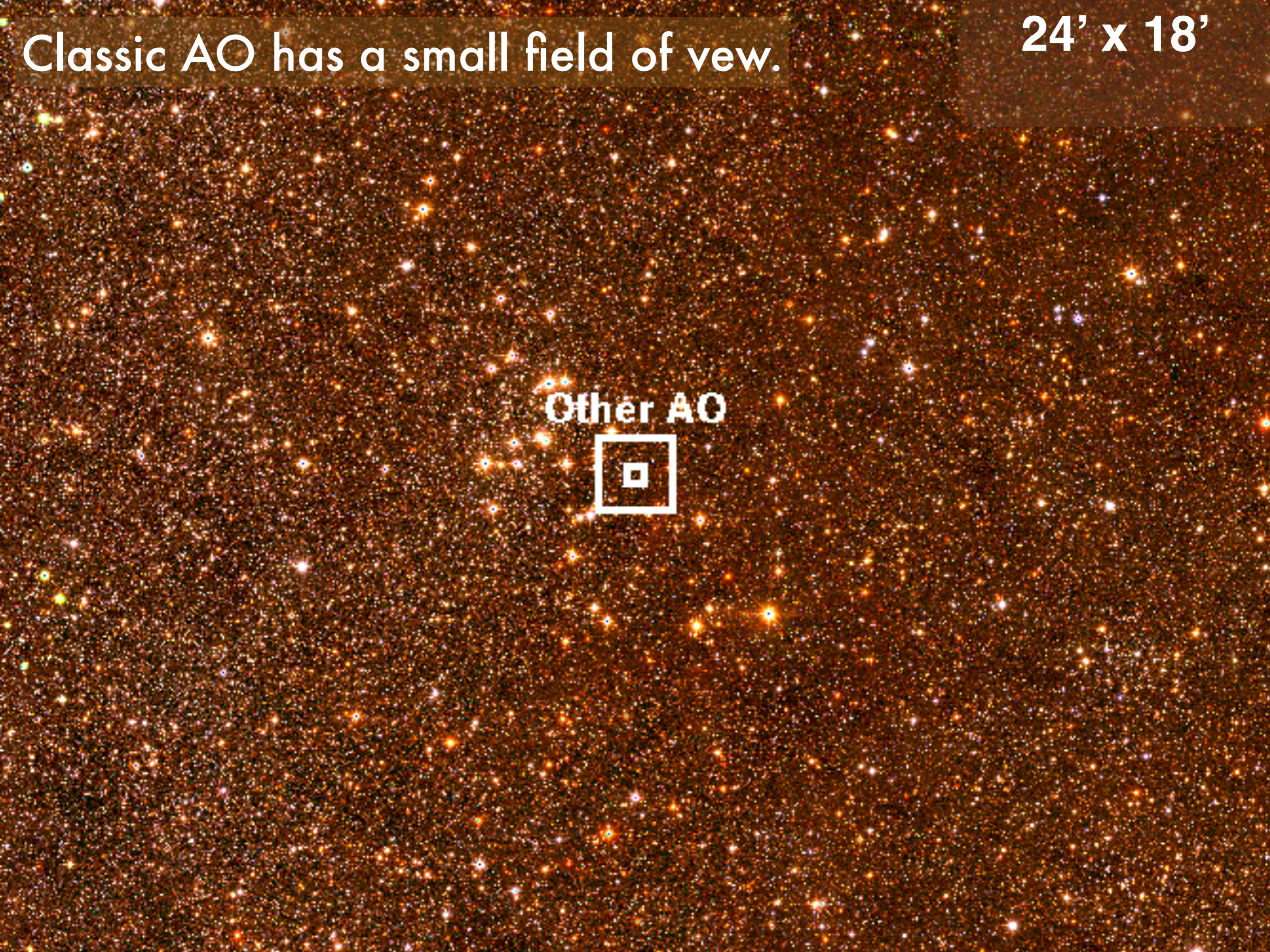


Expanding the Adaptive Optics Field of View

Jessica R. Lu
UC Berkeley



Classic AO has a small field of view.

24' x 18'

Other AO



Ground Layer Adaptive Optics

Multiples
Guide Stars

Correct Lowest
Turbulence

Science targets

Guide
stars

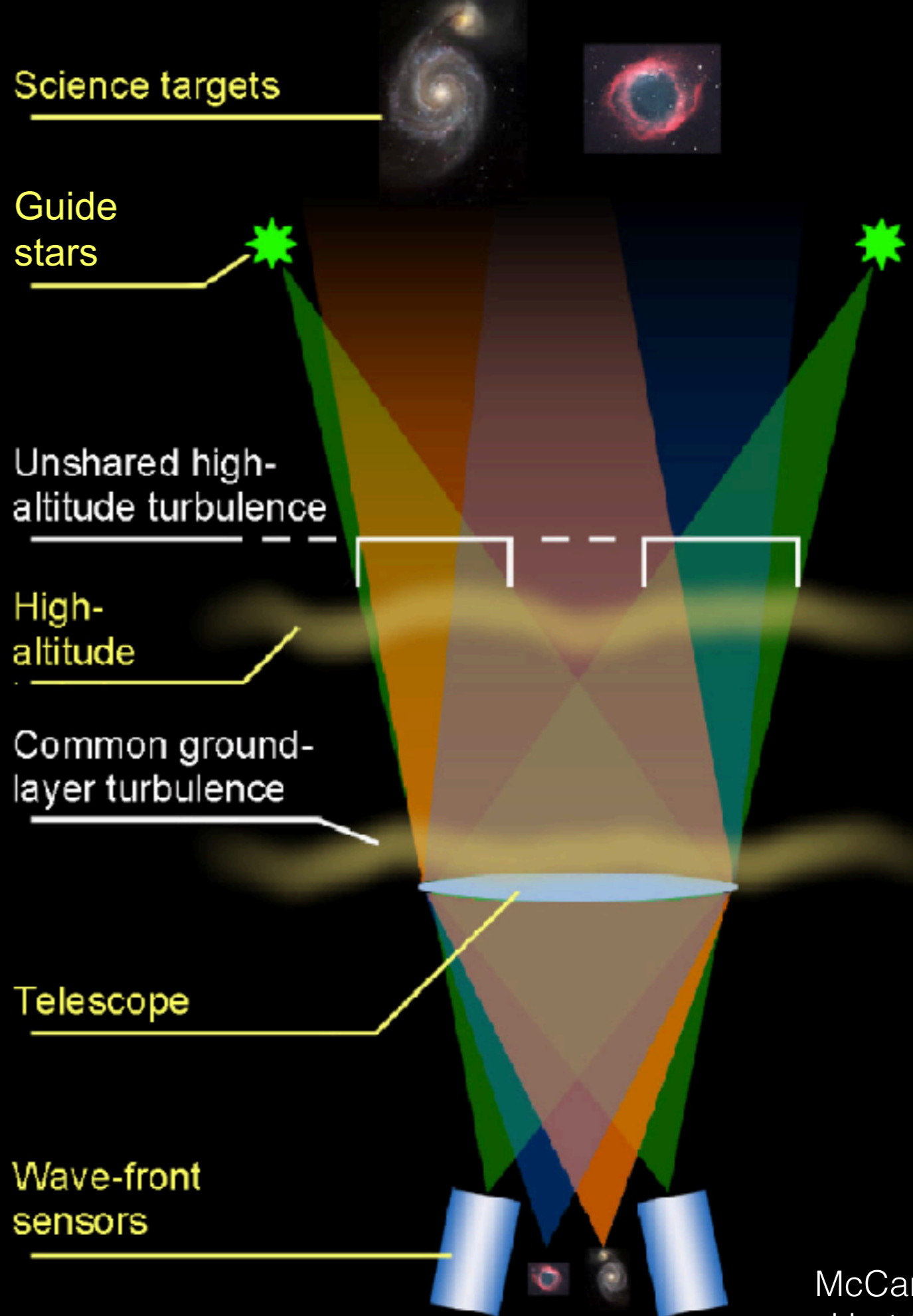
Unshared high-
altitude turbulence

High-
altitude

Common ground-
layer turbulence

Telescope

Wave-front
sensors





'imaka (*scenic view*)
pathfinder for wide-field
ground-layer AO

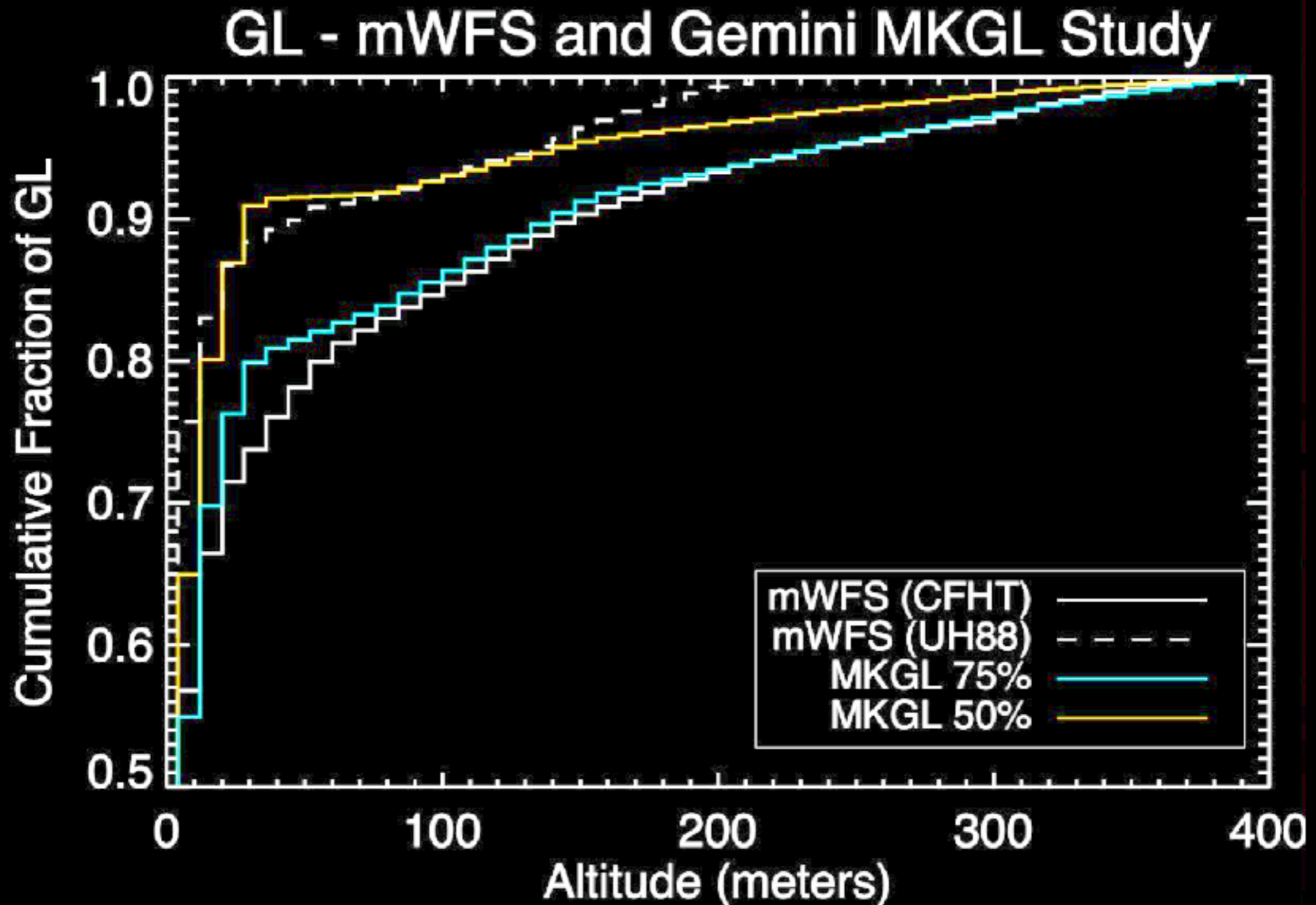
Principal Investigator:
Mark Chun
Project Scientist:
Jessica Lu

