Update on the LBTI: a versatile high-contrast and high-resolution infrared imager for a 23-m telescope

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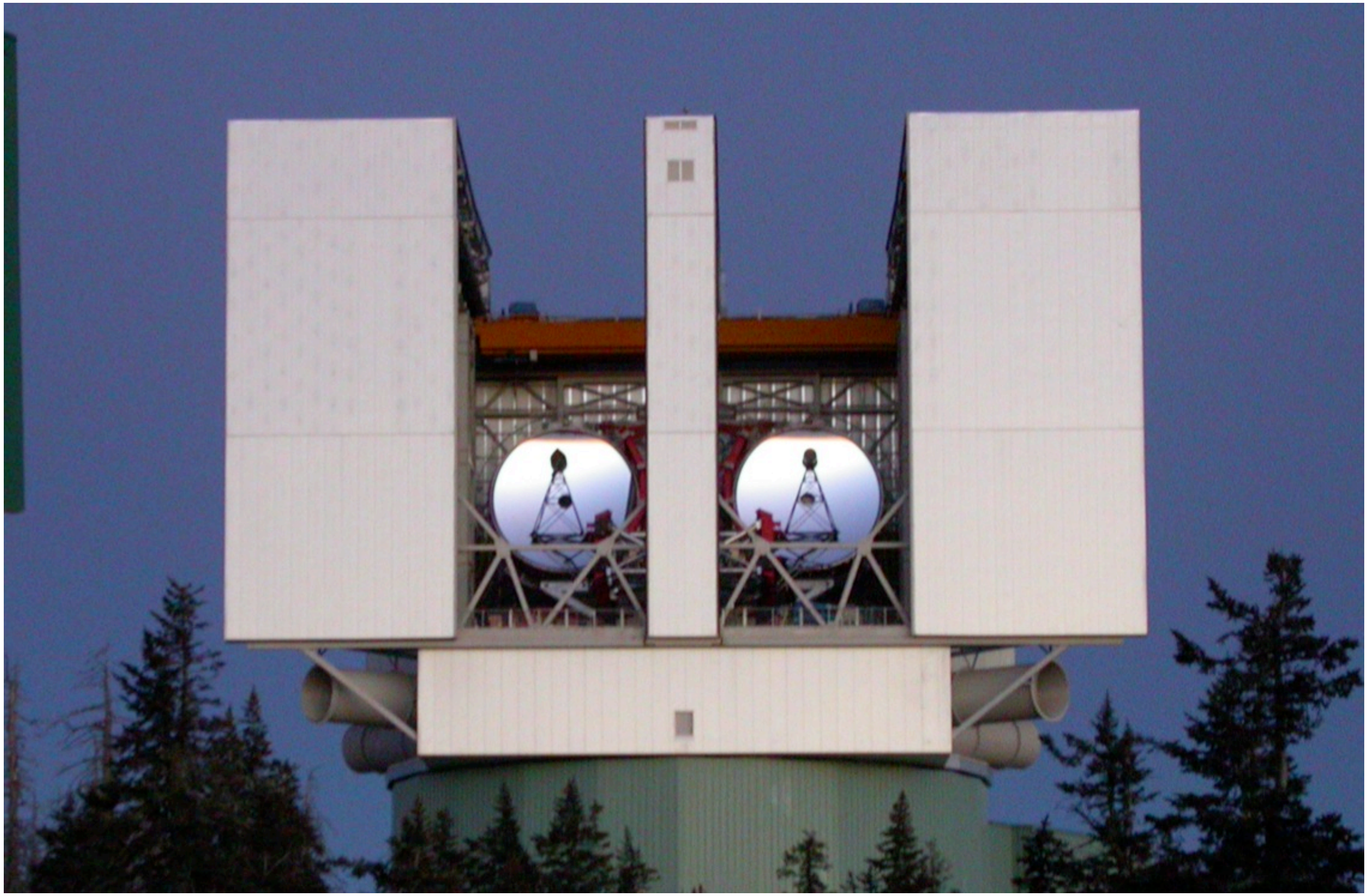
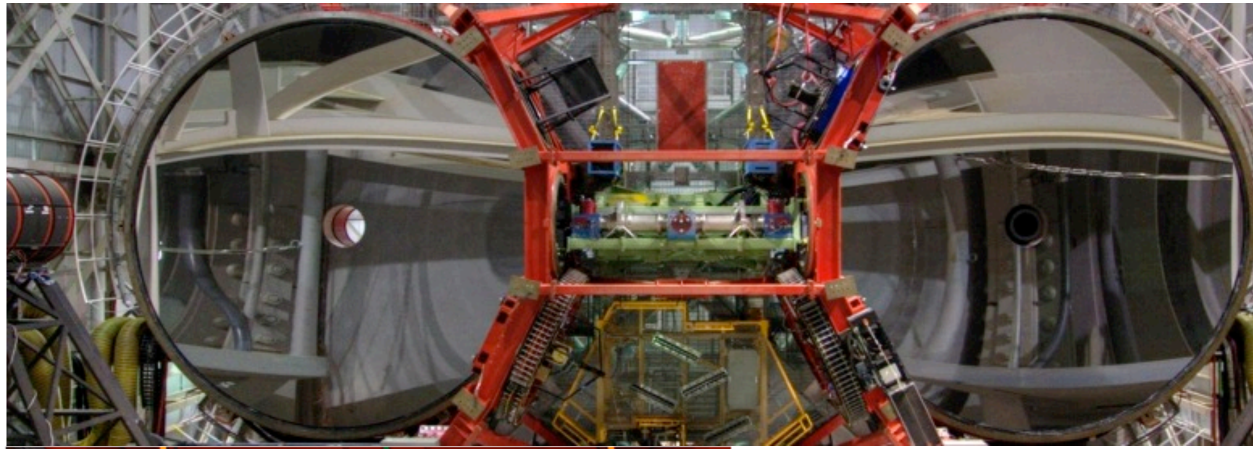
OHP (France) – September 24th, 2013

The Large Binocular Telescope (LBT)

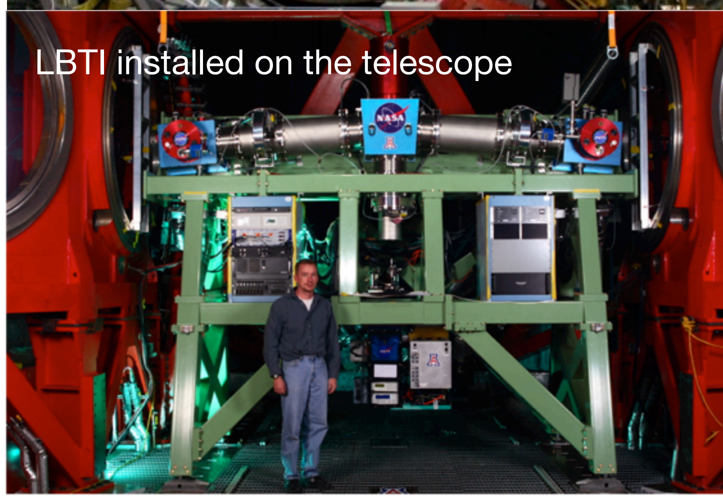


- Partners: Arizona, Italy, Germany, The Research Corporation, Ohio State University
- Location: Mt Graham, Arizona, elevation 10400 feet (3170 meters)

LBTI key parameters



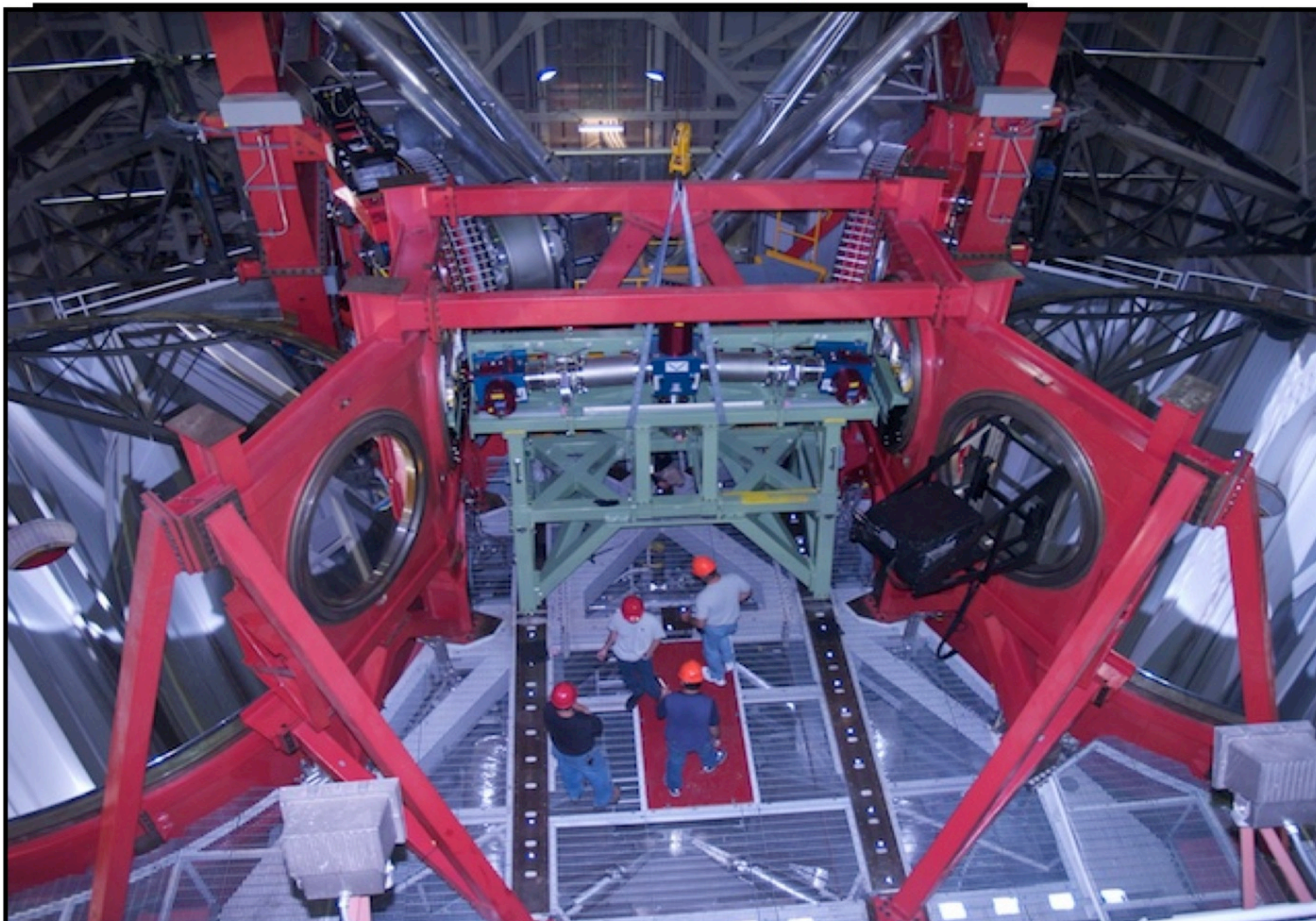
Sensitivity
LBTI has two 8.4 m mirrors mounted on a single structure.



