



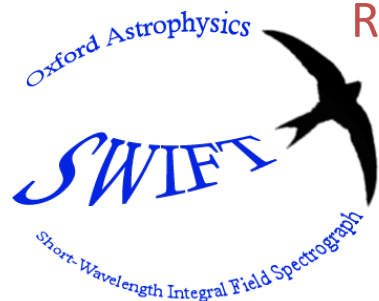
Oxford Astrophysics

15x optical zoom and diffraction limited integral field spectroscopy with the Oxford SWIFT spectrograph

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(University of Oxford)

David Freeman (Kidger Optical Associates)

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Palomar Operations Team

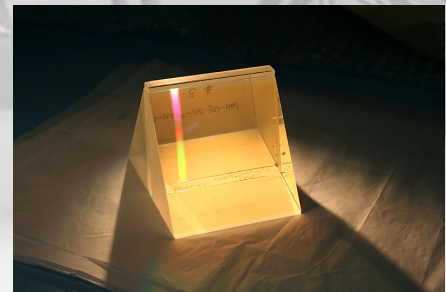
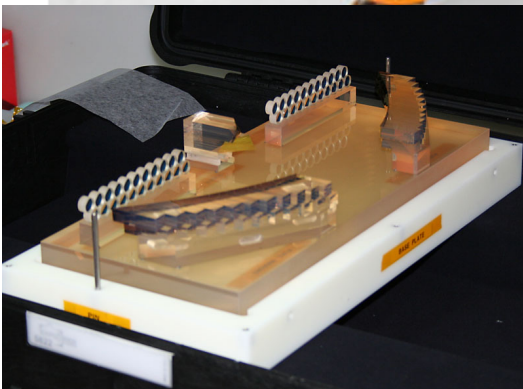
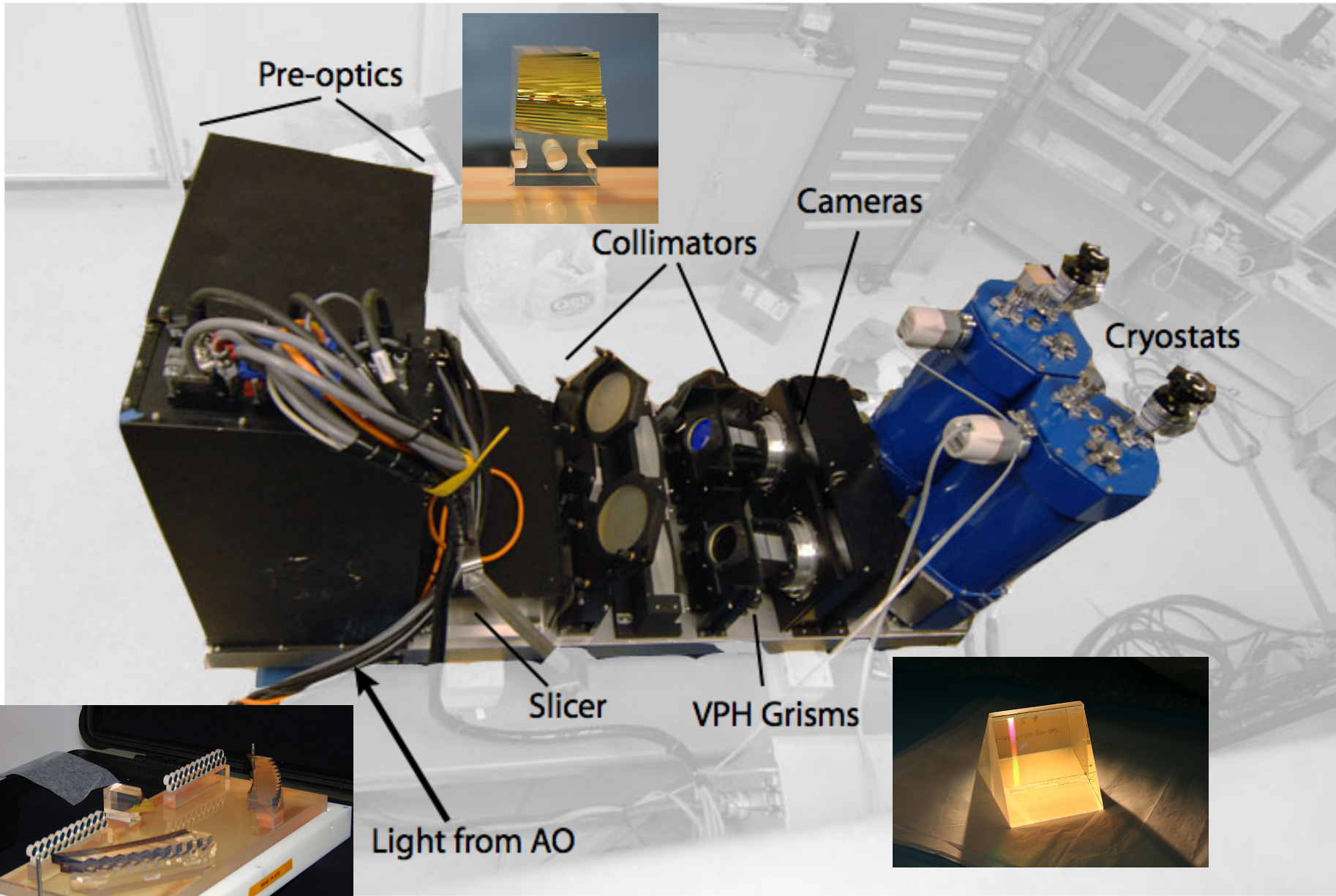