Telescope: UH 2.2 m
Funding: NSF-ATI, Mt. Cuba
Foundation

Olivier Lai, Douglas Toomey,
Max Service, Fatima Abdhurraman,
Christoph Baranec, Dora Fohring

UH IfA, MKIR, Subaru, Gemini, Laval,
UH Hilo, UC Berkeley

Maunakea is an ideal location for **ultra** wide-field adaptive optics (UltraWAO).



24' x 18'

Other AO



24' x 18'
'imaka Field

11' x 11' Optical

7' x 7' Infrared

Other AO



PI: M. Chun
PS: J. Lu



First Light

**Dec 2016 to
Jan 2017**



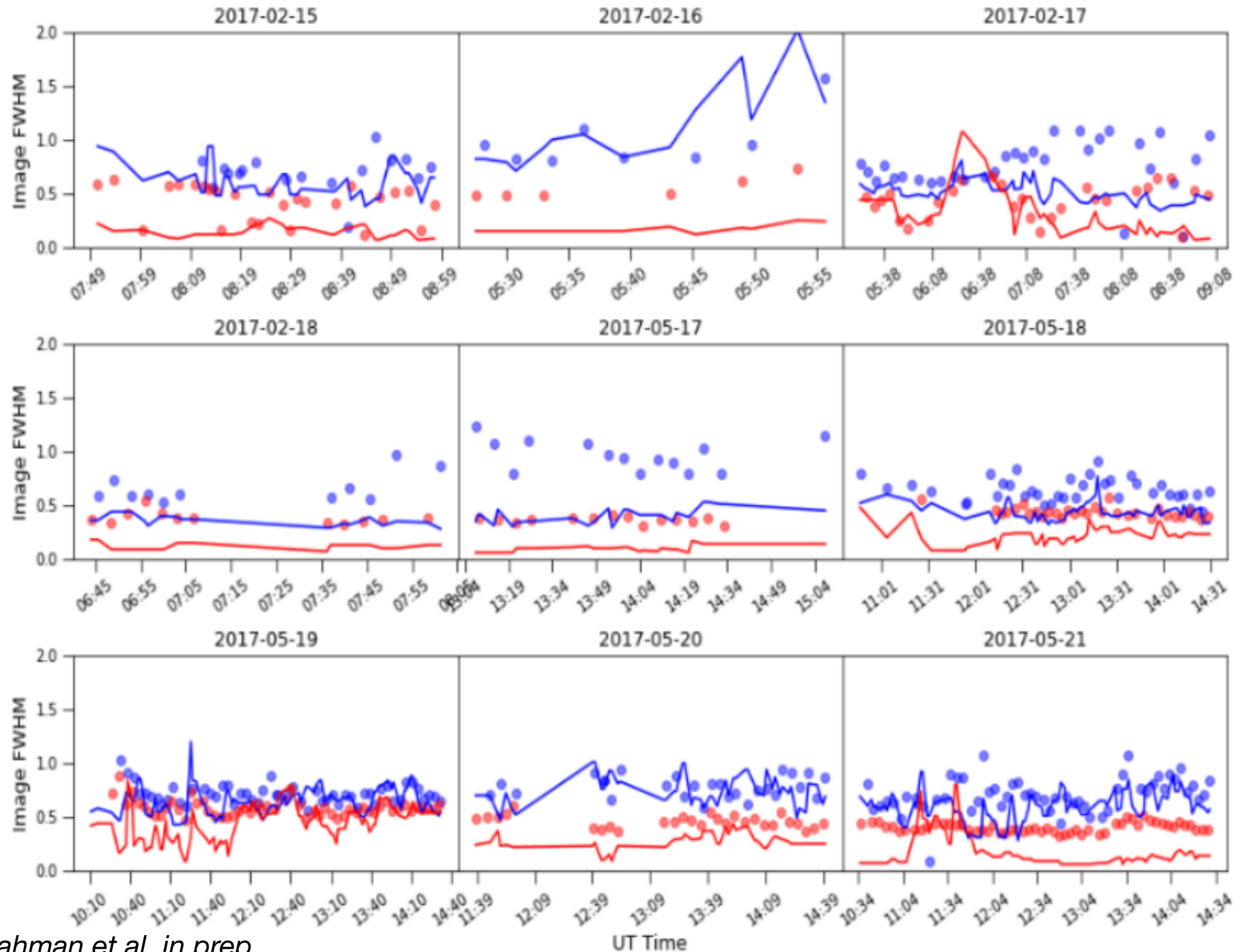
'imaka First Light
4' x 5' Commissioning Camera

'imaka
Open Loop

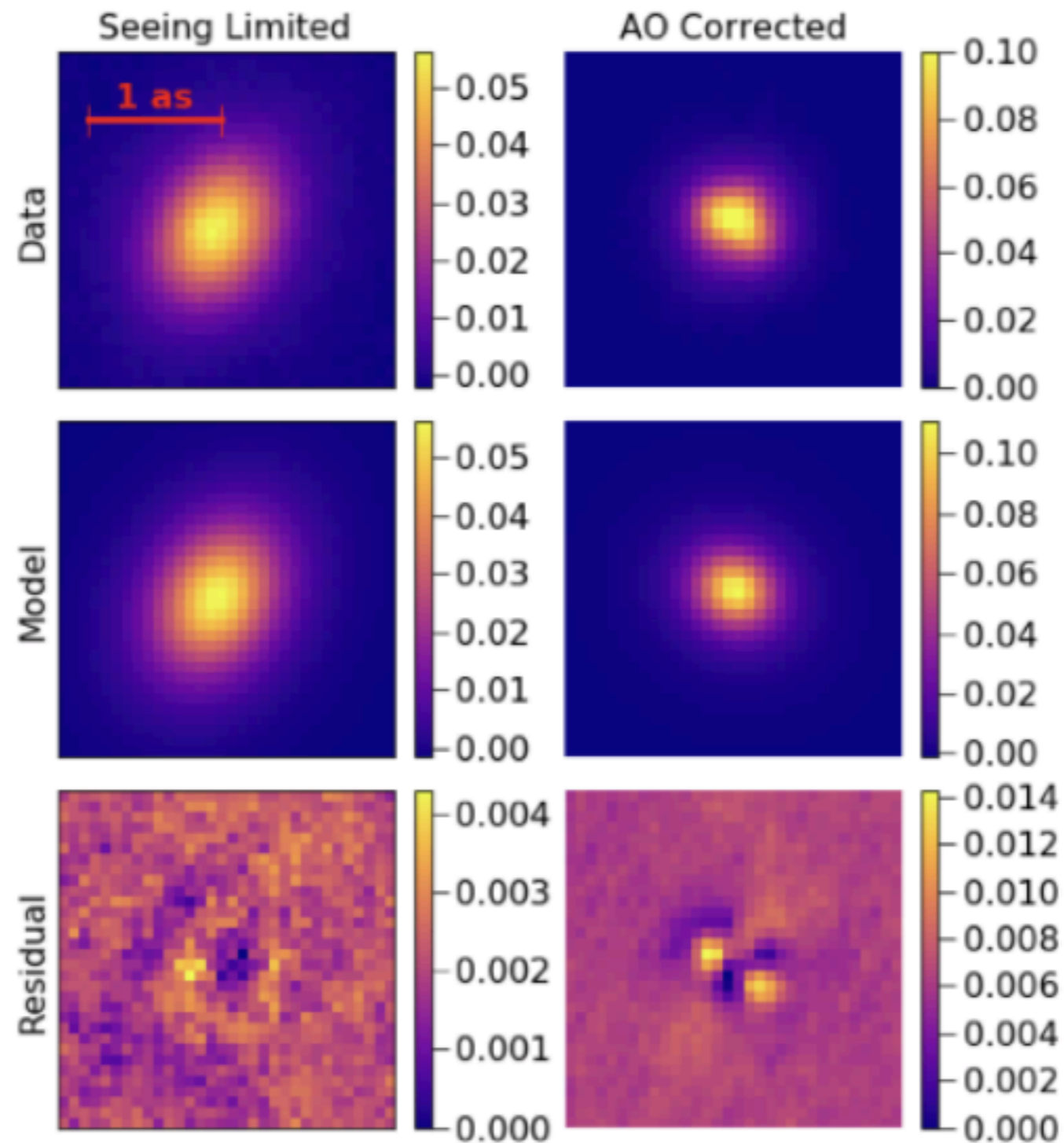
'imaka First Light
4' x 5' Commissioning Camera

'imaka
Closed Loop

Data set of alternating images with GLAO on/off.