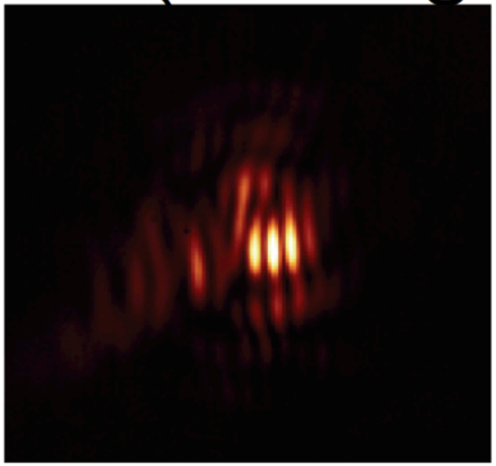
High Contrast
The AO system creates an image with a Strehl of >90% at 3.8 μm.

Resolution
Beam combination provides the equivalent resolution of a 22.7 m telescope.

LBTI was installed in September 2010

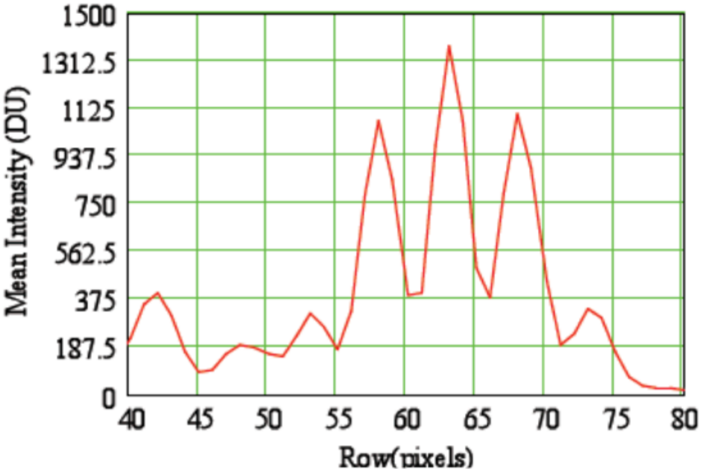


First Fringes!
(First night on sky: Oct. 14, 2010)

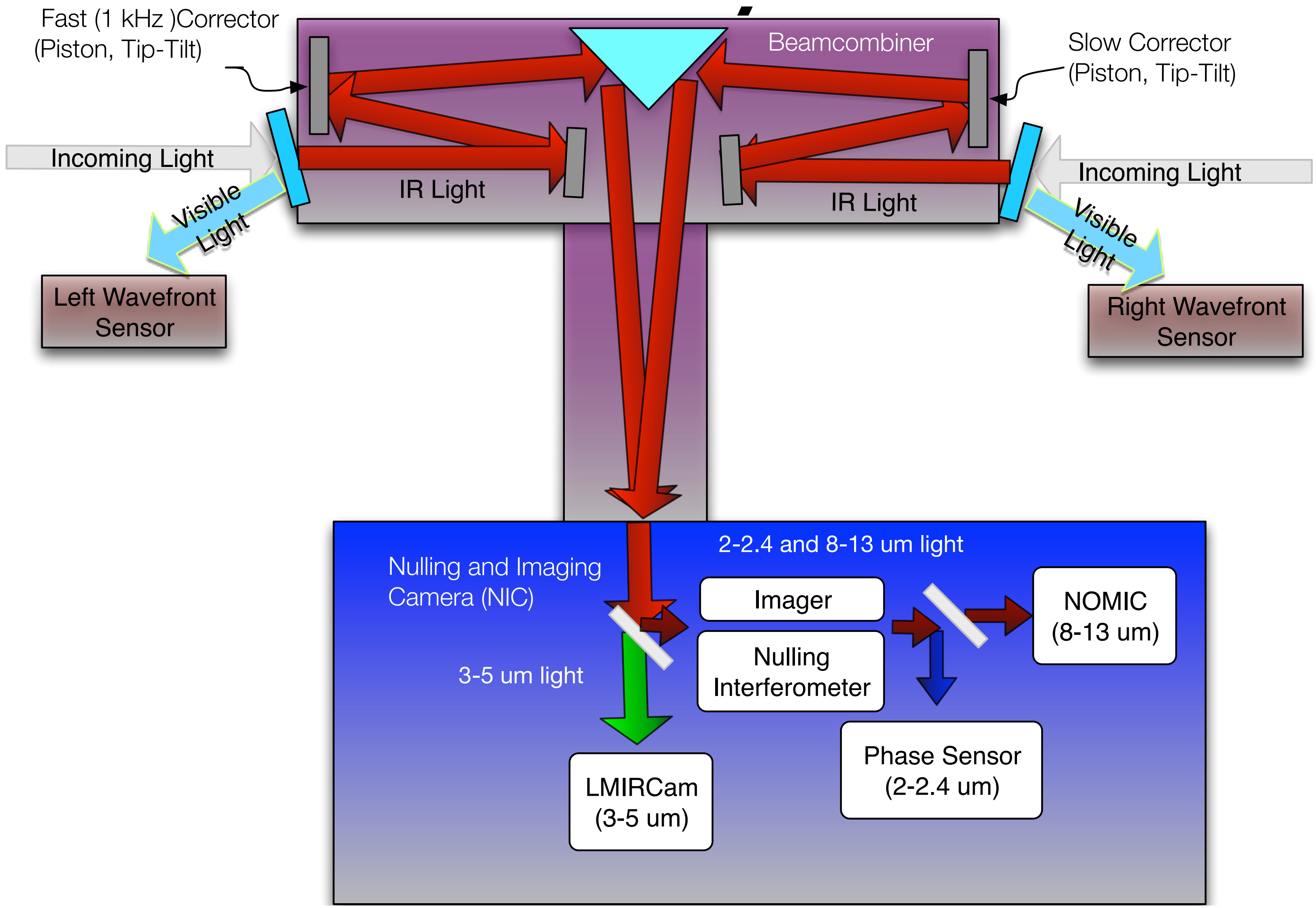


Beta Peg: Combined 10μm image from the LBTI imager. Image is "seeing limited" under poor weather conditions (seeing ~1.2 arc sec).

This image shows that:
- The two telescopes are co-pointed and tracking to 0.3"
- The pathlength difference between the two beam paths is less than ~10 μm and stable.



LBTI Components



LBTI science Cameras

	LMIRcam	NOMIC
Wavelength Coverage (µm)	2.9-5.1(1.5-5.1 capable)	8-14 (8-25 capable)
Throughput	>30%	>20%
Pixel Size	0.011”	0.018”
FOV	20”	12”
Minimum Strehl	90% (3.8 µm)	98% (11 µm)
Spectral Resolution	350	100
5 sigma detection, 1 hour	19.0 (7 µJy) @ L’	13.3 (200 µJy) @ N
Spatial Resolution	40 mas @ L’	100 mas @ N’

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Minimum Strehl	90% (3.8 µm)	98% (11 µm)
Spectral Resolution	350	100
5 sigma detection, 1 hour	**~2 M_J planet at 1 Gyr**	**~1 zodi debris disk**
Spatial Resolution	**0.4 AU at 10 pc**	**1 AU at 10 pc**

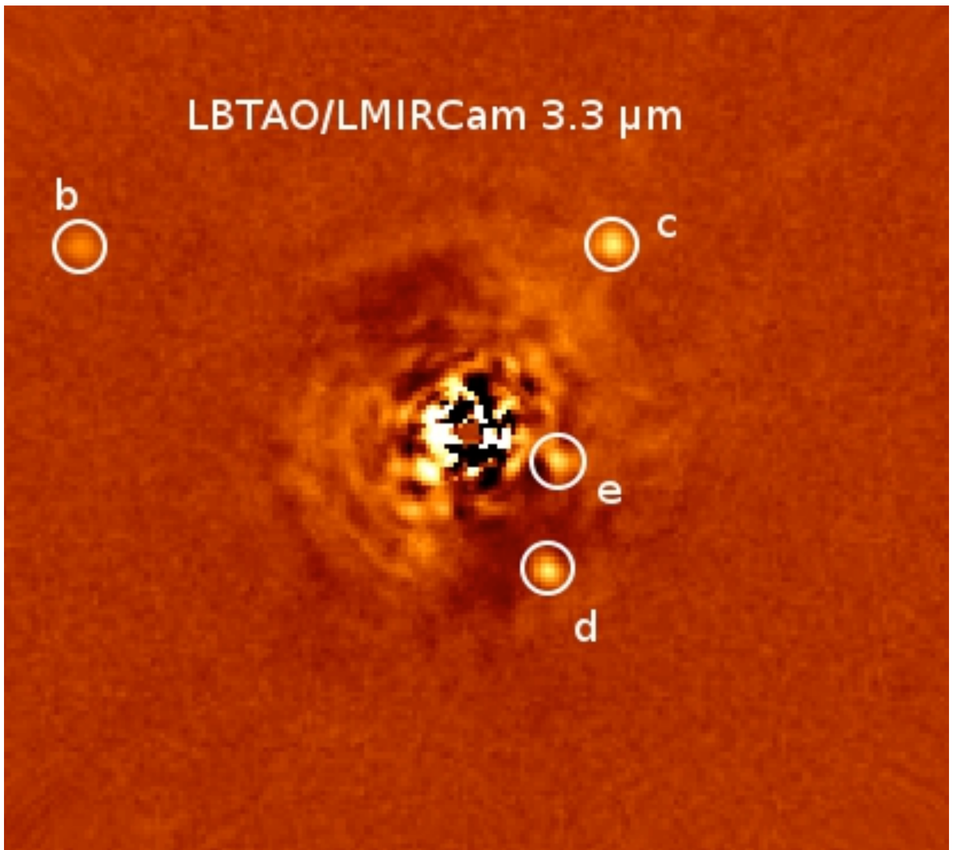
Observers

…still a lot of staff. As scripting becomes more routine, we should be able to condense down to 1 AO operator, 1 science camera operator, 1 fringe-tracker operator and 1 night planner.

UA making special LBTI remote observing room to help lessen travel burden.