SWIFT—PALMAO/LGS

2008-2010

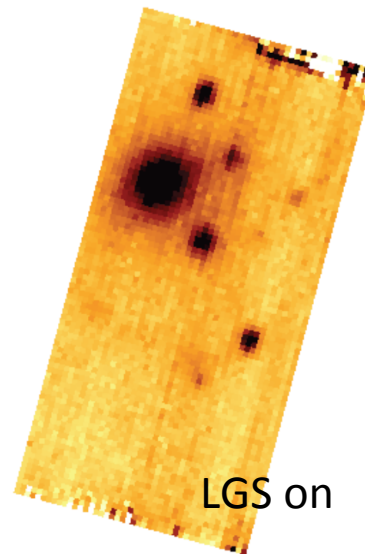
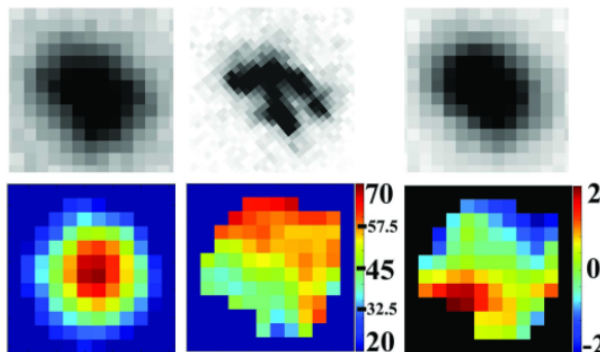
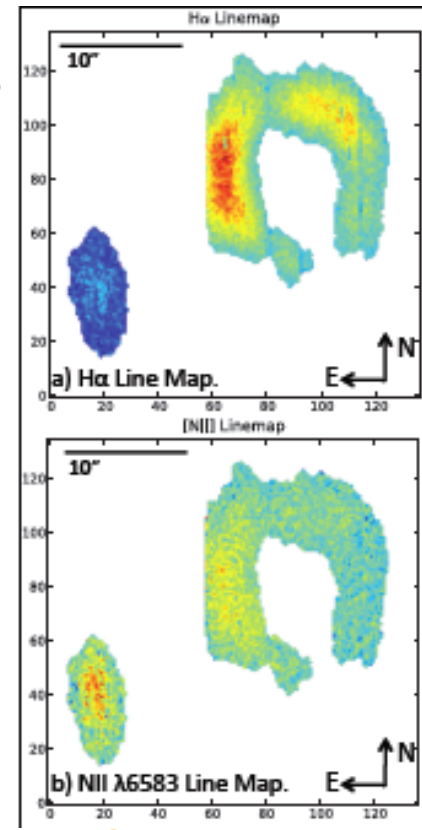
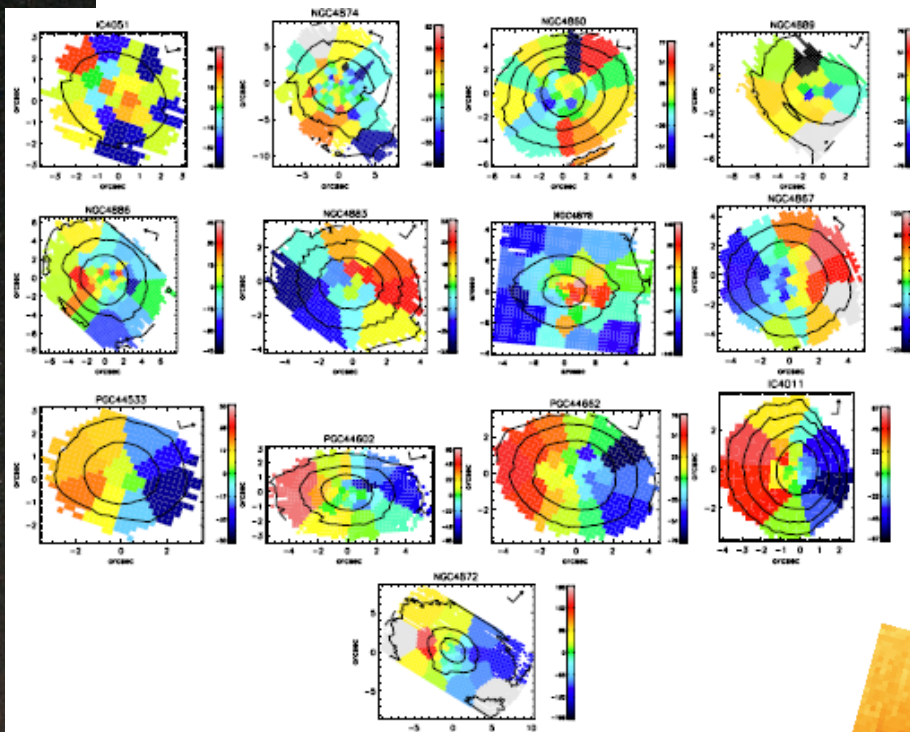
- I/z band integral field spectrograph
 - Palomar 200" + PALMAO/LGS adaptive optics
 - De-magnifying image slicer
 - 89×44 spaxels field-of-view
 - Fixed format spectrograph
 - Wavelength range 0.65—1.05 μ m
 - Spectral resolving power $R \approx 4000$
 - Interchangeable spaxel sizes
 - 235mas, 160mas, 80mas
 - Fully depleted very red-sensitive LBNL 4kx2k CCD
- Instrument designed to study galaxy dynamics/composition
- Facility instrument available to whole Palomar community