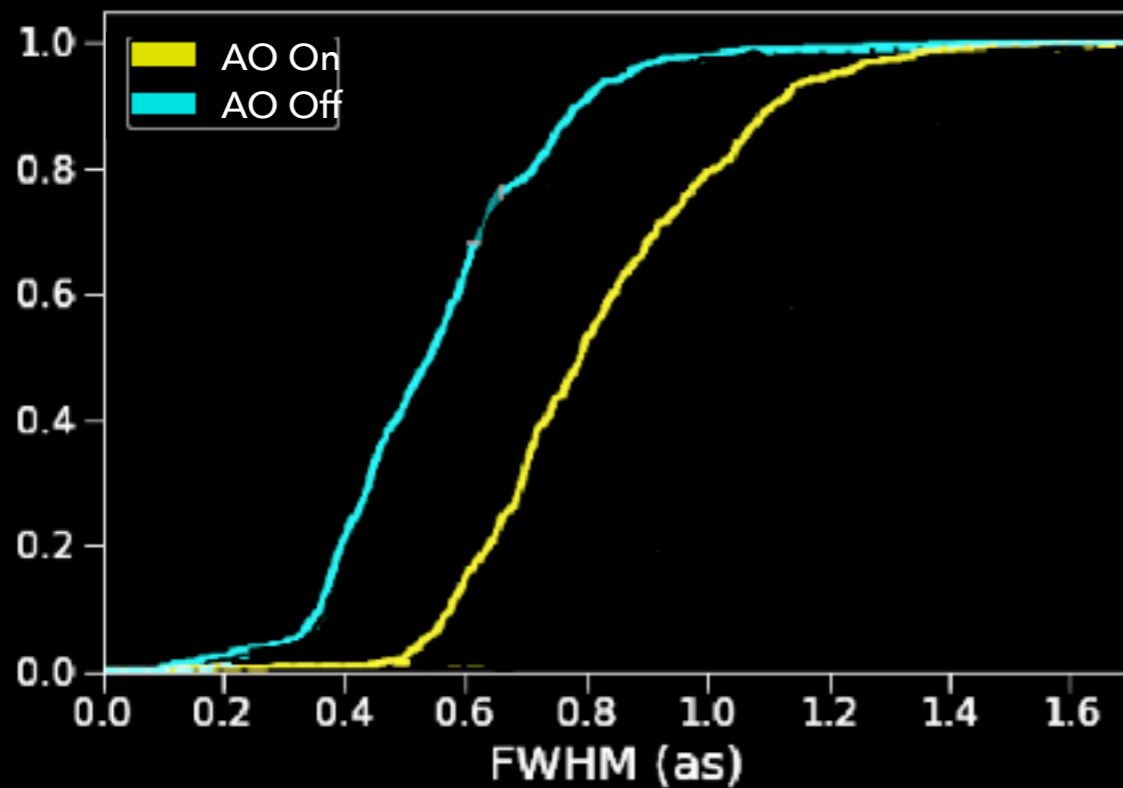


GLAO gets rid of atmospheric and instrumental blurring of the point spread function (PSF).



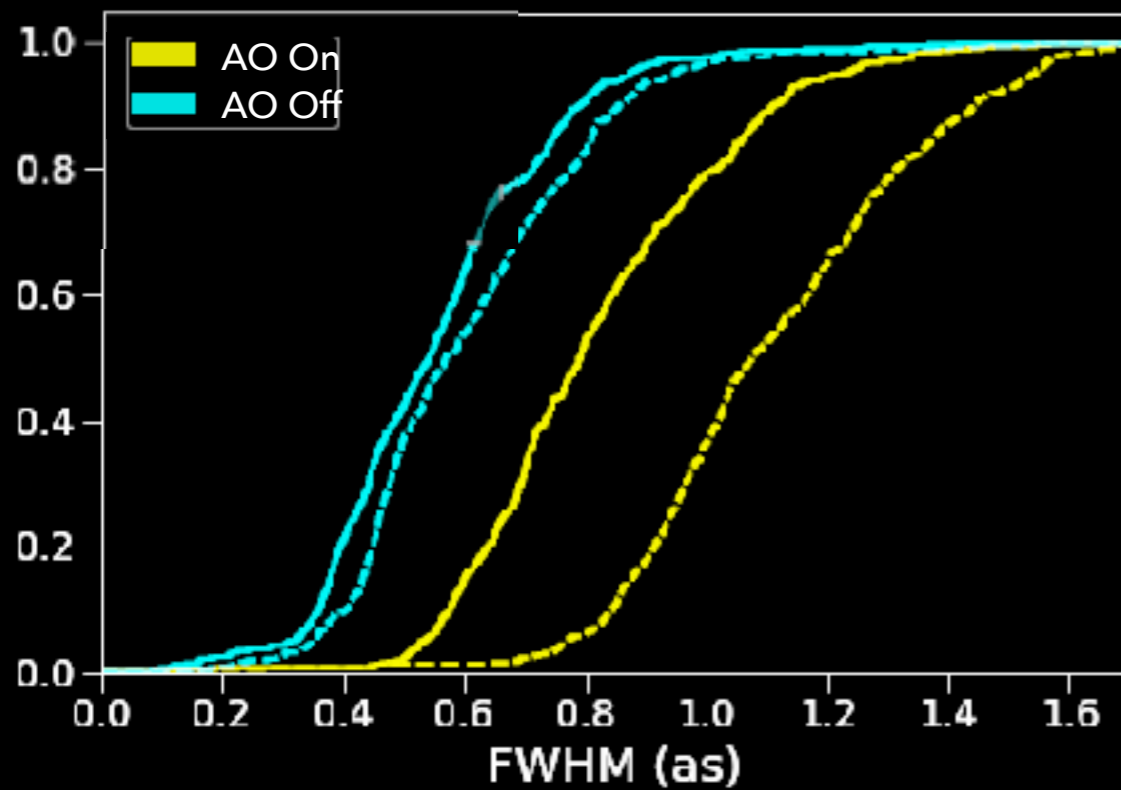
GLAO improves PSF size and elongation.

- ▶ AO-corrected: 0.4" in Run 3. Generally: minor FWHM decreases 31%



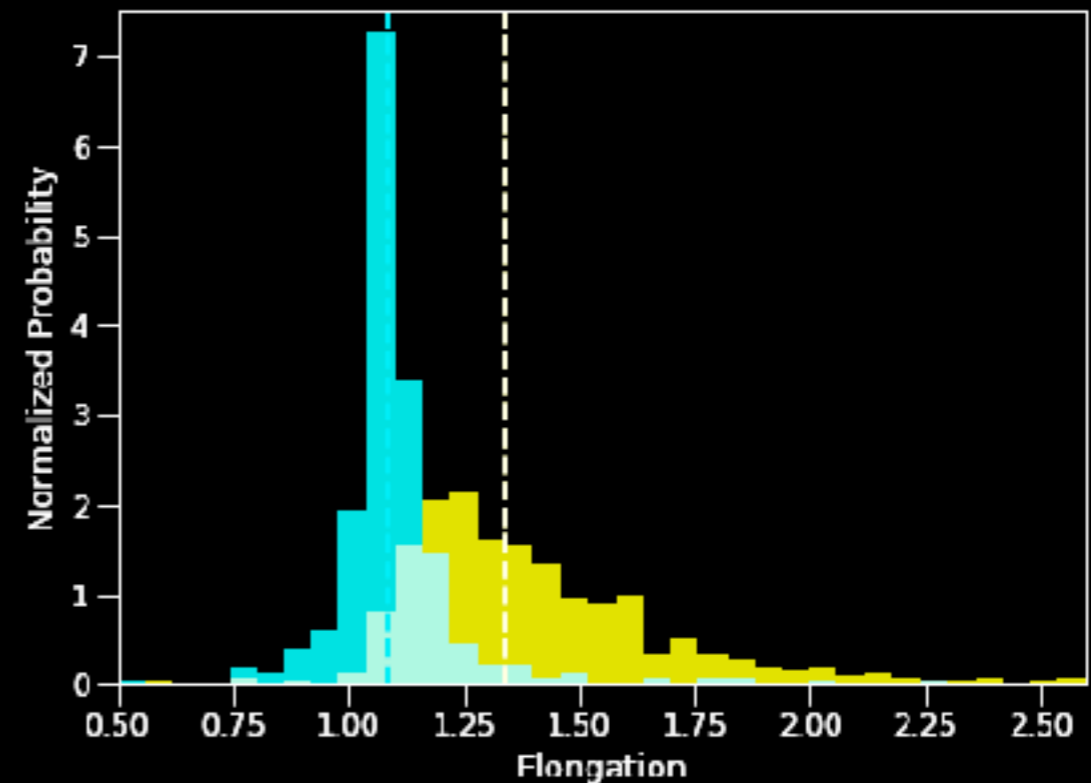
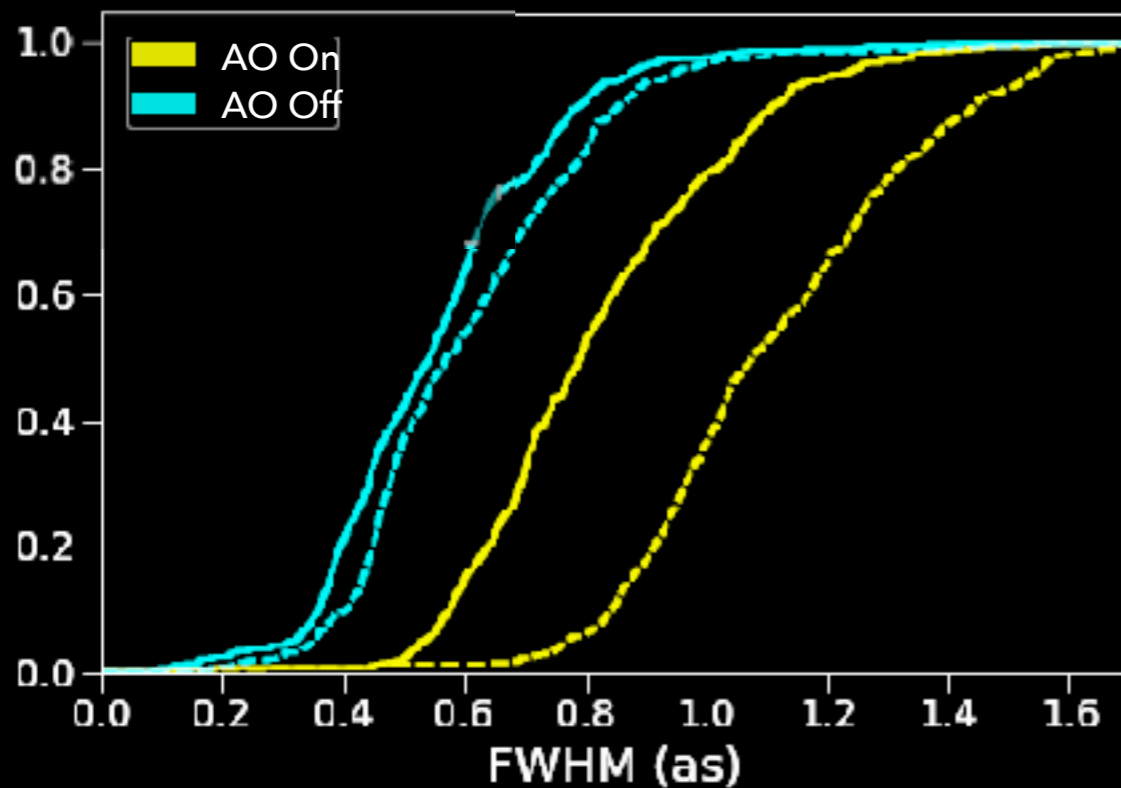
GLAO improves PSF size and elongation.