LEECH:
LBTI Exozodi Exoplanet Common Hunt

HR 8799



Skemer et al. (ApJ, 2012)

- 4 micron direct-imaging search for exoplanets, which started in April 2013.
- 60 nights in parallel with HOSTS survey (do no harm rule).
- 70 nights from Arizona, Notre Dame, Virginia, Minnesota, Italy and Germany (will do simultaneous nulling eventually, which will be used by HOSTS).
- More sensitive to exoplanets than any previous survey.

HOSTS:

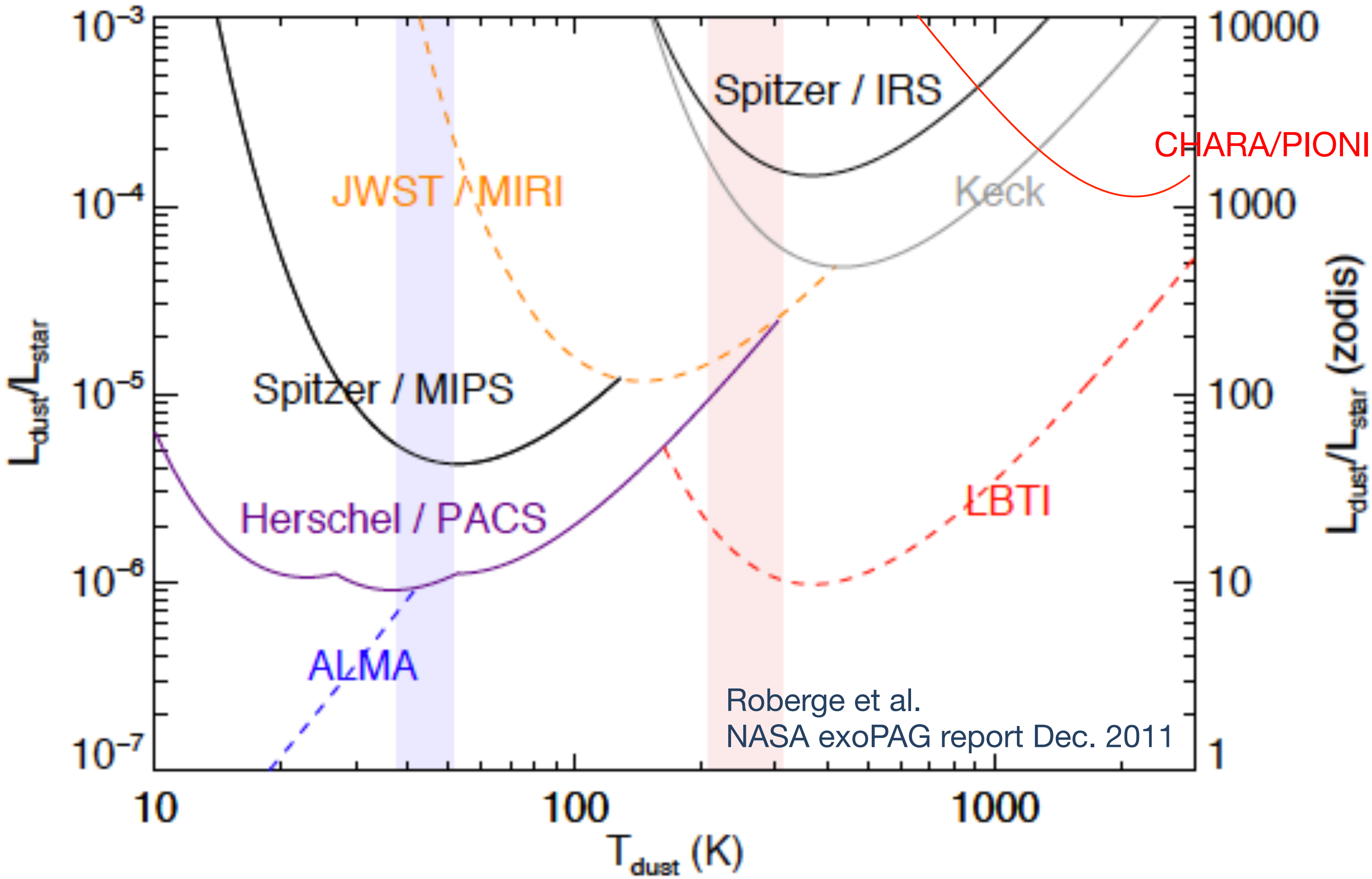
Hunt for Observable Signatures of Terrestrial Planetary Systems

ASTRO2010 Decadal Survey:

"... need to characterize the level of zodiacal light present so as to determine, in a statistical sense if not for individual prime targets, at what level starlight scattered from dust will hamper planet detection".

- NASA-supported 60 night survey to be carried out in the 2013-2016 time frame.
- Top level goal is to reduce risk for future NASA exoplanet imaging missions.
- Search actual candidate stars for exozodiacal emission.
- Understand trends and correlations for zodiacal dust:
    - Comparison to outer disk strength
    - Dependence on age and stellar mass.
    - Existence and influence of Jupiter-mass planets.

LBTI exozodi program in context



Comparison of current facilities' sensitivity to exozodiacal dust. LBTI can detect dust in the habitable zone down to 10 zodis.

Required performance

Photometric sensitivity

- A solar level zodiacal dust disk around a G5 star at 10 pc results in a flux of 42 μJy in the nulled focal plane.
- The requirement is a 1-sigma limit of 150-300 μJy for a 10 min. integration.

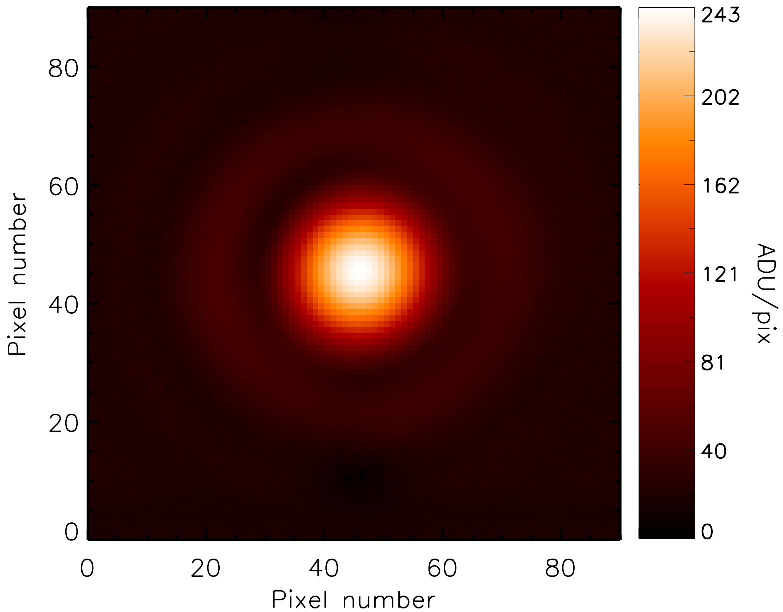
This is a 1-sigma detection level of 3-7 zodis.

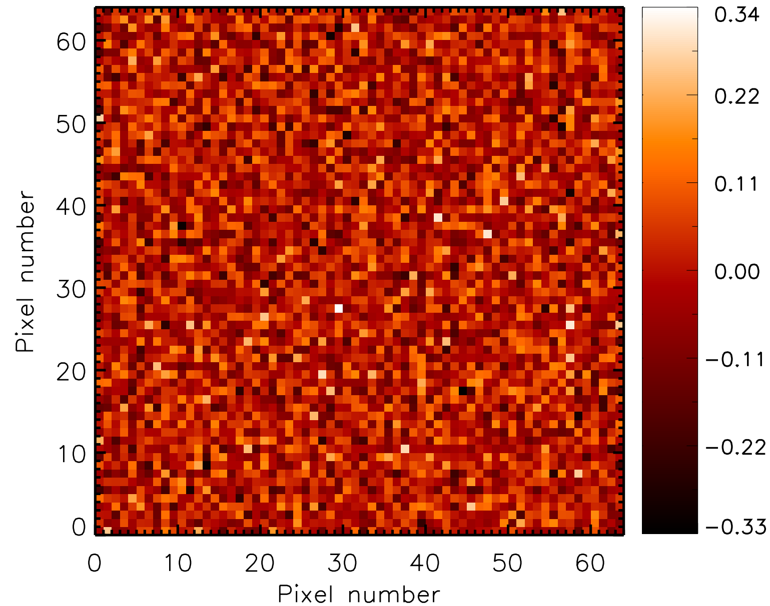
Calibrated null stability

- A G5 star at 10 pc has an 11 μm flux of 1.2 Jy.
- The flux of a solar level zodiacal dust disk is 5x10^-5 of its star.
- Approximately 1/2 of the flux is transmitted to the final focal plane.
- The requirement is a calibrated uncertainty in the nulled star of 0.75-1.5x10^-4 for a 3 hour integration time.

This is a 1-sigma detection limit of 3-6 zodis.