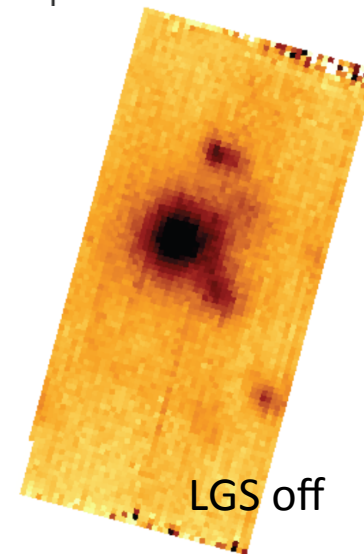


SWIFT—PALMAO/LGS

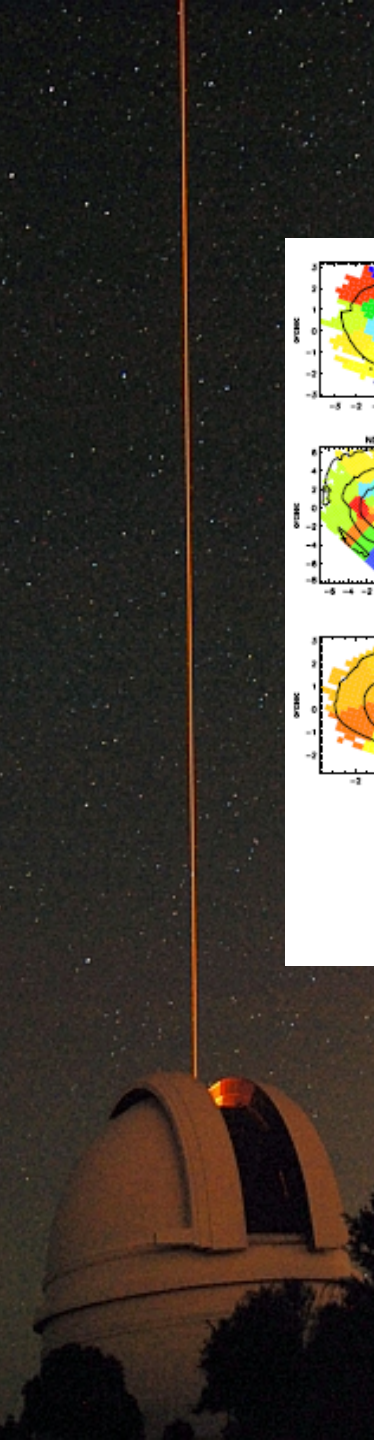
2008-2010



LGS on



LGS off

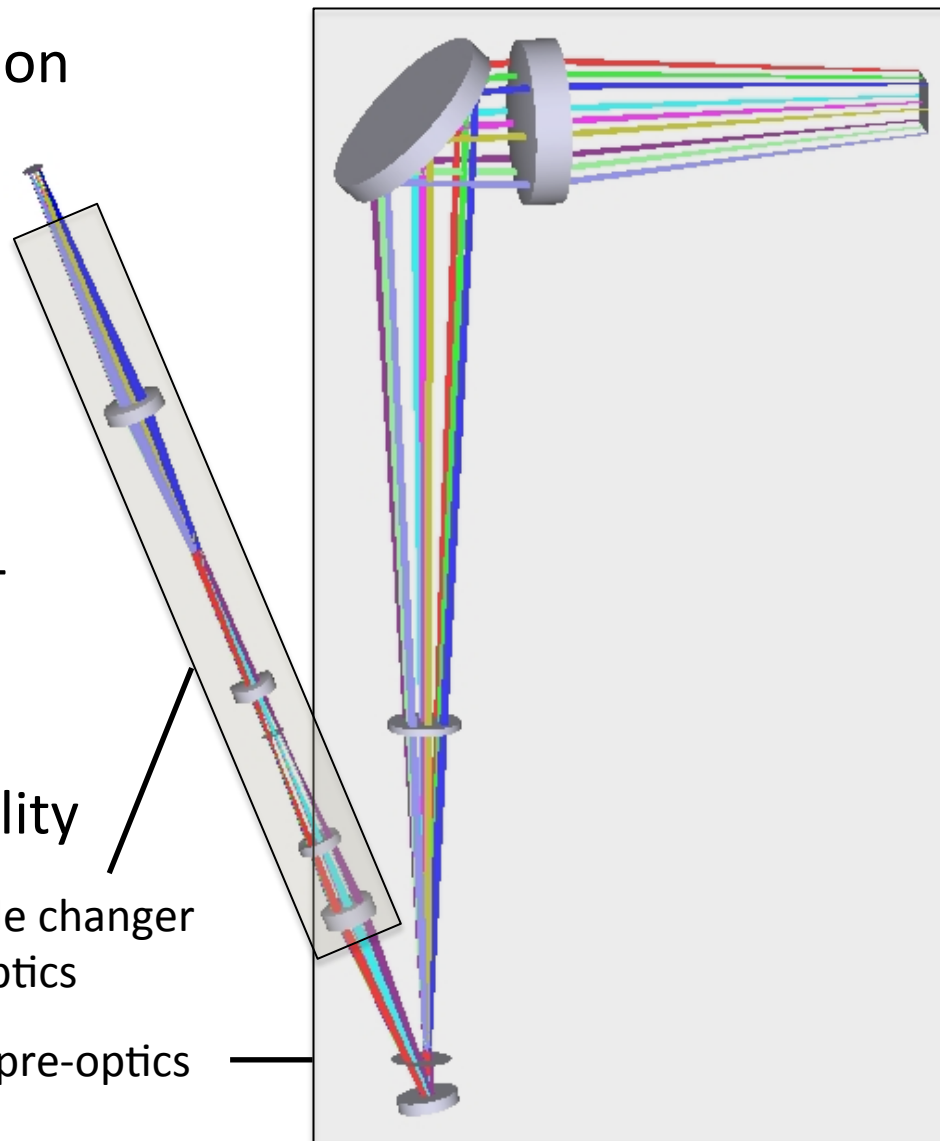


SWIFT – PALM3K/NGS/high-contrast 2011—...