- ▶ AO-corrected: 0.4" in Run 3. Generally: minor FWHM decreases 31%; major, 48%

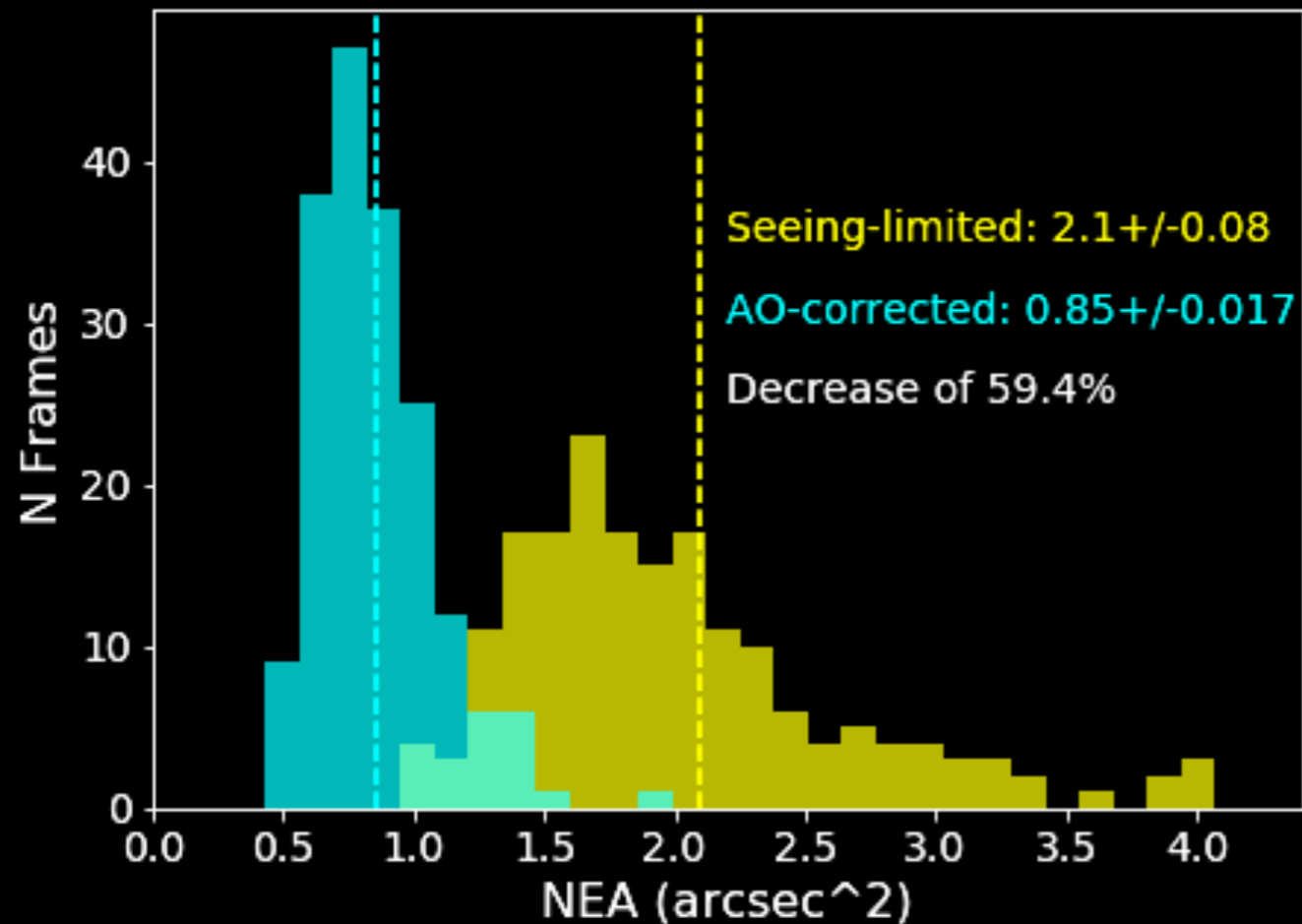


GLAO improves PSF size and elongation.

- ▶ AO-corrected: 0.4" in Run 3. Generally: minor FWHM decreases 31%; major, 48%
- ▶ Median elongation ($\text{FWHM}_{\text{major}}/\text{FWHM}_{\text{minor}}$) decreases from 1.45 to 1.05



GLAO improves noise equivalent area.



- ▶ Defined in King, 1982:

$$\sigma^2 = \alpha b / \Sigma f_i^2$$

- ▶ Photometric precision scales with NEA, astrometry with NEA^{1/2}

GLAO improves both infrared and optical, but improvements decrease at shorter wavelengths.

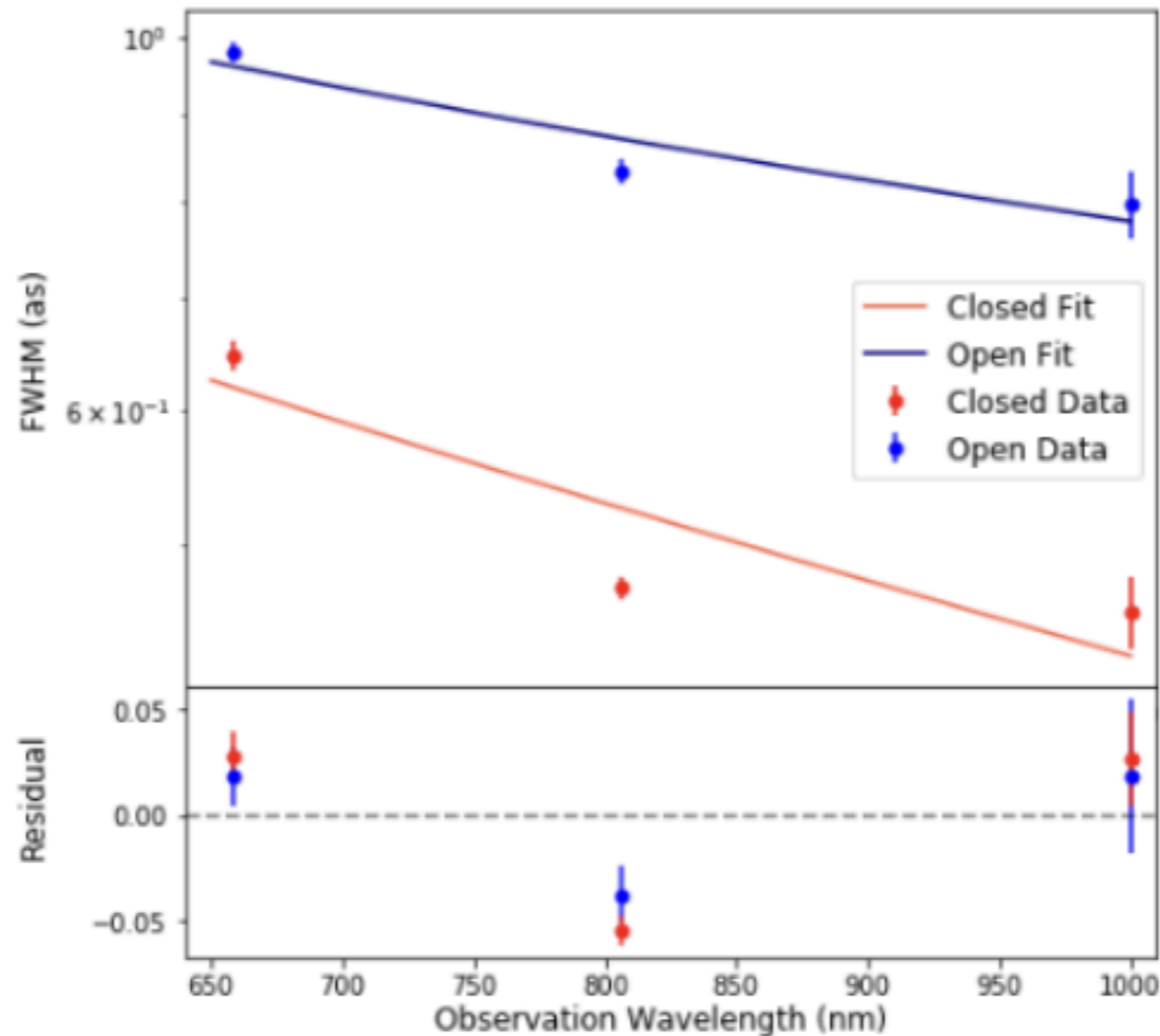
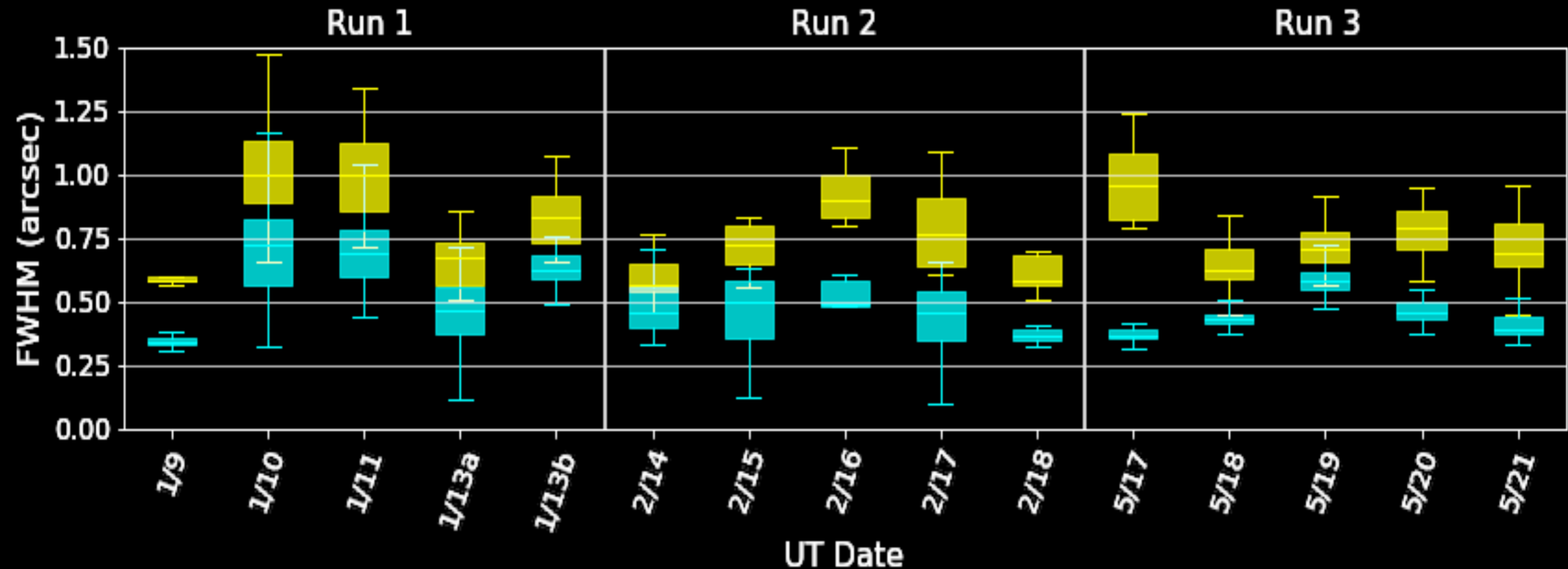