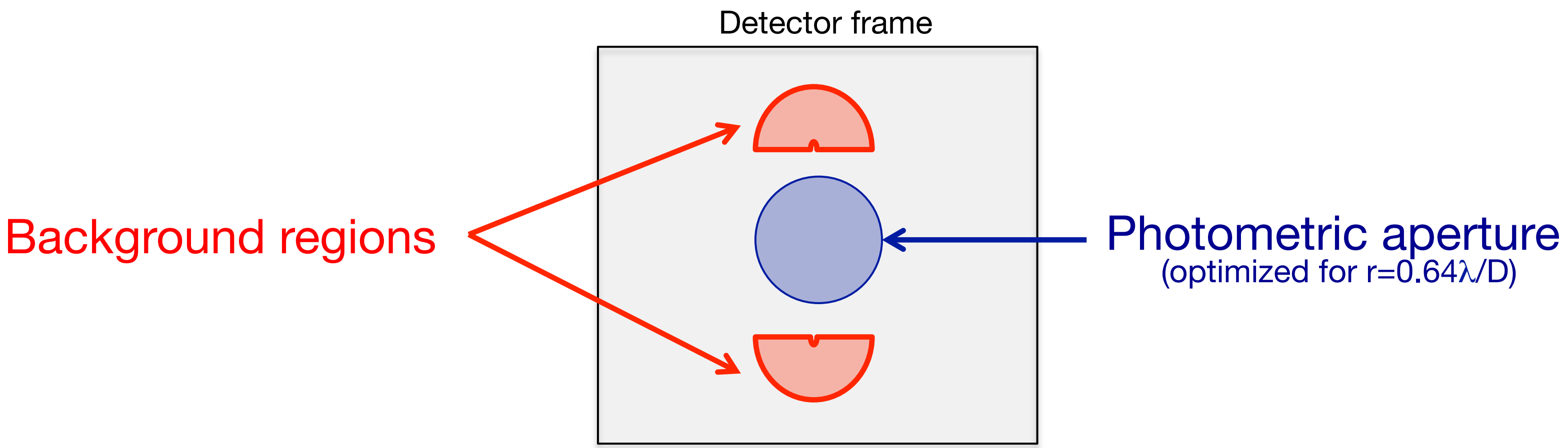
Measurements: photometric sensitivity

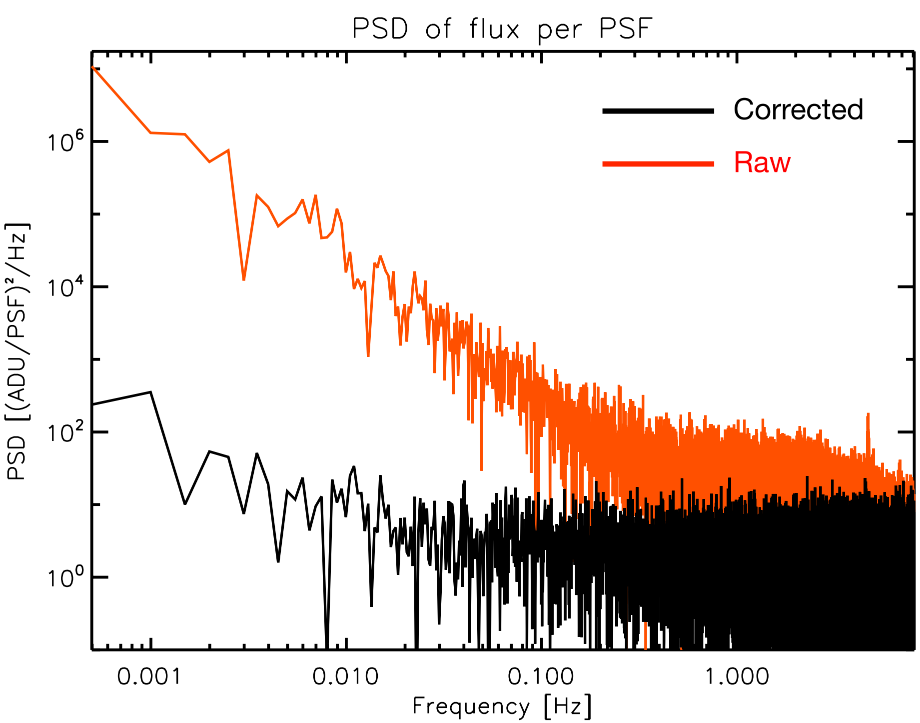


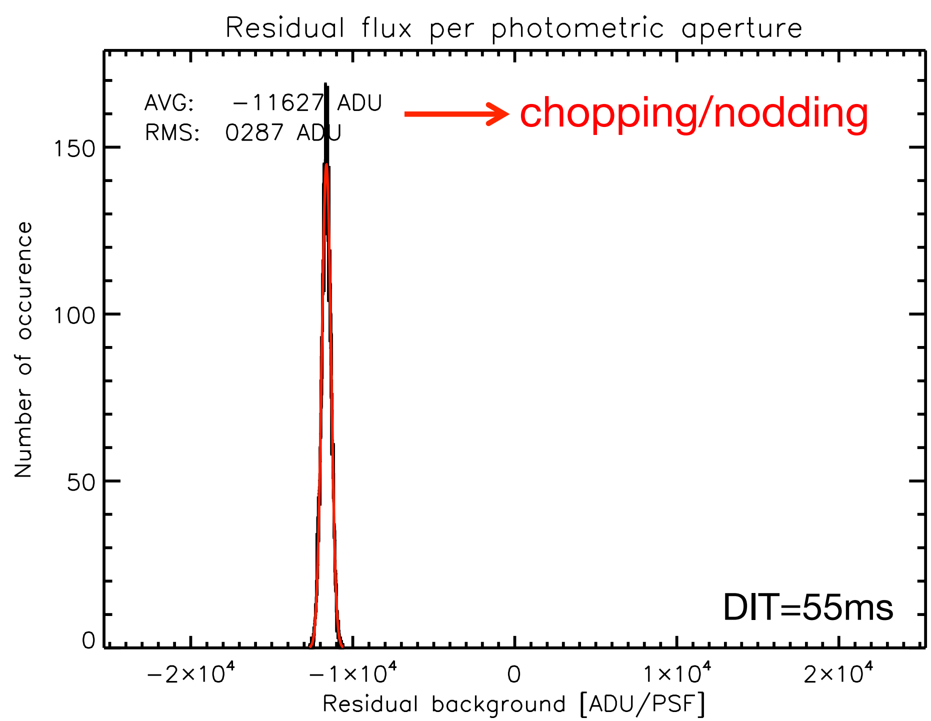


- June 2013 data demonstrated noise of 70 mJy in t=55 ms exposures.
- Extrapolated to 10 minutes, this is a noise of 700 µJy.
- This is ~2x above the photometric noise requirement.
- Data showed room for improvement in two areas:
  - Background flux was 2-2.5x the expected final amount.
  - Electronic noise contributed to the 70 mJy limit (1/3 total)

Measurements: background subtraction

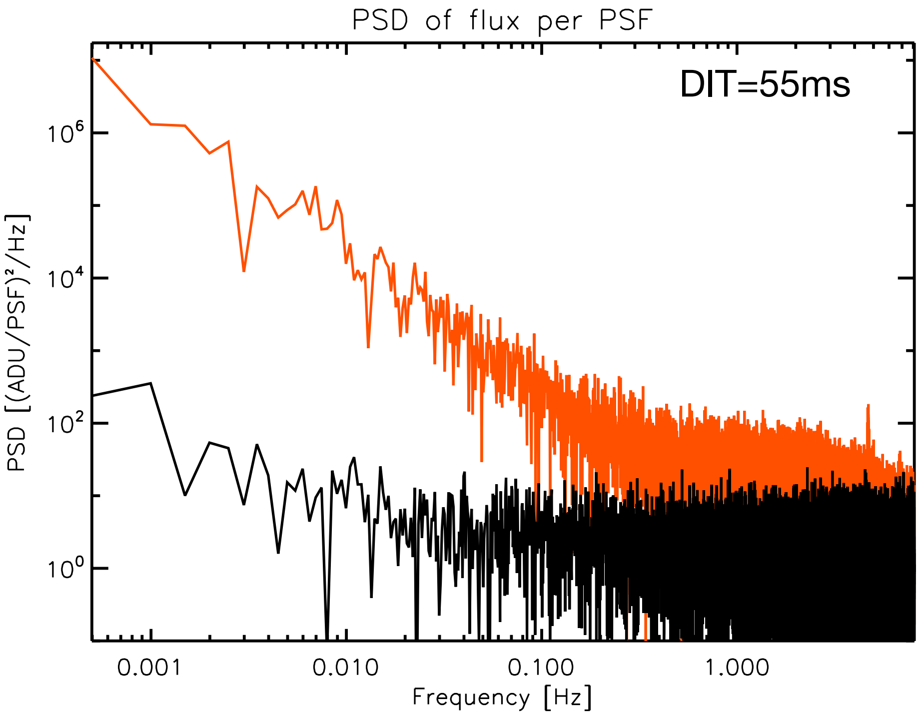




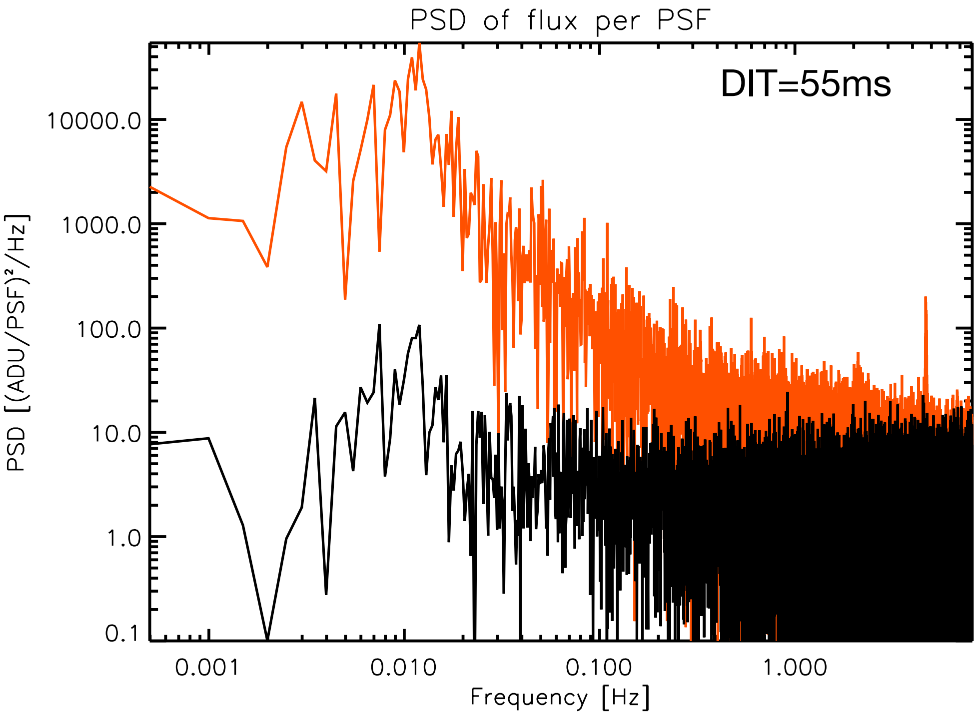


Measurements: background subtraction

- 40-min of sky data nodding every ~1min30 (June 27th 2013)
- Offset reduced to ~8 ADU/PSF (+ Gaussian noise)