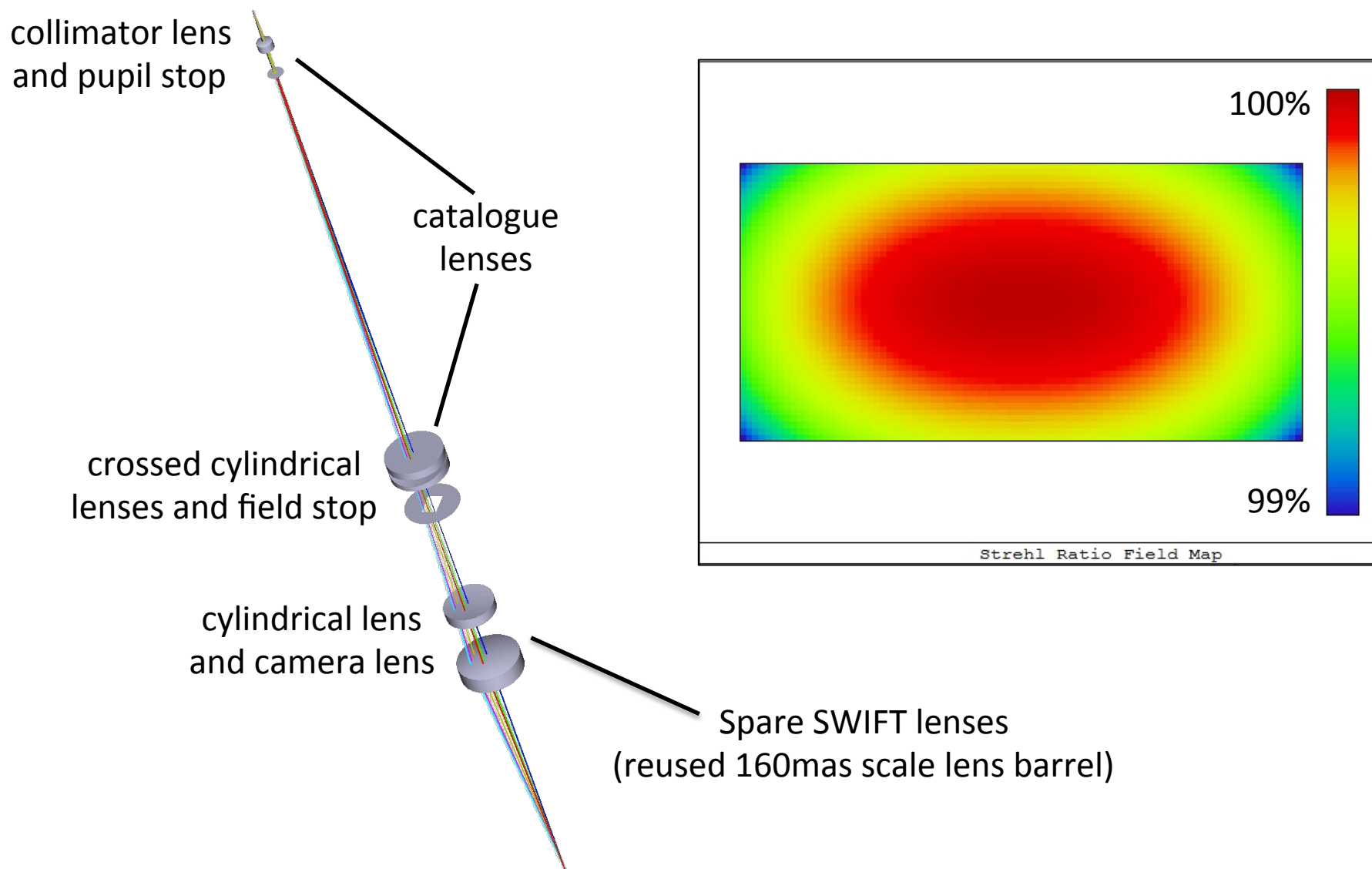
- PALAO system decommissioned in mid 2010 to enable upgrade to PALM3K
 - Focus on high contrast AO
 - Laser indefinitely postponed
- SWIFT returned to Oxford for refurbish and upgrade to exploit PALM3K high contrast abilities;
 - Design of a new 16-milliarcsecond scale to sample diffraction limit at 800nm
 - Implement a ‘blocking bar’ to stop bright sources saturating detector
 - Modify calibration system accommodate 200x range in flux

16mas scale design requirements

- Provide 5× higher magnification than smallest scale (80mas)
 - 1.5x0.7" field of view
- Anamorphic magnification $\times 37.92/\times 75.85$
- Fit in existing design volume
- Use off-the-shelf lenses or reuse spare SWIFT lenses
 - Replace 160mas scale
- Diffraction limited image quality



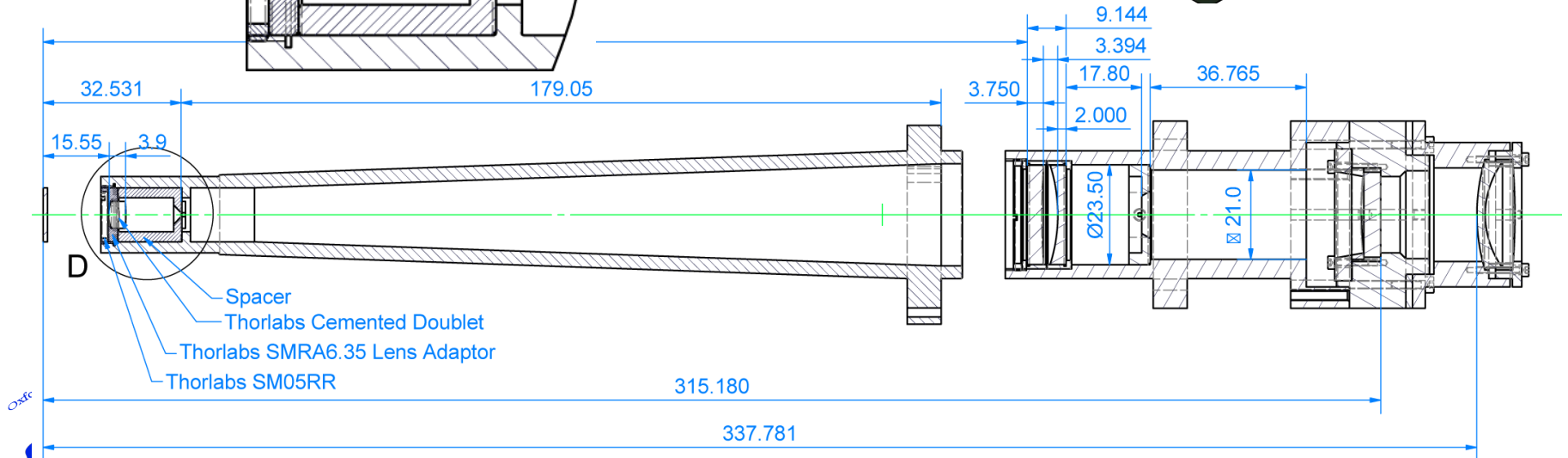
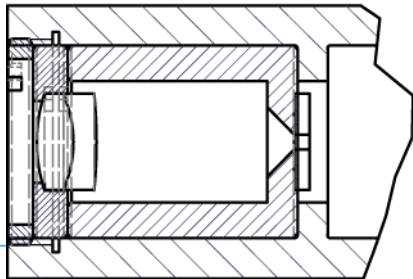
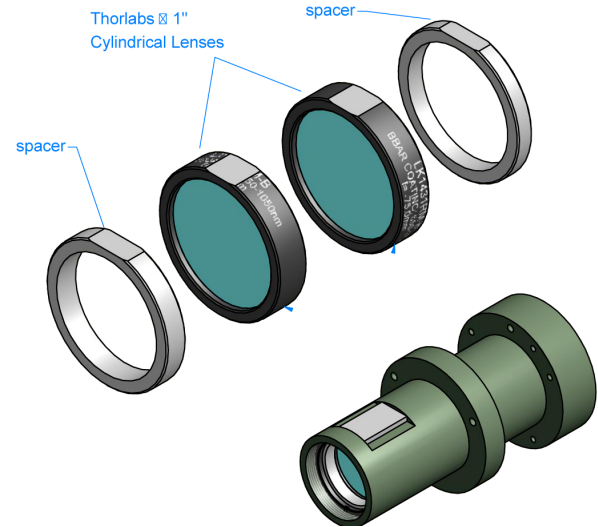
layout & strehl ratio