Figure 13. Wavelength dependence of PSF size is shown here as FWHM for seeing-limited and AO-corrected images for all nights as a function of observation wavelength, with no wavelength calibration applied. The best fit model is shown with solid lines. The lower panel shows the corresponding residual.

GLAO improves PSF stability for long-duration exposures.

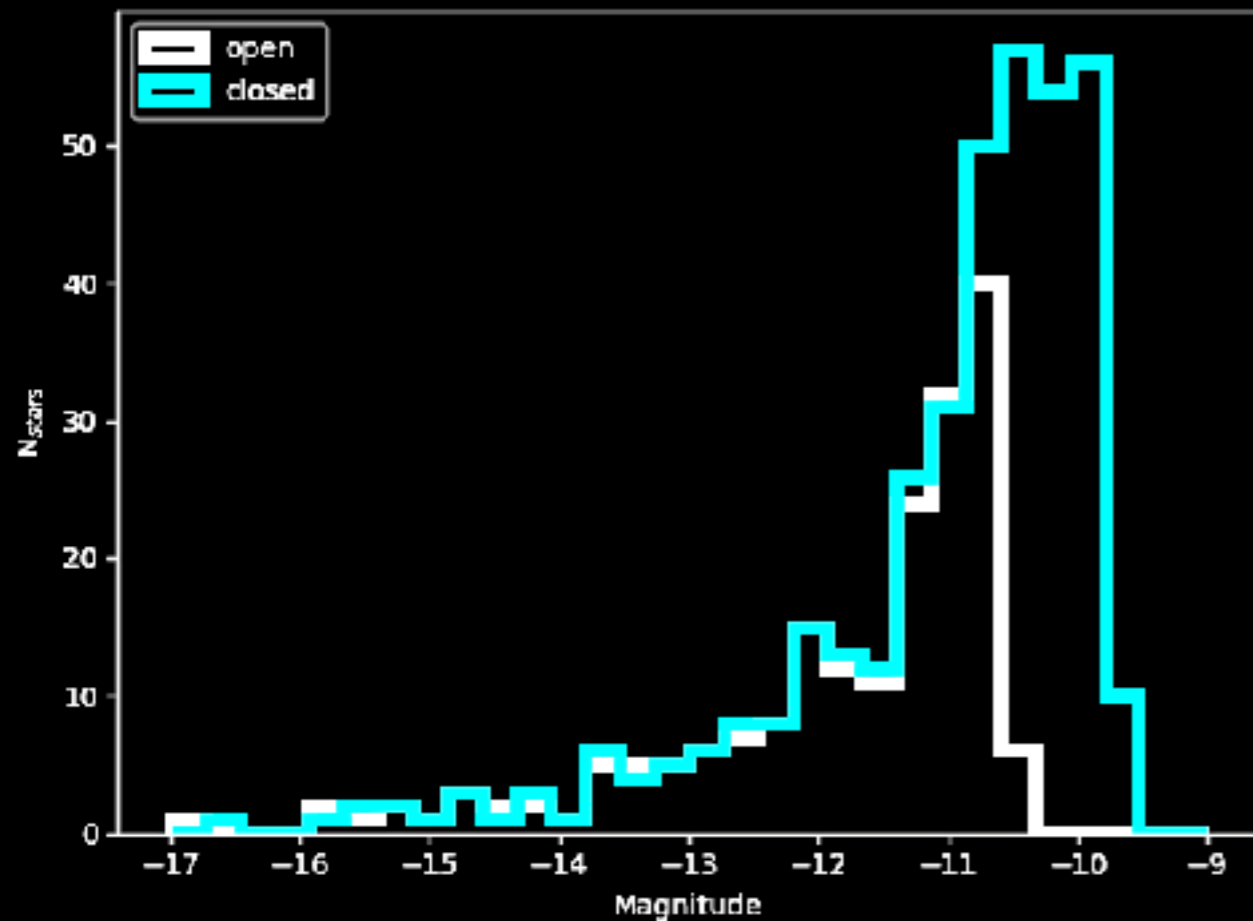


Many different conditions over 15 nights.

FWHM projected to $\lambda = 500$ nm
Observations mostly at R (~ 650 nm) and I (~ 800 nm)

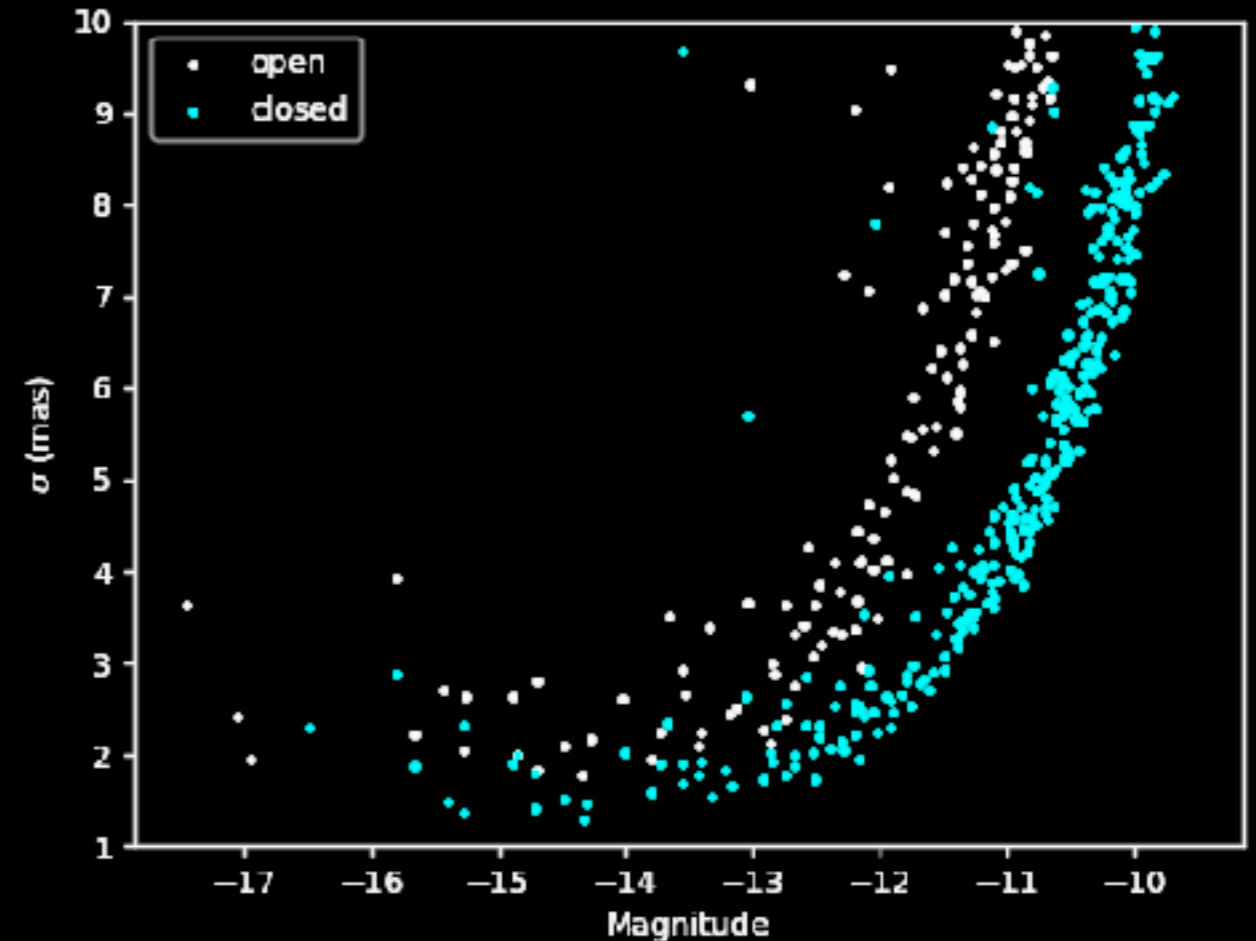
Improved astrometry and sensitivity with GLAO. (preliminary)