WITHOUT NODDING SUBTRACTION



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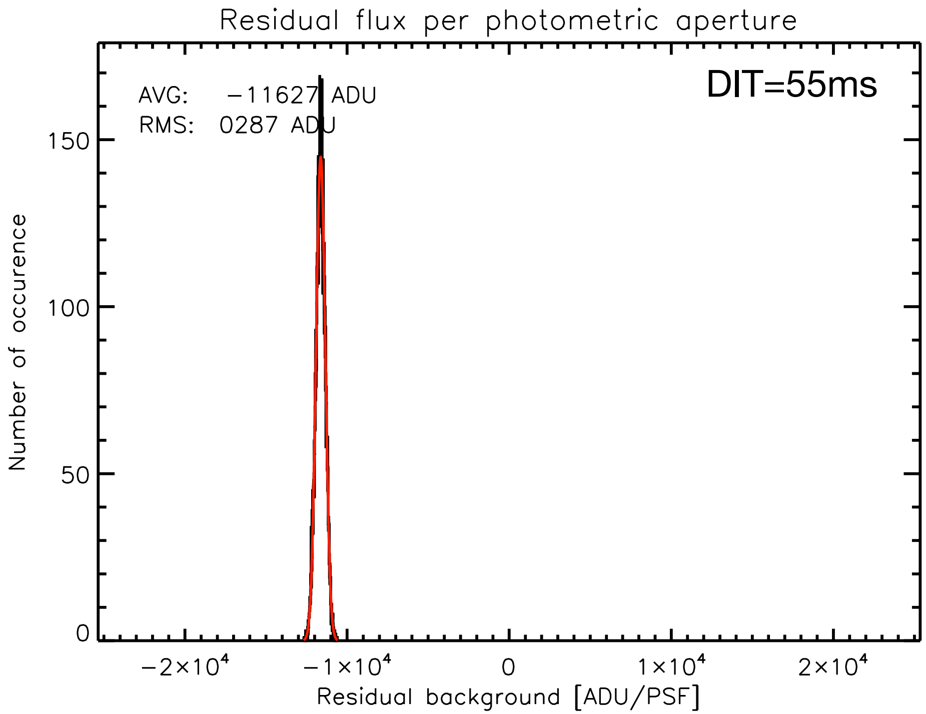

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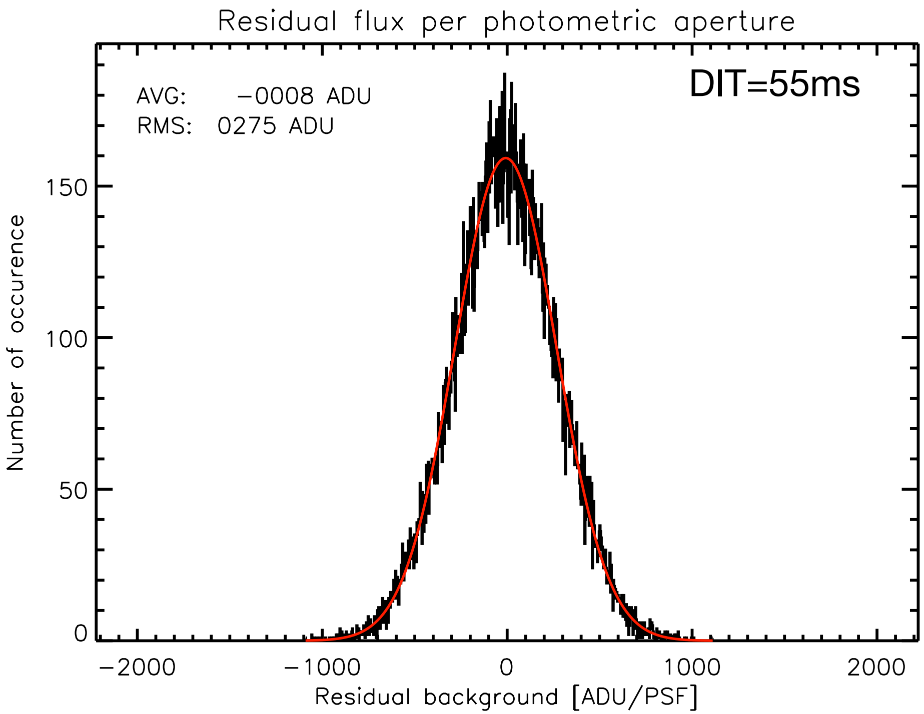
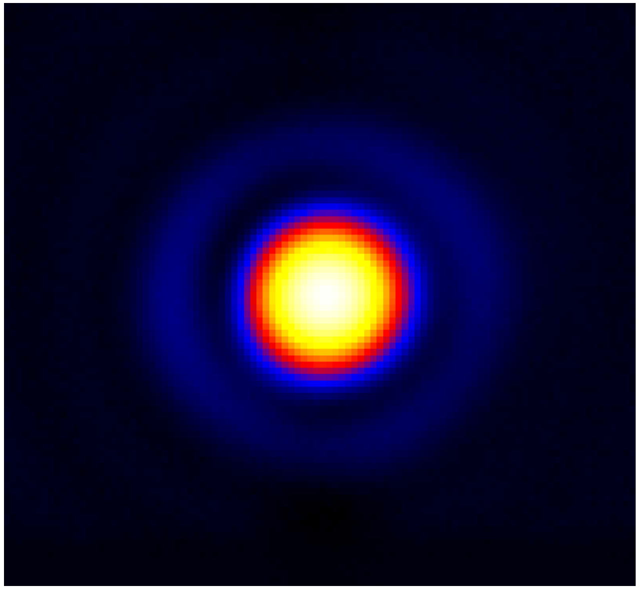
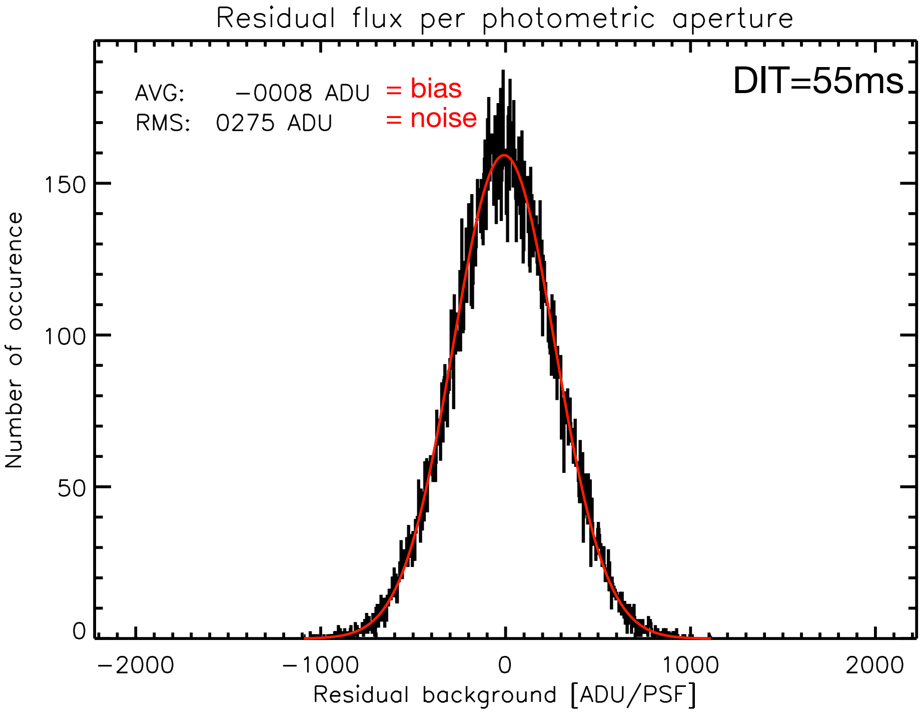


WITH NODDING SUBTRACTION

Measurements: background subtraction

Vega on June 27th (40 min of integration)

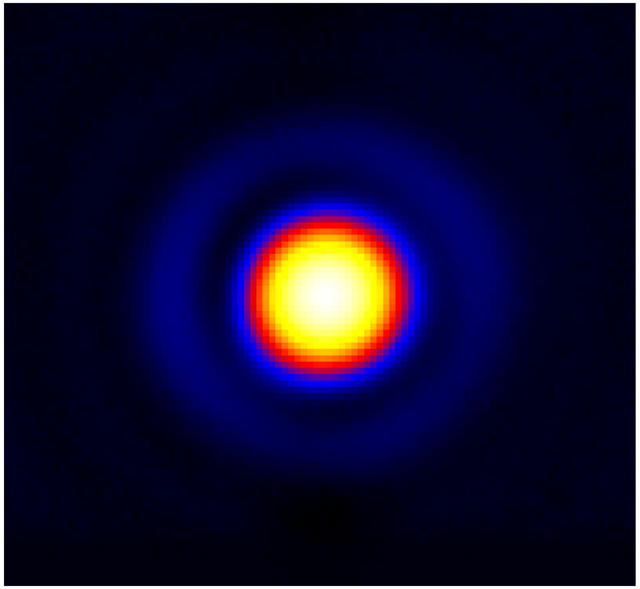


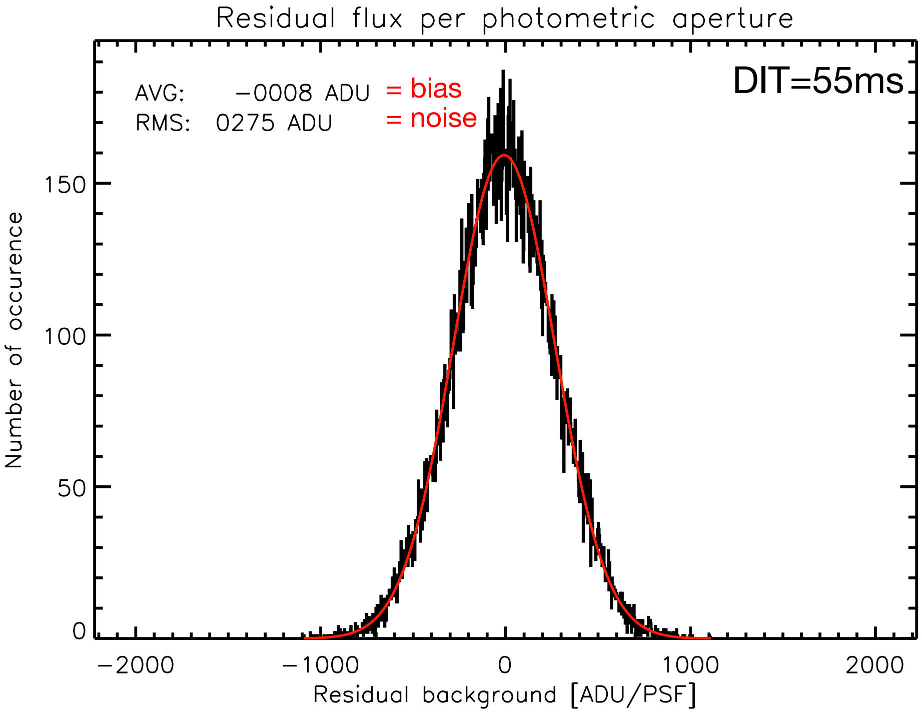


- Measured Vega's flux ~ 2.2×10^5 ADU/PSF in 55ms (optimum aperture)
- Background noise is ~0.2% in 55ms (i.e., 0.07 Jy)
- Background bias is ~0.004% (i.e., 0.001 Jy)