mechanical design

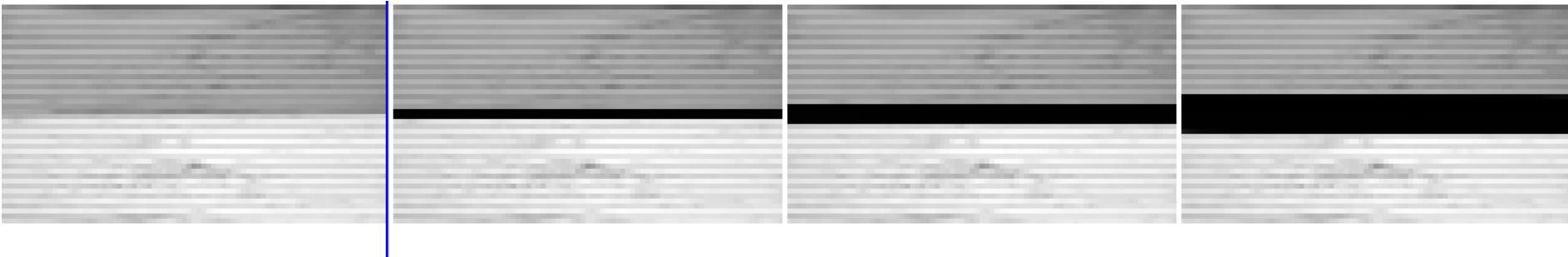
- Replaces 160mas scale changer
- Reuses 160mas lenses

D (2 : 1)



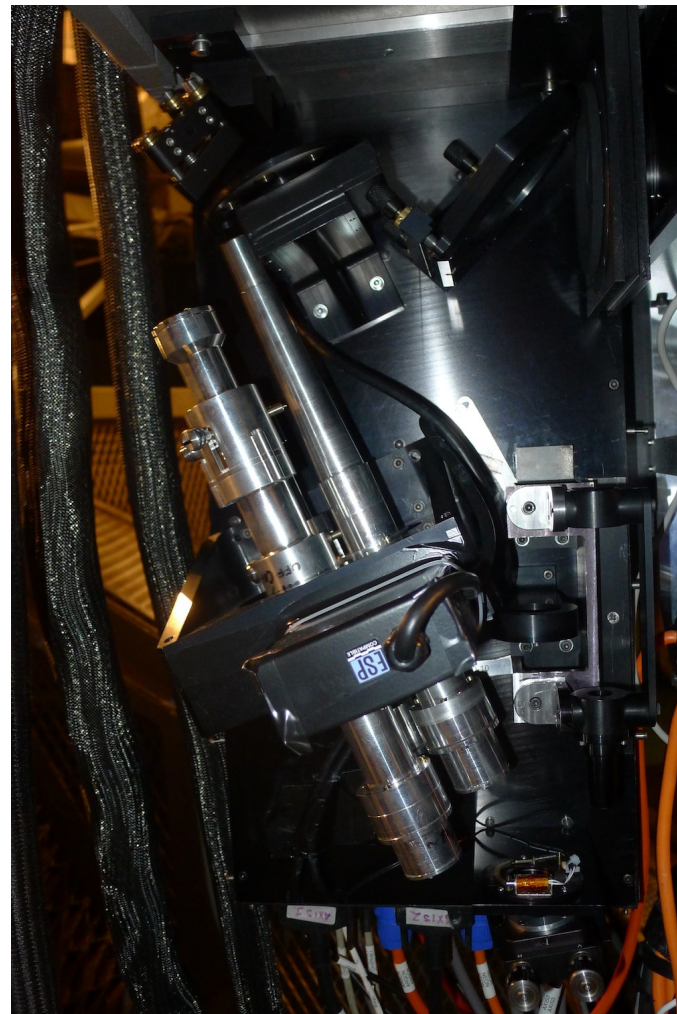
Supporting systems

- Modified calibration system to have adaptable iris diaphragm to control arc flux
 - Factor of 15x in pixel scale is 225x in flux per pixel!
- Added a (very) poor man's occulting stop to avoid saturating on bright stars
 - Moveable blocking bar in the slicer exit focal plane
- Both achieved with <\$100 off-the-shelf servo motors and controllers