Number of Stars Detected



193 stars in open
376 stars in closed

Astrometric Precision



	Open	Closed
Bright	2.4 mas	1.9 mas
Faint	6.9 mas	3.5 mas

'imaka technical objectives

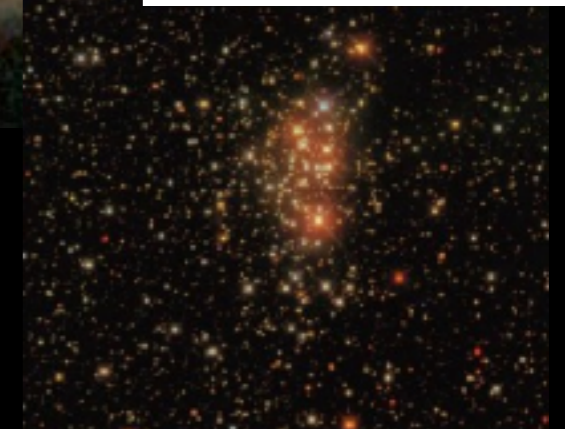
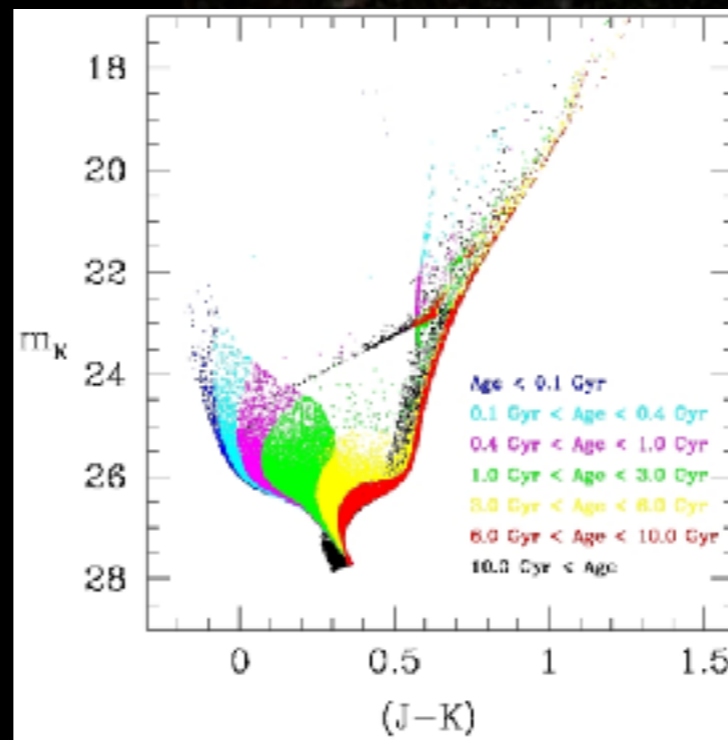
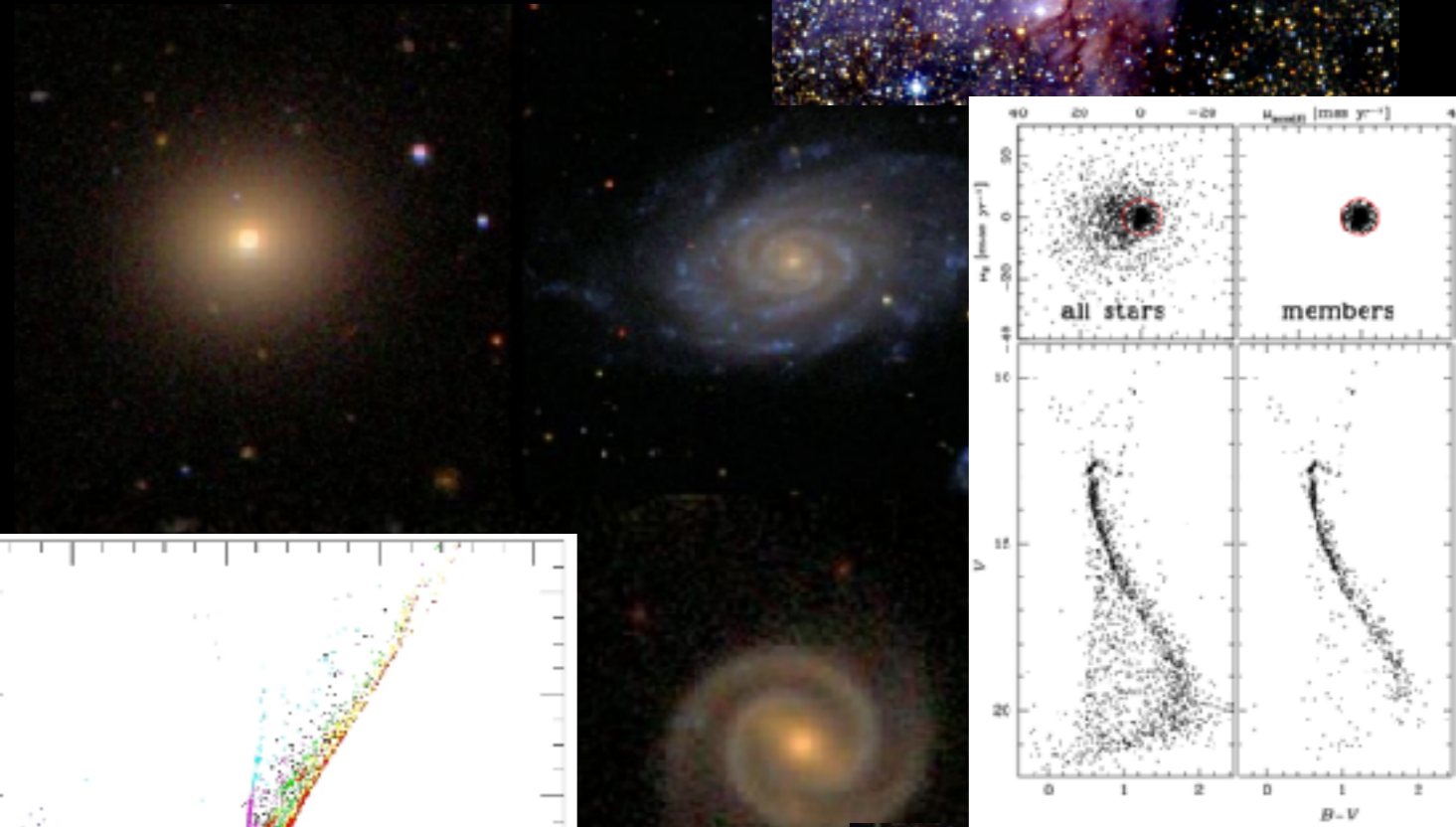
Test FOV vs. AO performance

Test sensitivity gains

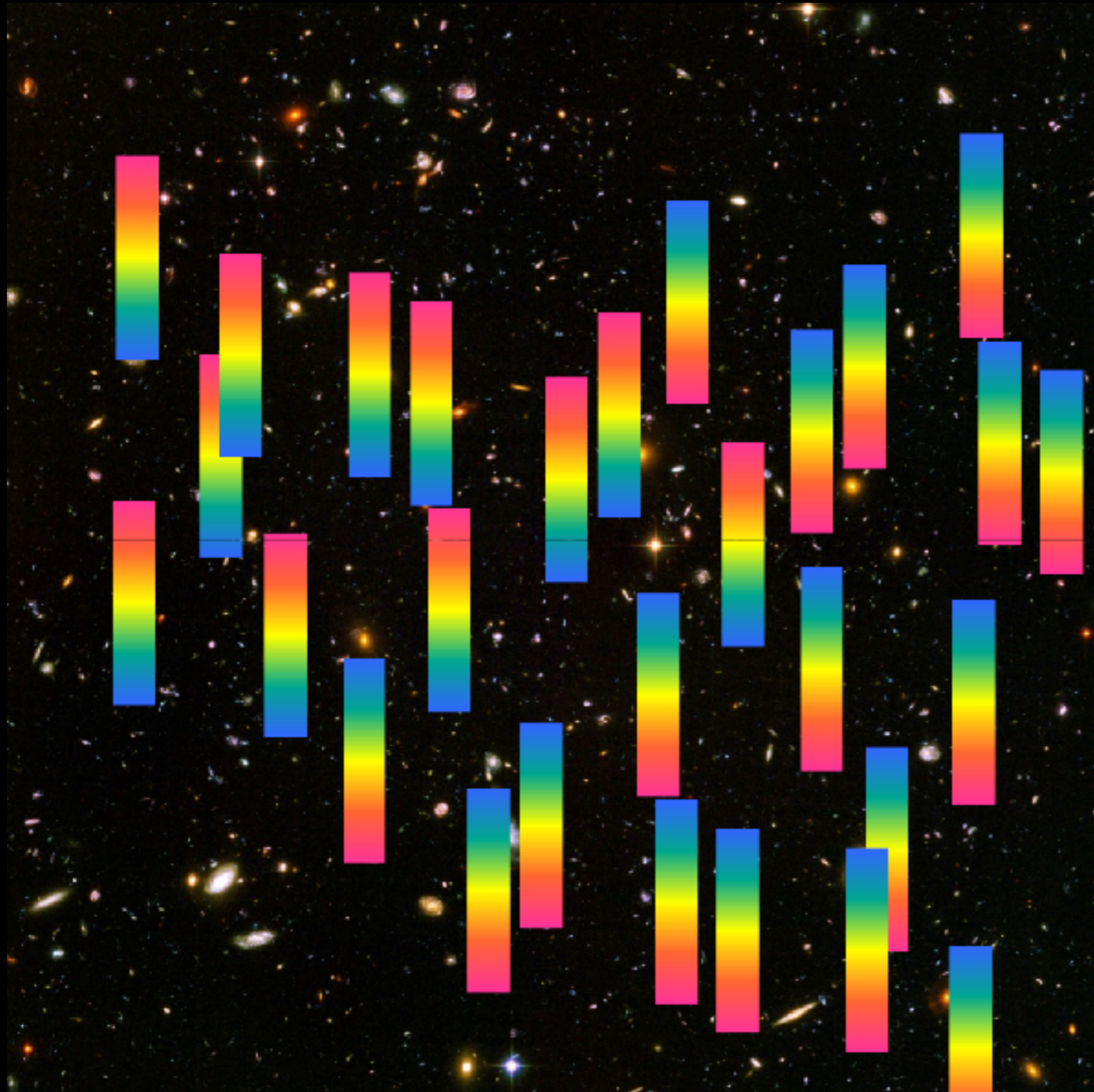
Test PSF uniformity and stability

Test astrometric capability

Test GLAO in a range of conditions



Future science with GLAO on larger telescopes on Maunakea.