Measurements: background subtraction

Vega on June 27th (40 min of integration)

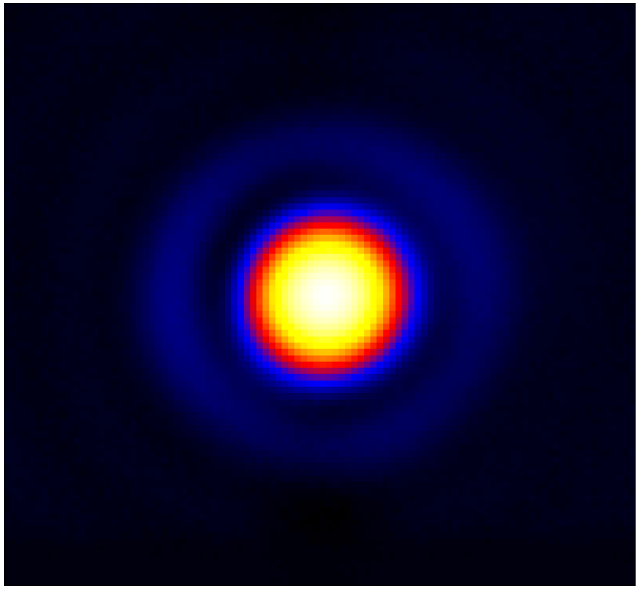


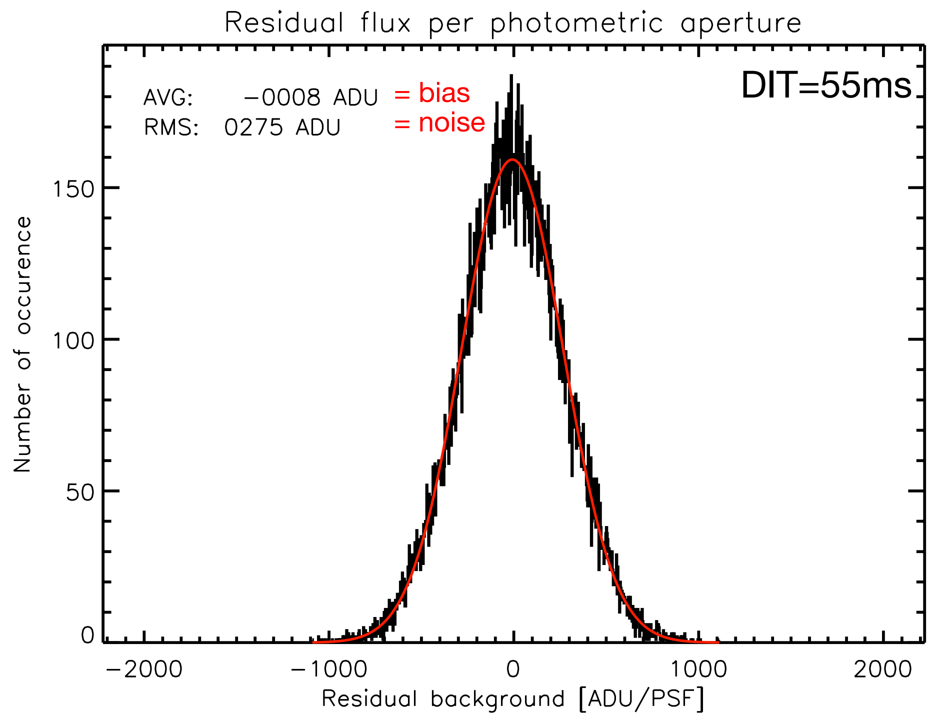


- Measured Vega's flux ~ $2.2*10^5$ ADU/PSF in 55ms (optimum aperture)
- Background noise is ~0.2% in 55ms (i.e., 0.07 Jy)
- Background bias is ~0.004% (i.e., 0.001 Jy) **= 2.7e-6 of background subtraction**

Measurements: background subtraction

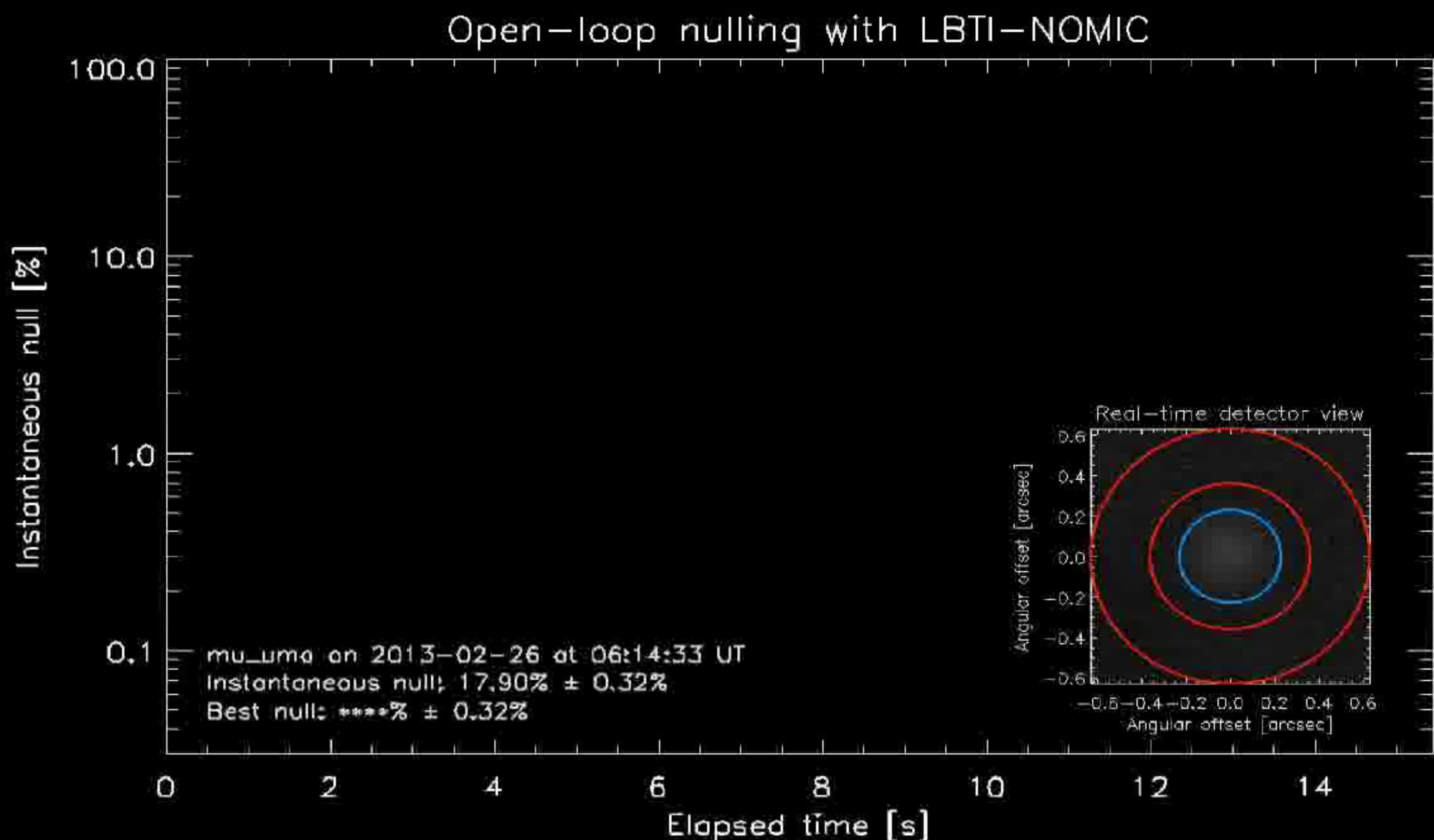
Vega on June 27^{th} (40 min of integration)



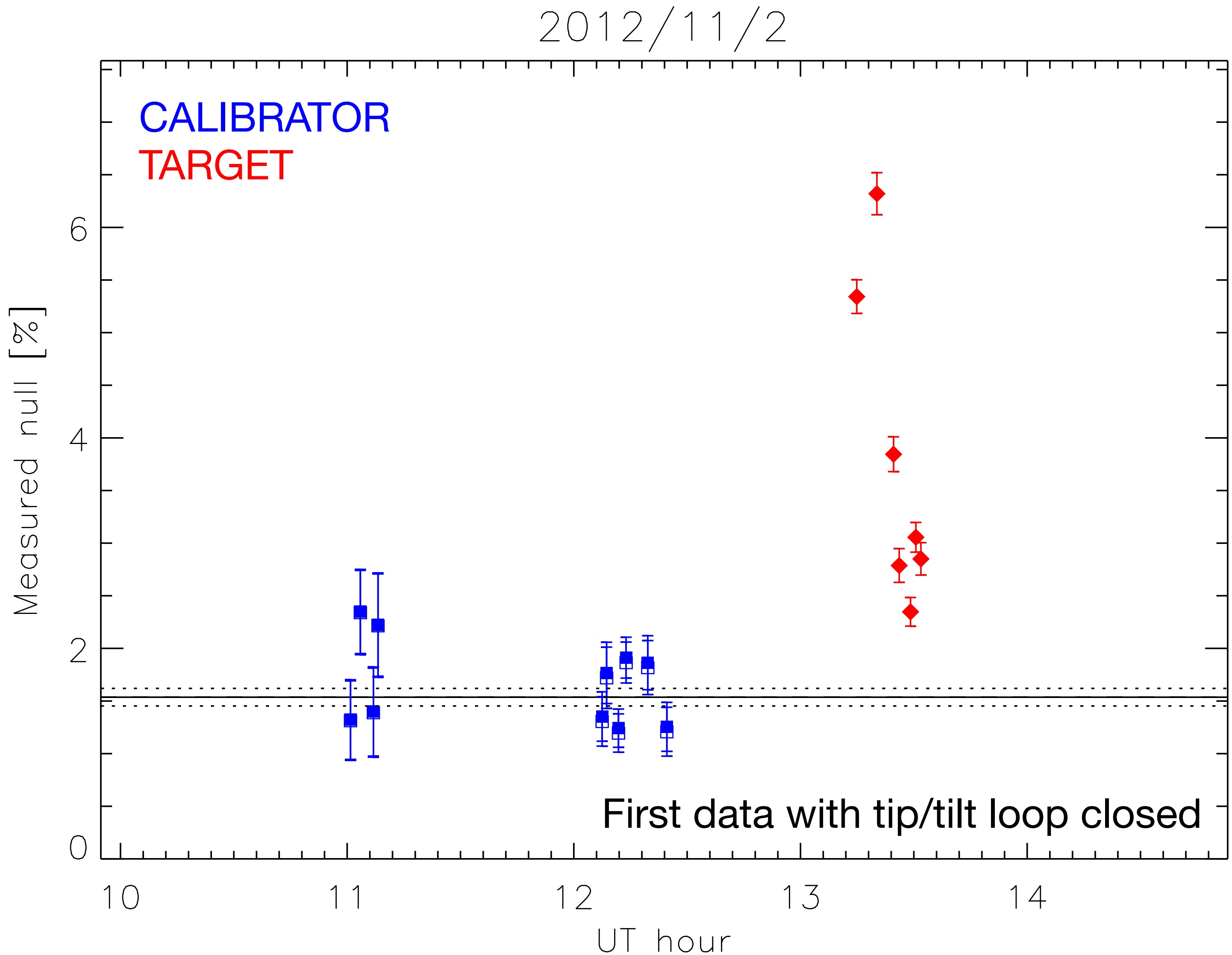


- Measured Vega's flux ~ $2.2*10^5$ ADU/PSF in 55ms (optimum aperture)
- Background noise is ~0.2% in 55ms (i.e., 0.07 Jy)
- Background bias is ~0.004% (i.e., 0.001 Jy) **= 1 zodi for Vega**