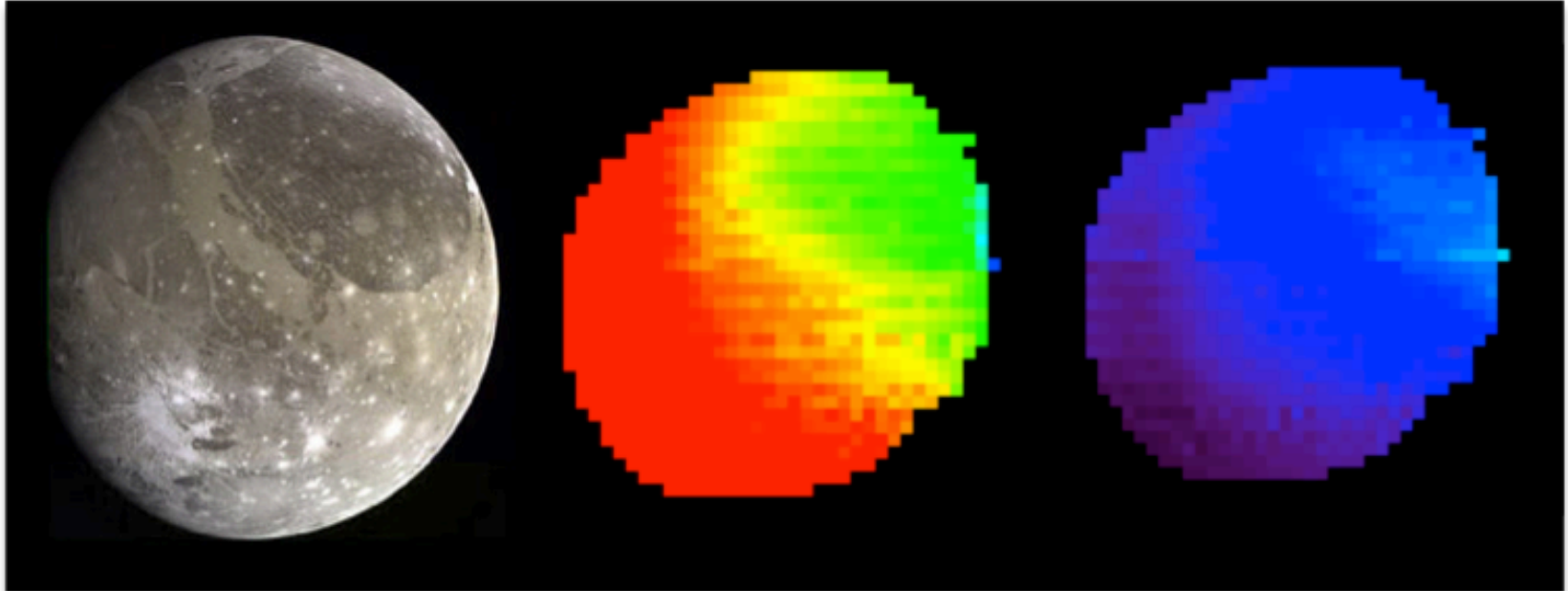


Commissioning

- October 2011: test mount to Palm3k in AO-lab
 - Aligned pupil and focus
 - Found field centre of 16mas scale in larger scales
- December 2011: commissioning run with Palm3k on Palomar 200"
 - Bad weather and seeing (2–4") stopped us from using the 16mas scale altogether
 - Non-common path errors limited internal (AO stimulus) image quality to $\sim 0.1''$



Commissioning — Ganymede



A: Galileo regio (dark region, upper right) from Galileo imaging in 1996

B: SWIFT image at 635 nm, bright emission (red) from water-ice bright sulci, dark over Galileo regio (green).

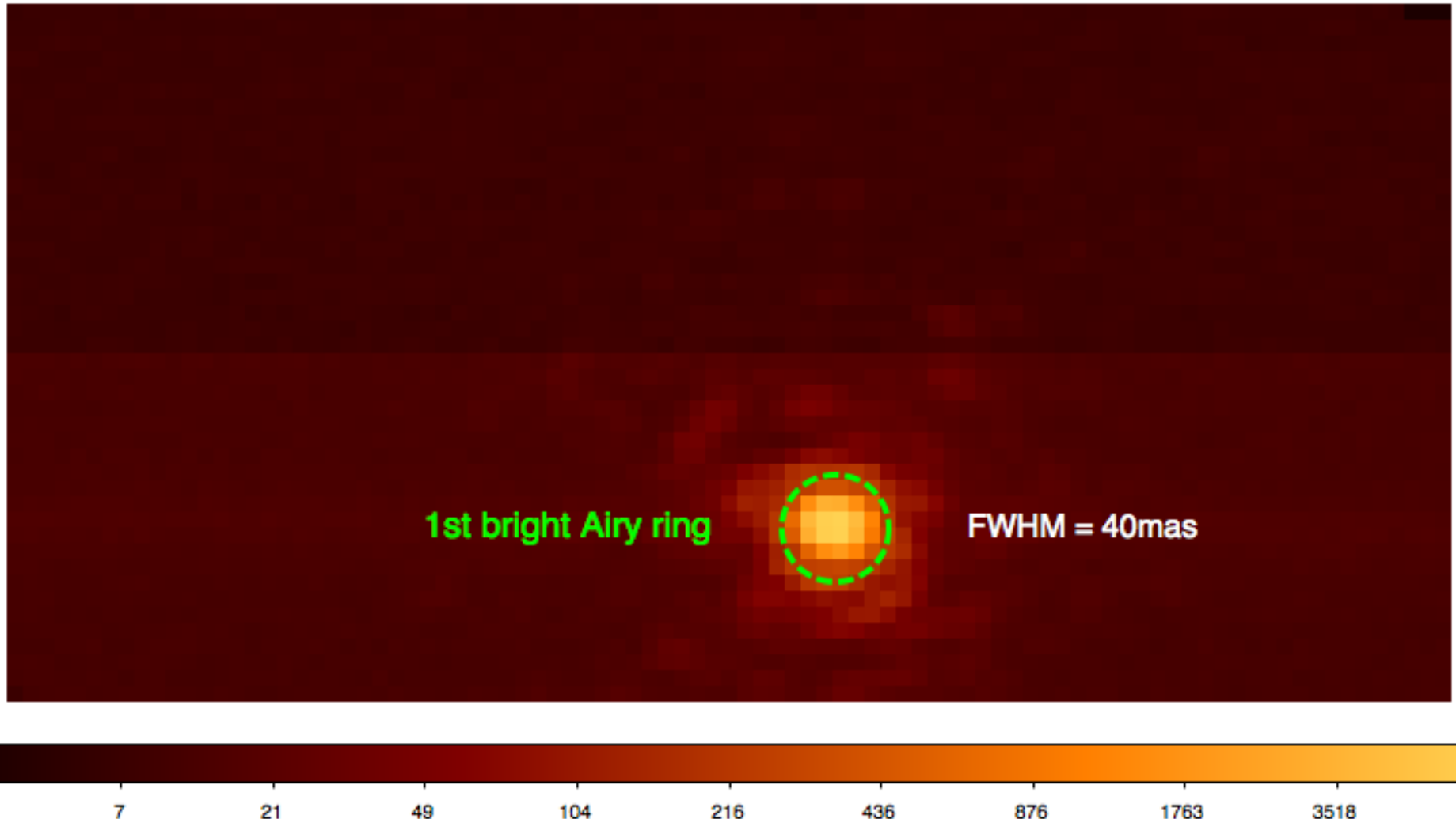
C: SWIFT image at 1035 nm, bright emission (blue) over Galileo regio, where there's little ice absorption, darker over sulci region.

