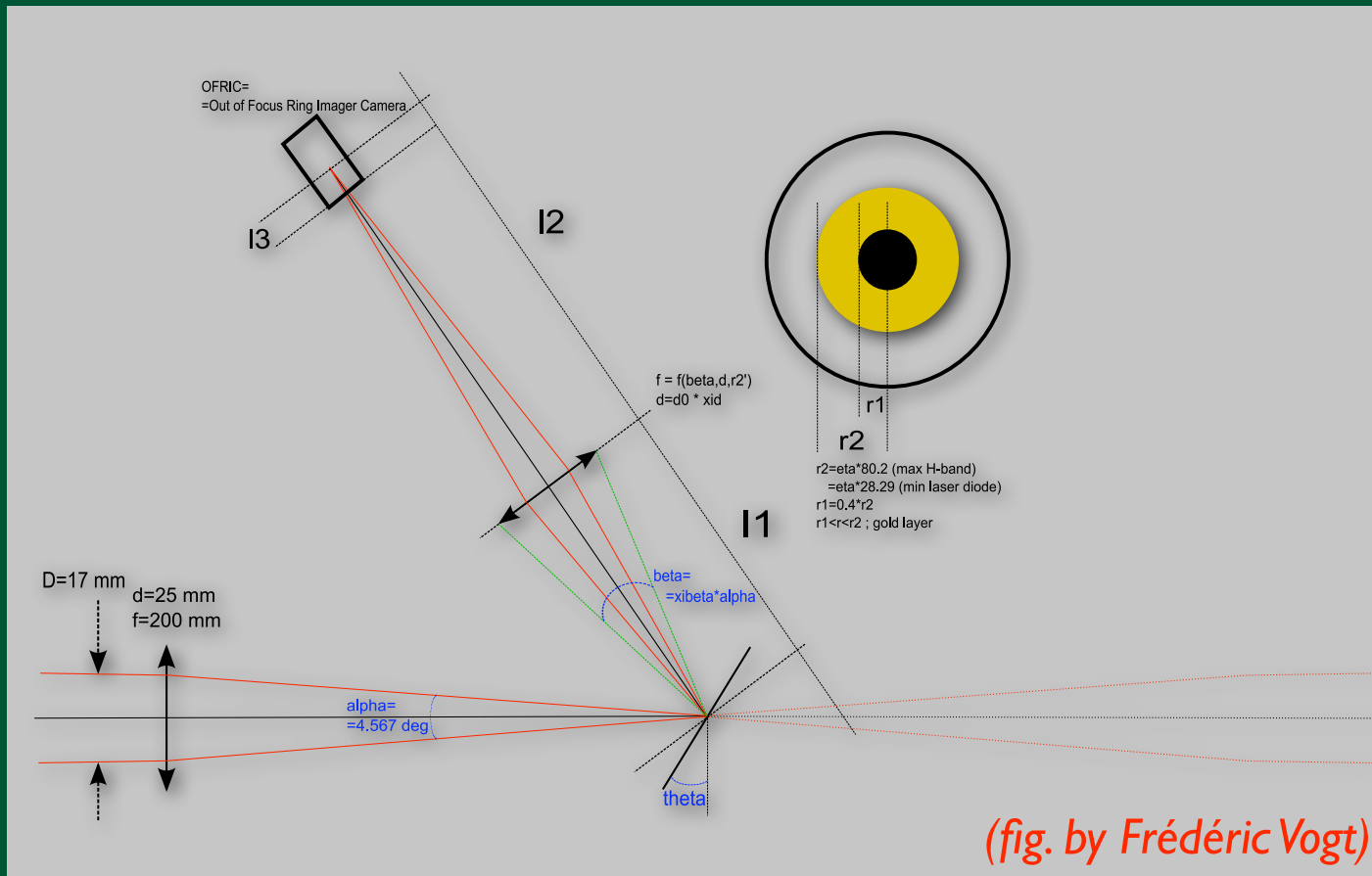
PIAA-^I: 1st lab demonstration



Lozi et al, 2009, arXiv0903.5001L



coronagraphic low-order WFS



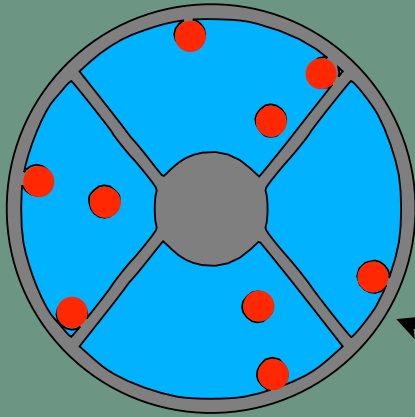
Simultaneously measure tip-tilt ($\text{rms} \sim 10^{-3} \lambda/D$) and defocus ($\sim 2 \times 10^{-3} \lambda$) in the lab with a dual zone focal plane mask