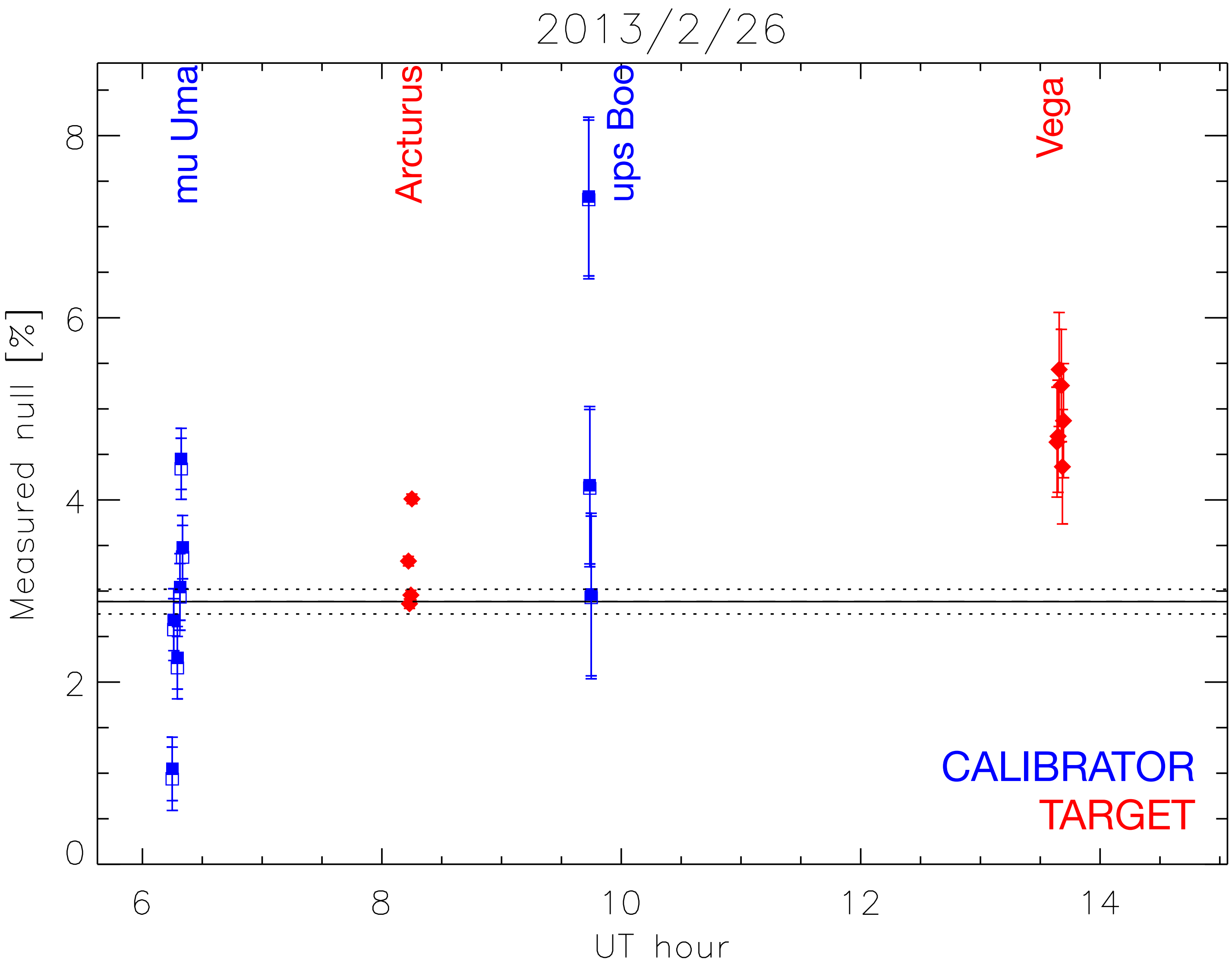
Measurements: calibrated null stability



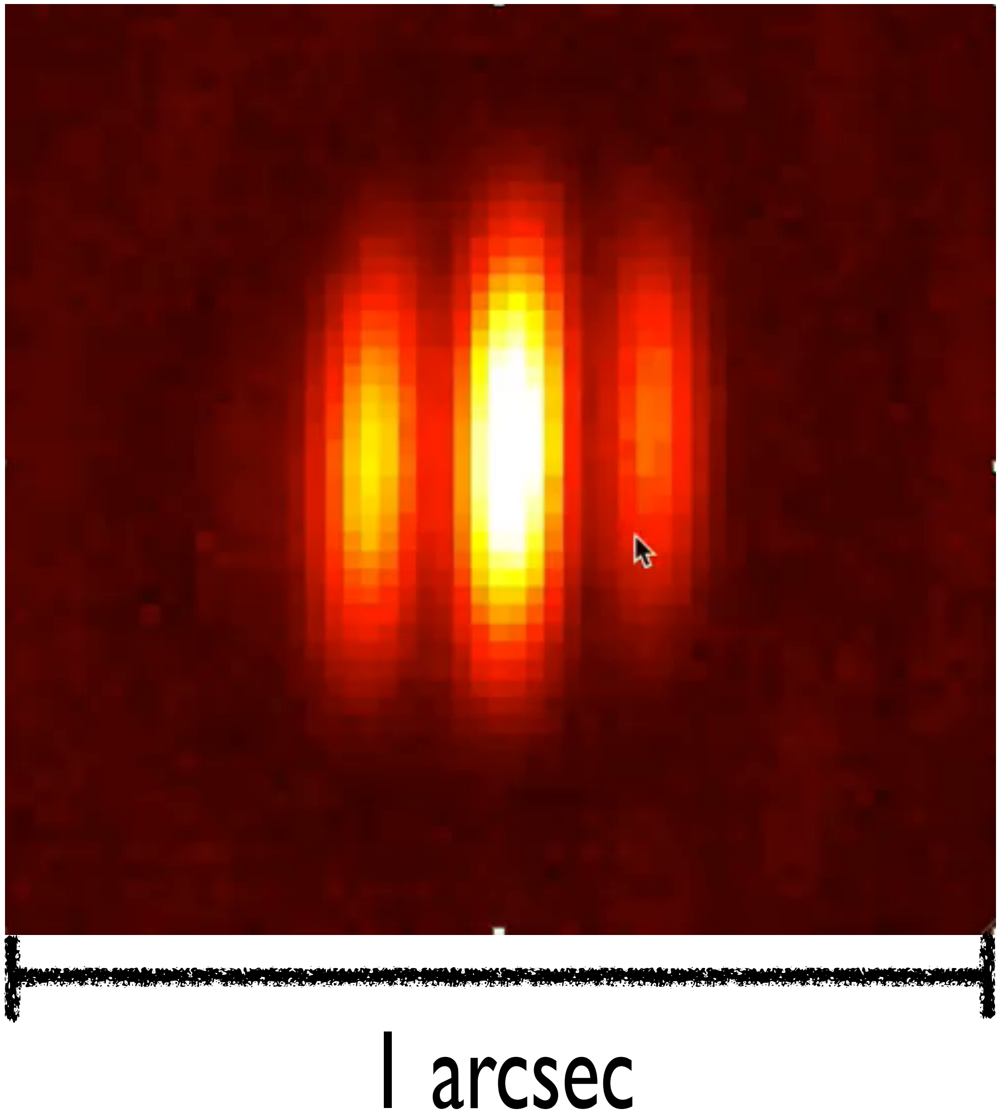
Measurements: calibrated null stability



Measurements: calibrated null stability



Phase variations at 10.6 um



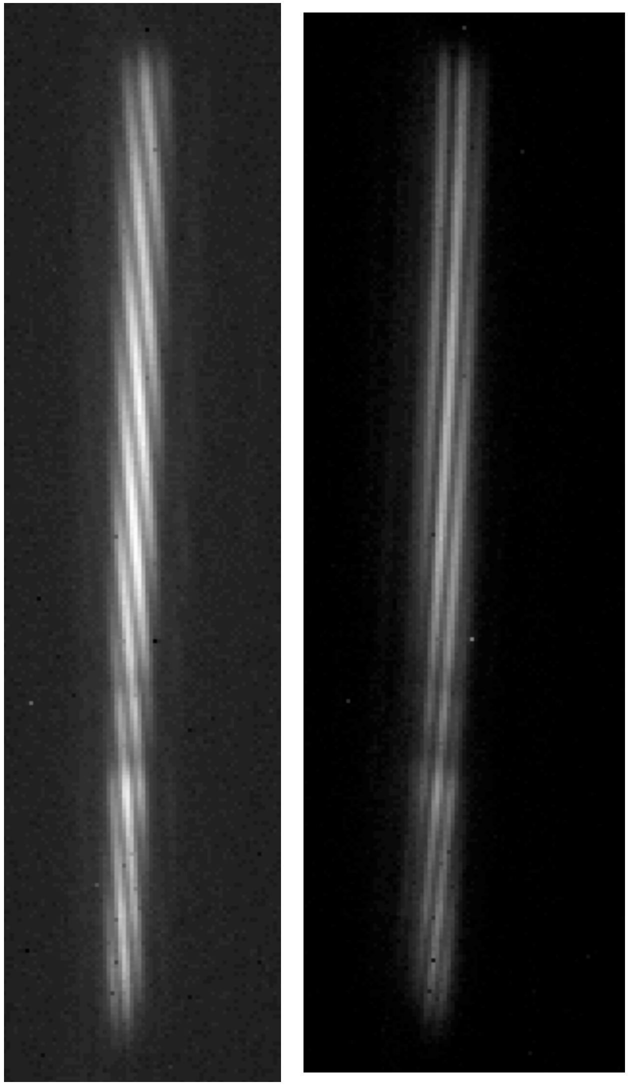
Visible seeing was 1.6”

Each image is 0.25 s

Phase variations from atmosphere.