July 2012 run

- 4 night run from June 30th to July 3rd (i.e. this week!)
- Weather finally cooperated!
 - Clear skies
 - Median seeing (1.0-1.3")
- System seems to be working very well, and doing adaptive optics in the visible...

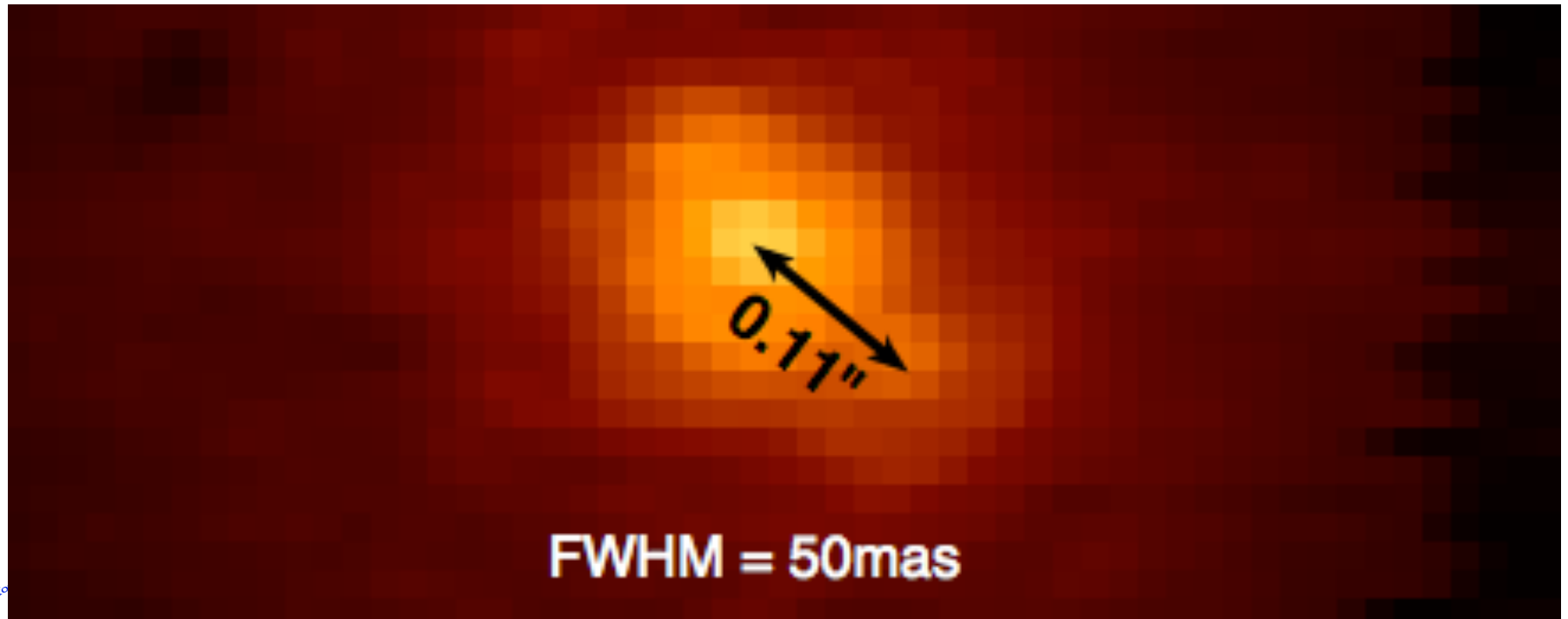
July 2012 — Internal PSF

- Image of AO-stimulus after correction for non-common-path aberrations of SWIFT



2nd July 2012 — Binary

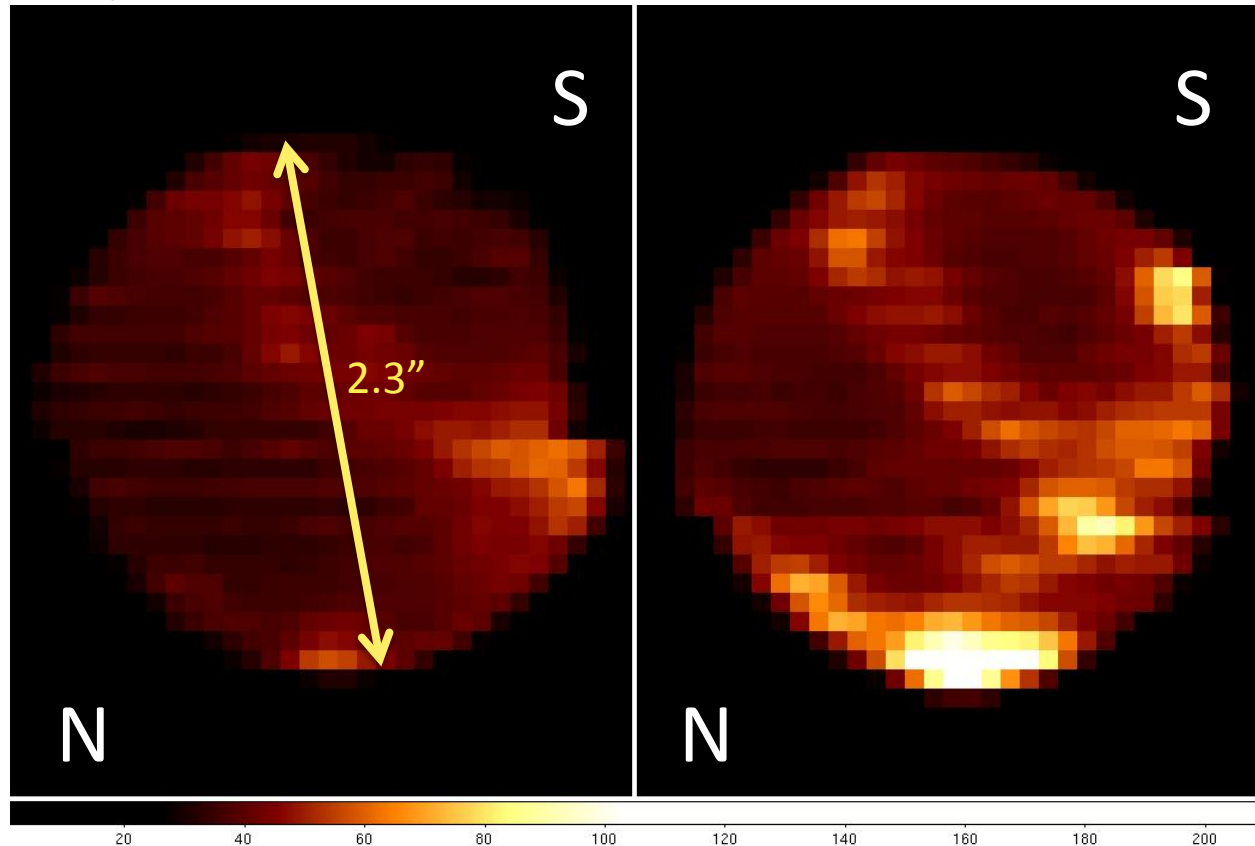
- Close binary (Horch 2010)
- $V_{\text{primary}} = 7.7$, 0.11" separation, $\Delta\text{mag} = 3.3$
- Narrow band channel map at 0.8 μm