Guyon et al, 2009, ApJ, 693, 75



non-redundant masking

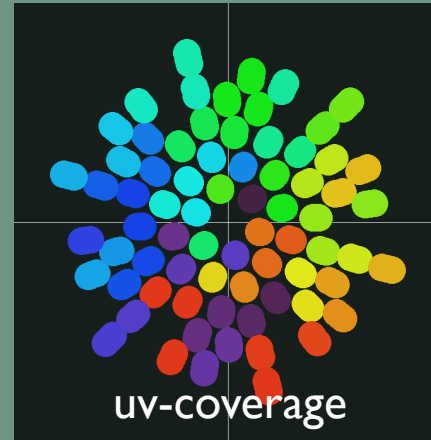
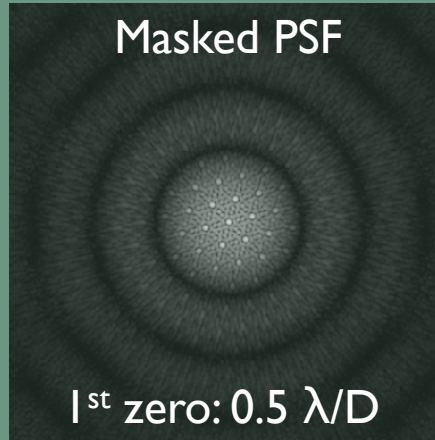
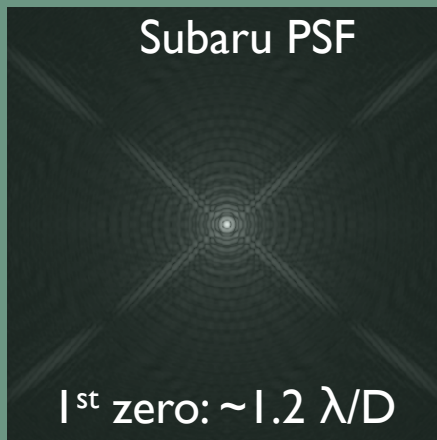
SCExAO provides access to two pupil plans...



Mask up to 80 % of the mirror and ...