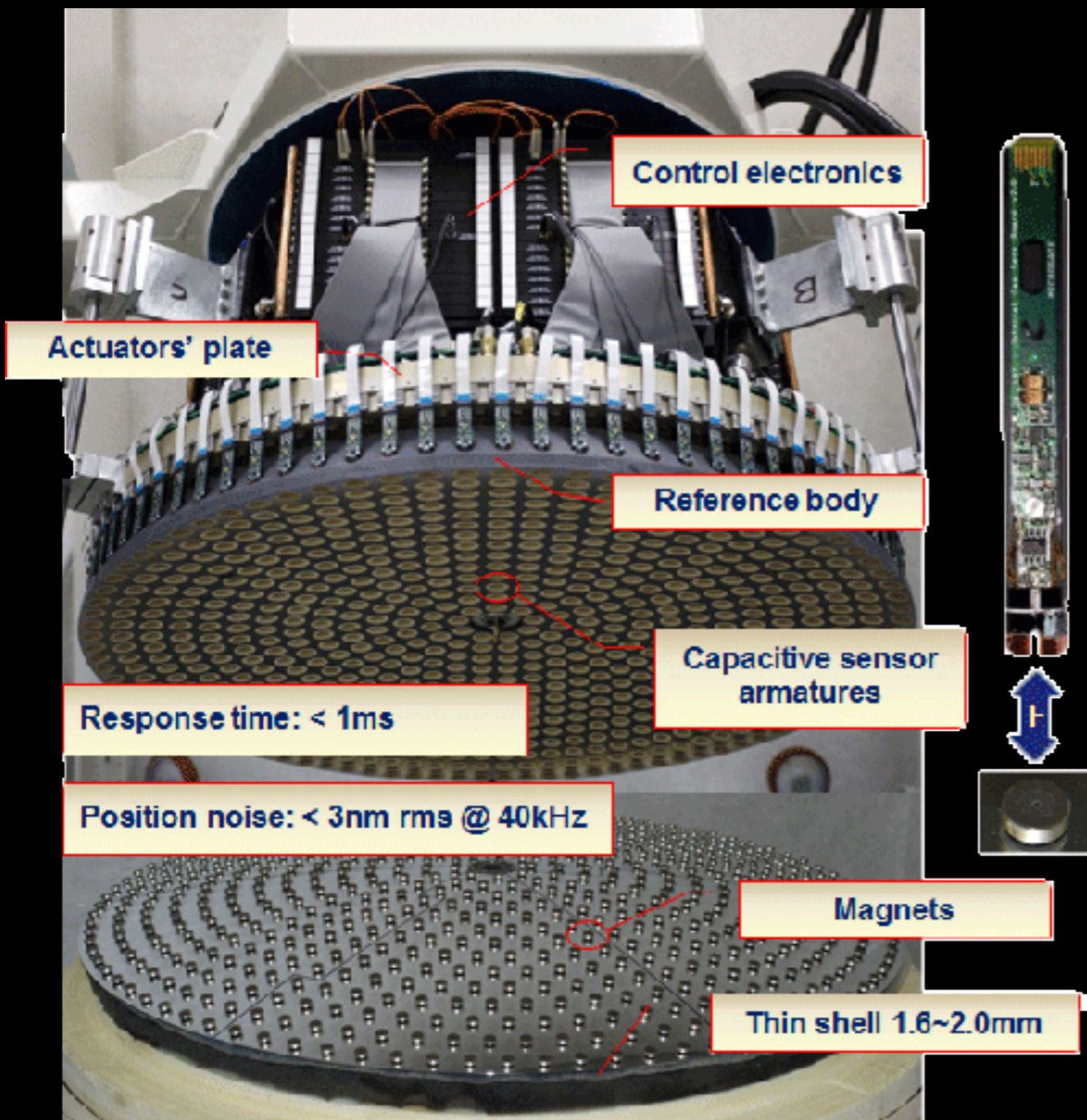


GLAO at Keck
GLAO at TMT

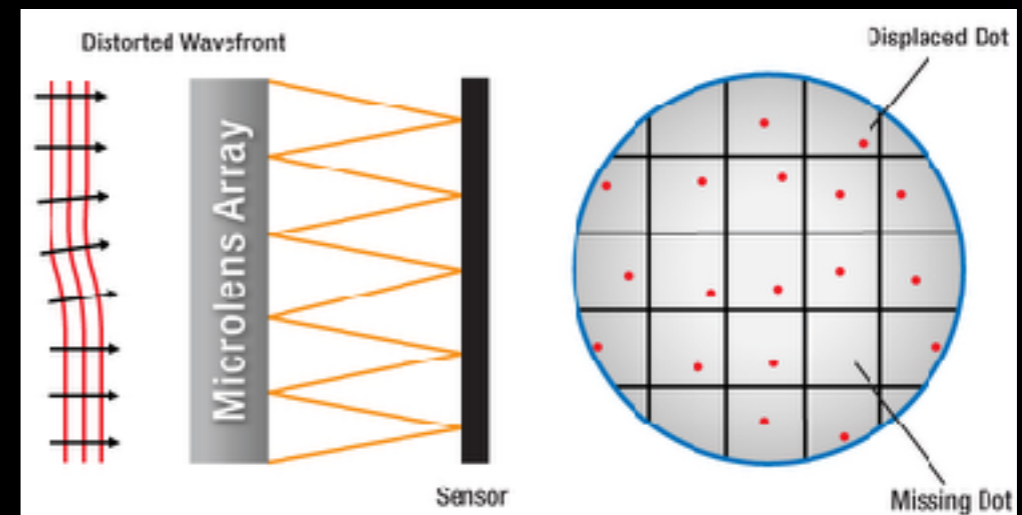
- deep galaxy mapping
- crowded stellar photometry
- crowded stellar astrometry
- sparse field astrometry