2nd July 2012 — Neptune

- 80mas scale, IQ~0.1-0.2''
- AO loops closed on Neptune (2.3'' diameter)
- High storm clouds above Methane absorption layer seen evolving as Neptune rotates

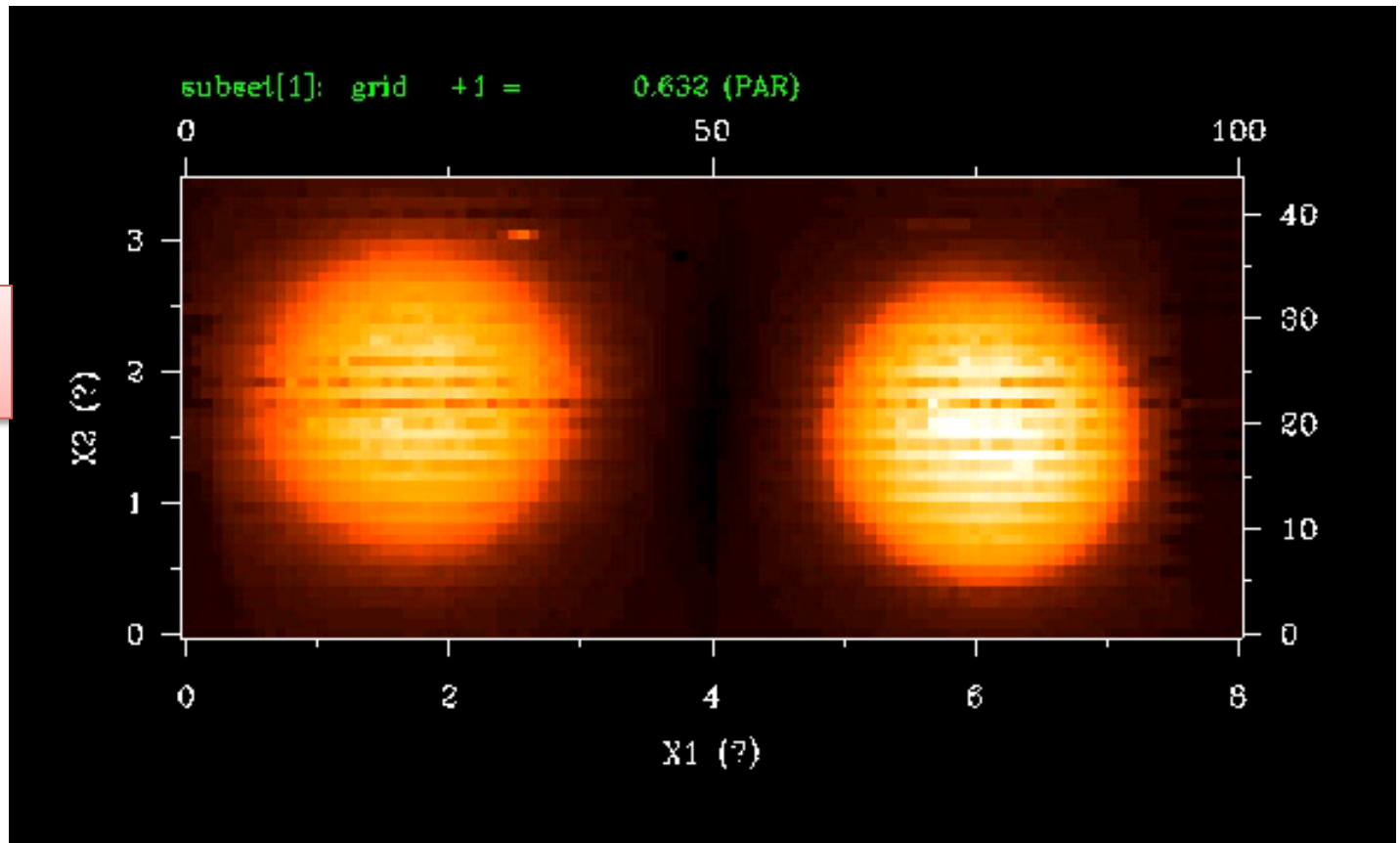
Quick data
reduction only!



2nd July 2012 — Neptune

- 80mas scale, IQ~0.1-0.2''
- AO loops closed on Neptune (2.2'' diameter)
- Comparison of two datacubes (650nm to 1050nm) taken 3 hours apart

Quick data
reduction only!



Conclusion

- 15× zoom from 235mas to 16mas shown to possible and successful
 - Minimised cost by using stock and existing optics
- Palm3k extreme adaptive optics can deliver extremely sharp images even in the red-visible
 - 50mas FWHM measured on sky at 800nm (in ~1.0" natural seeing)
 - Control of non-common path aberrations is critical
- Exciting new opportunities for high resolution IFU science on bright targets
 - Particularly interesting for solar system objects
 - Facility instrument available for all observers in the Palomar system