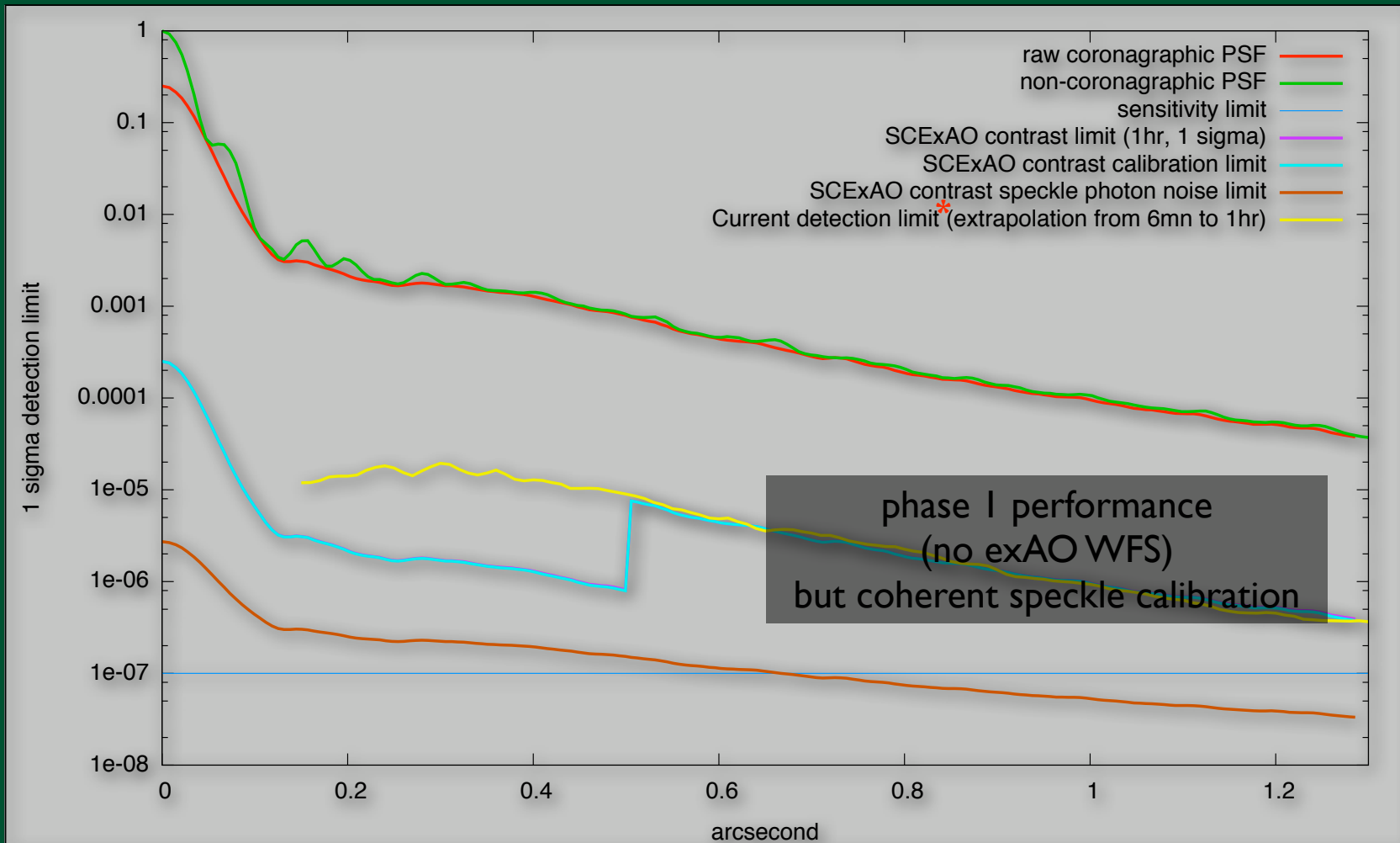
- Boost the resolution by a factor ~ 3
- Benefit from the self calibration properties of closure phase
- Become insensitive to non-common path errors

Example of **non redundant** 9-hole mask optimized for **Subaru + CH4s** filter



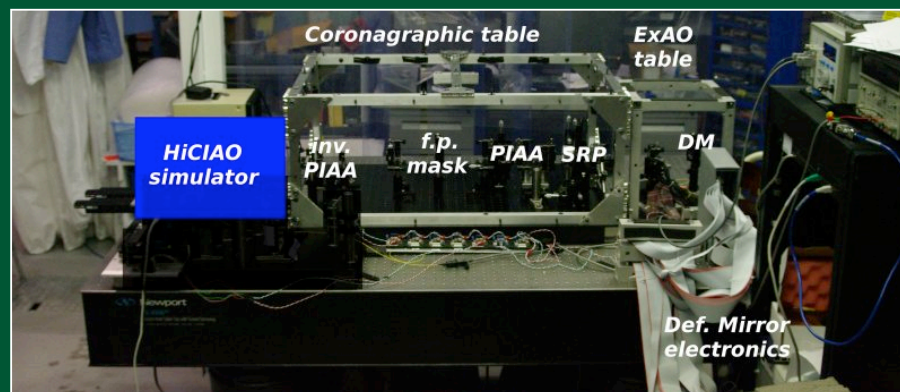


Preliminary contrast curves



*SEEDS team, private comm.

The Subaru Coronagraphic Extreme AO Project



- Project assembling well on its way
- Next milestone: new frame (01/2010)
- Real performance still difficult to assess
- Main unknown: statistical properties of the atmosphere
- Nevertheless, SCExAO addresses the right issues to open up a new fraction of the exoplanet parameter space

<http://www.naoj.org/Projects/SCExAO/>



System communication map