Ingredients for GLAO with high sensitivity and sky coverage

Adaptive Secondary Mirror



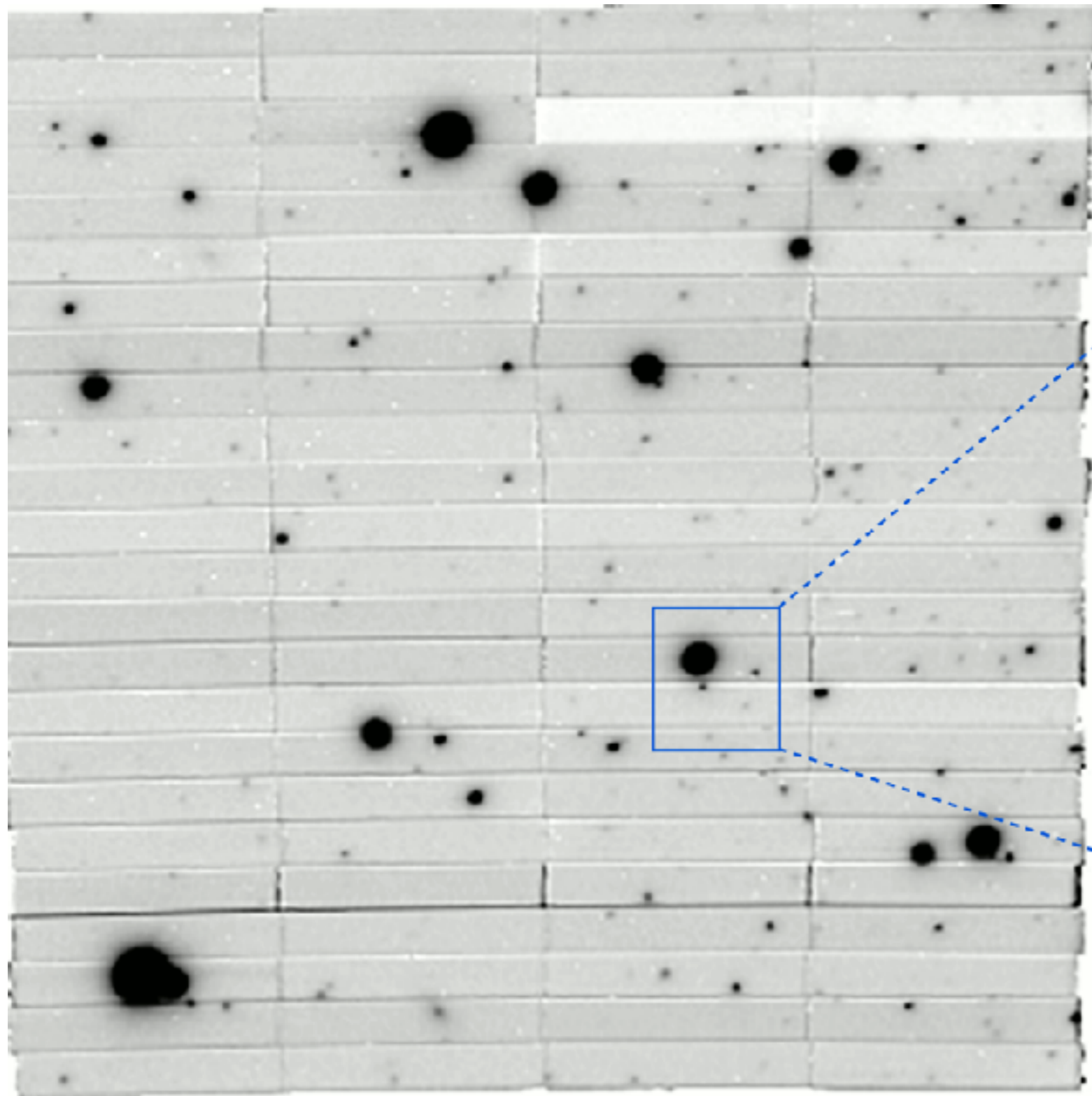
Wavefront Sensors



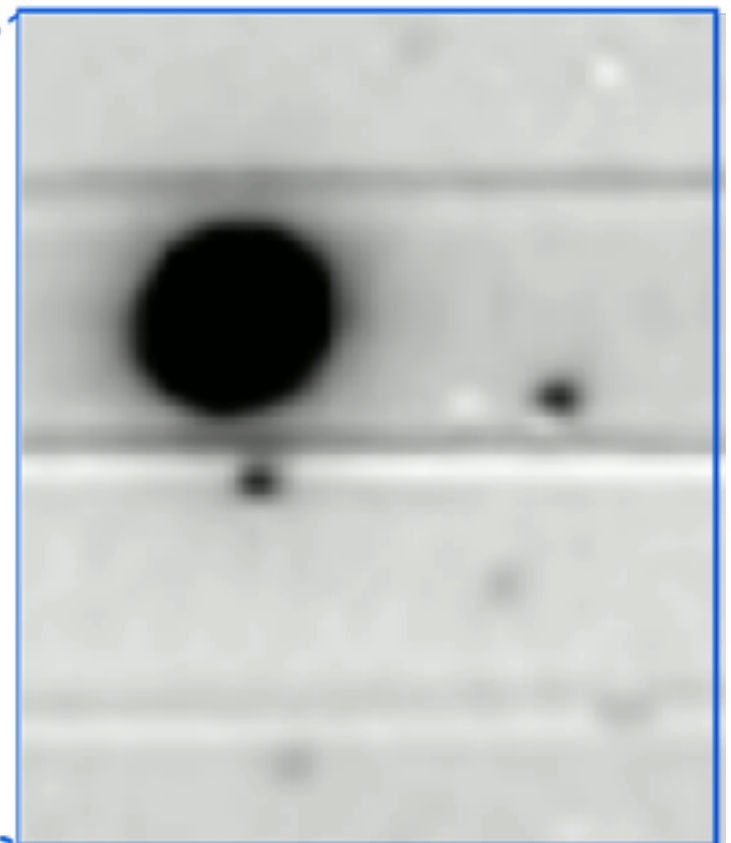
UV Laser Guide Stars



Are the science gains worth the cost?

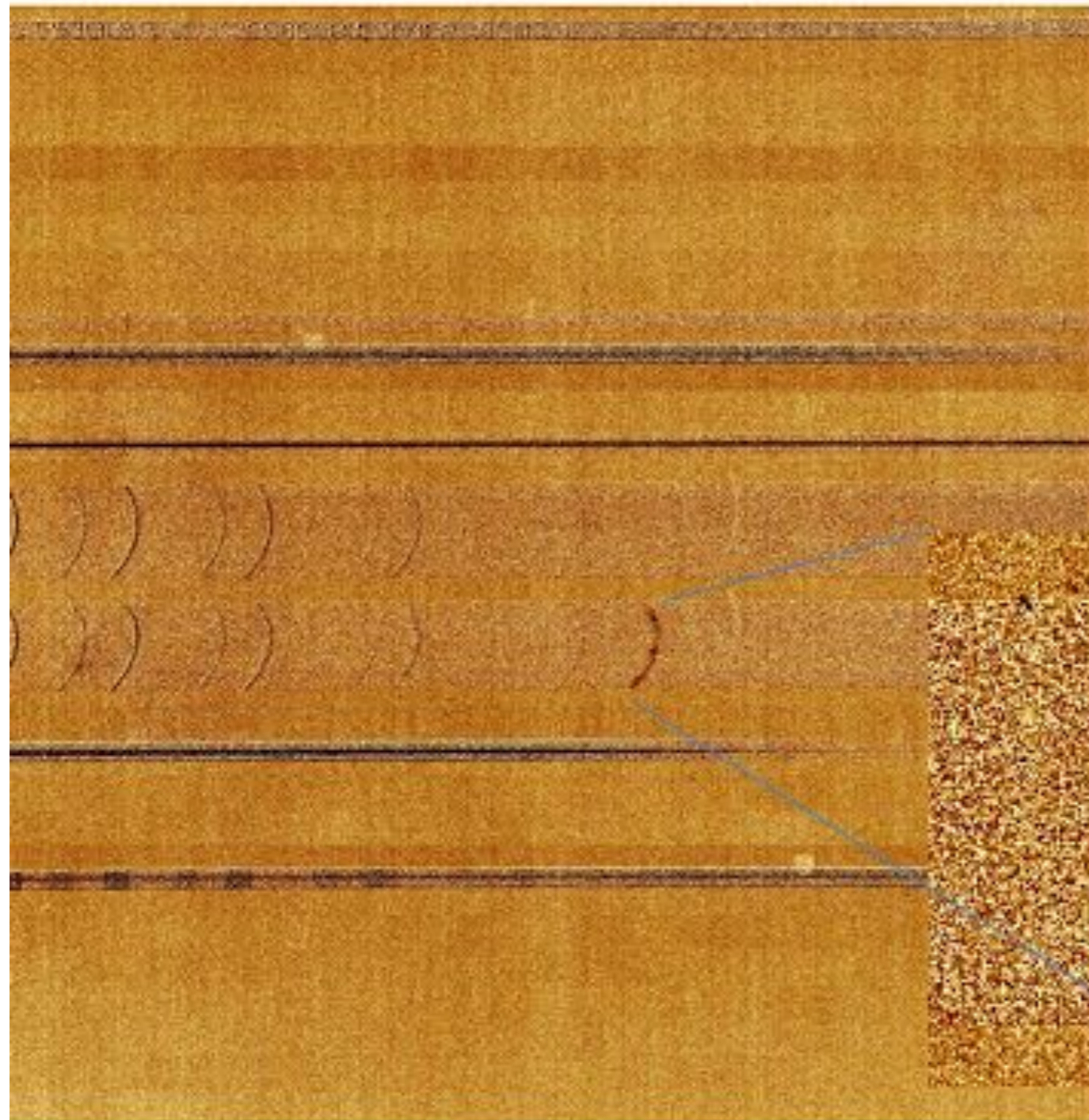


VLT MUSE+AOF
commissioning

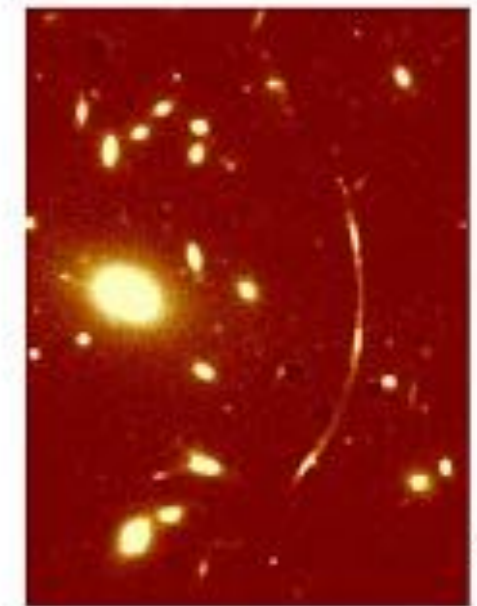


Are the science gains worth the cost?

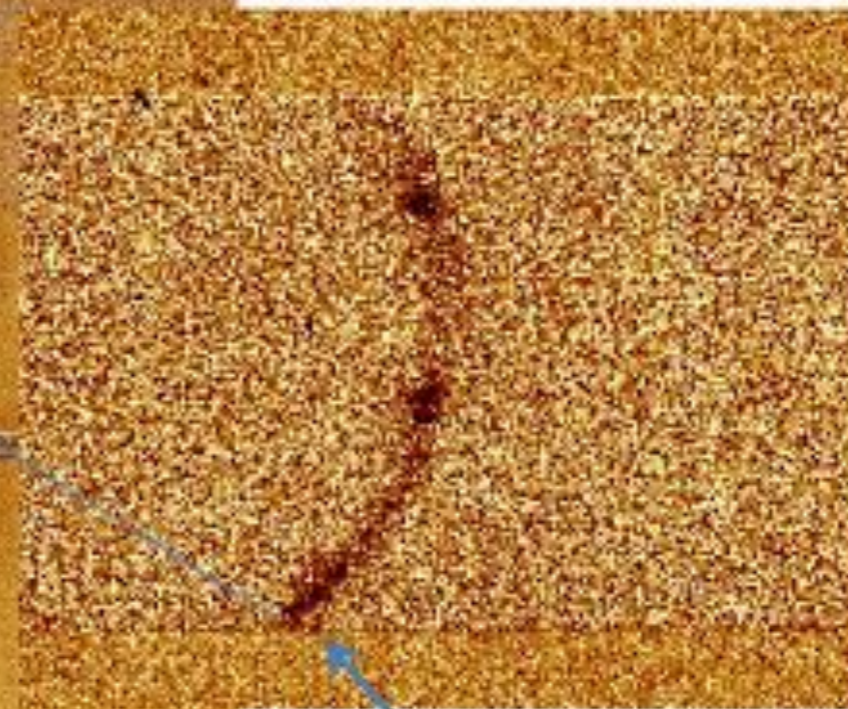
SDSSJ1110+6459 $z=2.49$



LBT



HST



H α detection
30min on source
0.5'' slitwidth,
N3.75 Camera

,clumpy structure' visible at 0.2'' resolution