Characterizing phase variations at L band

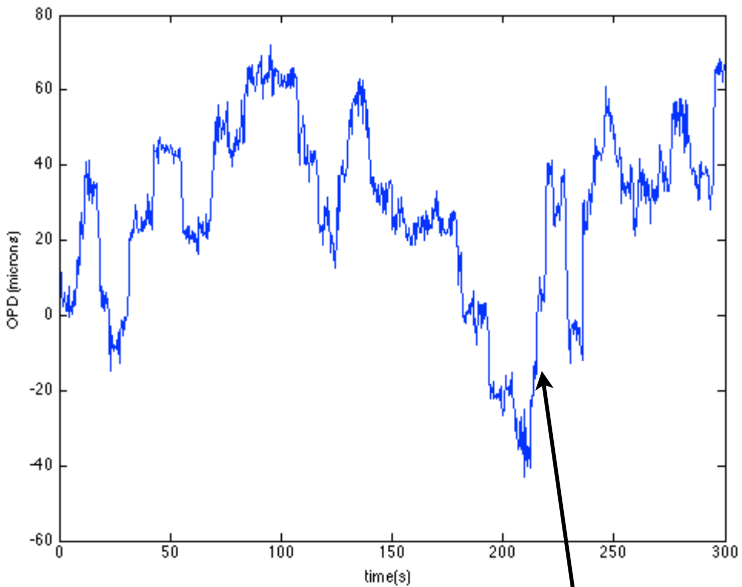
- New LMIRCam grisms allow dispersed interferometry.
- Can more easily track large pathlength variations.
- May observations with the LMIRCam grism were used to characterize this.



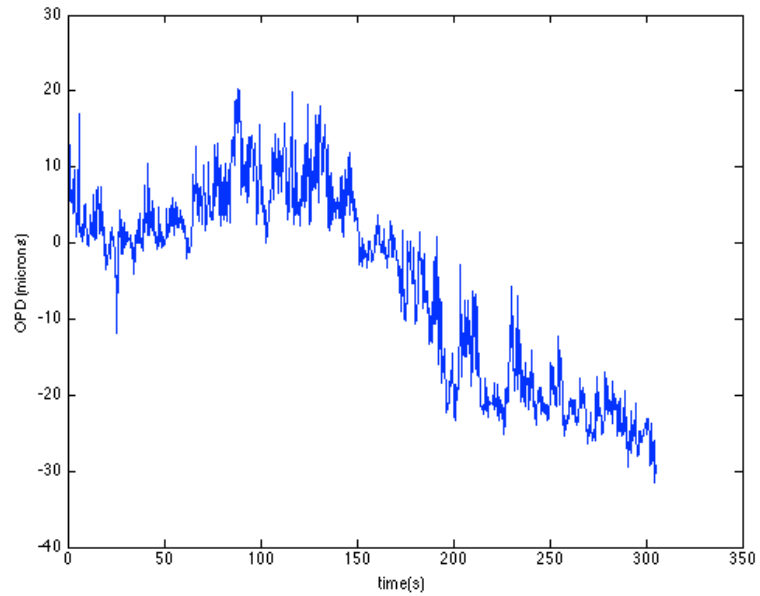
4.1 µm

3.0 µm

Pathlength variations



Focus Offloading

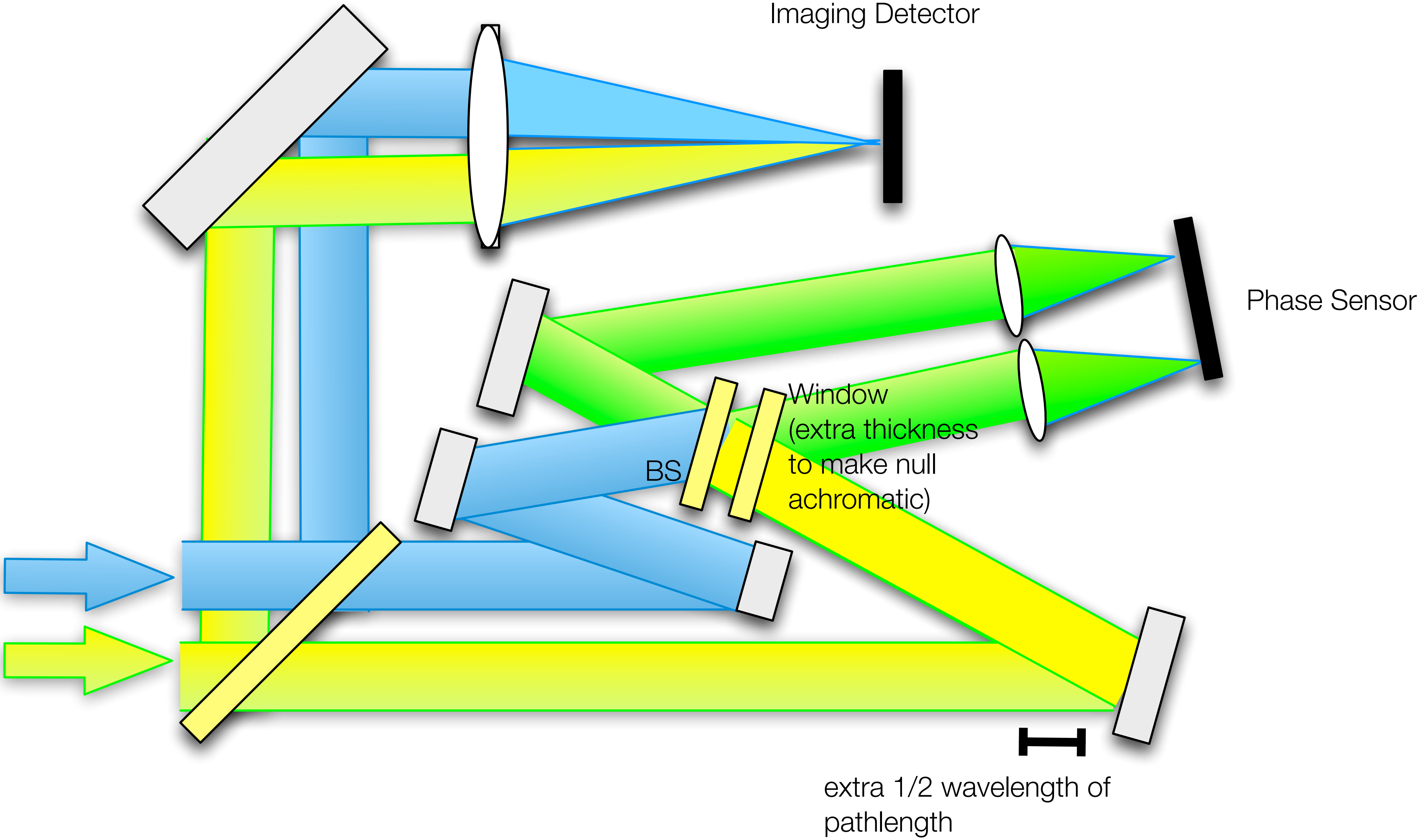


After optimizing AO focus telescope offloads

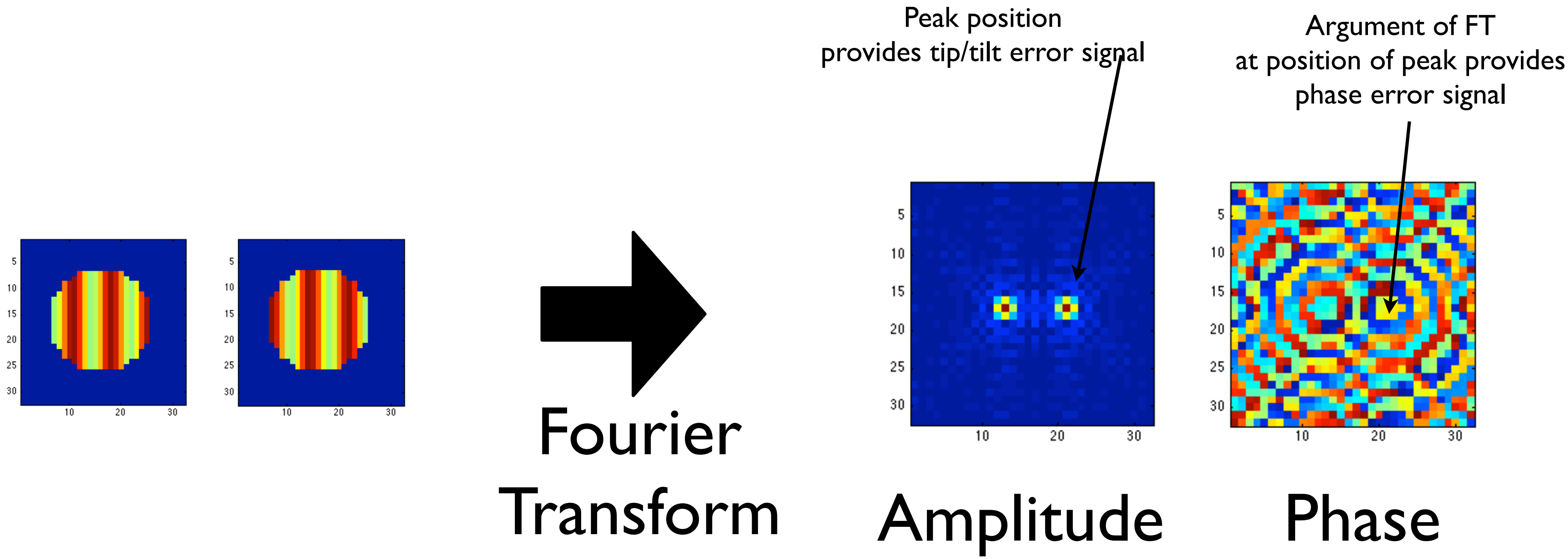
LBTI Built-in Phasing Alternatives

Image on Detector	Advantages	Disadvantages
Stellar images	most sensitive	nλ ambiguity tip-tilt will affect phase signal.
Spectra	no nλ ambiguity	tip-tilt will affect phase signal.
Pupil images	tip-tilt signal can be separated from phase	nλ ambiguity (but can be sensed easier.

Phase sensor

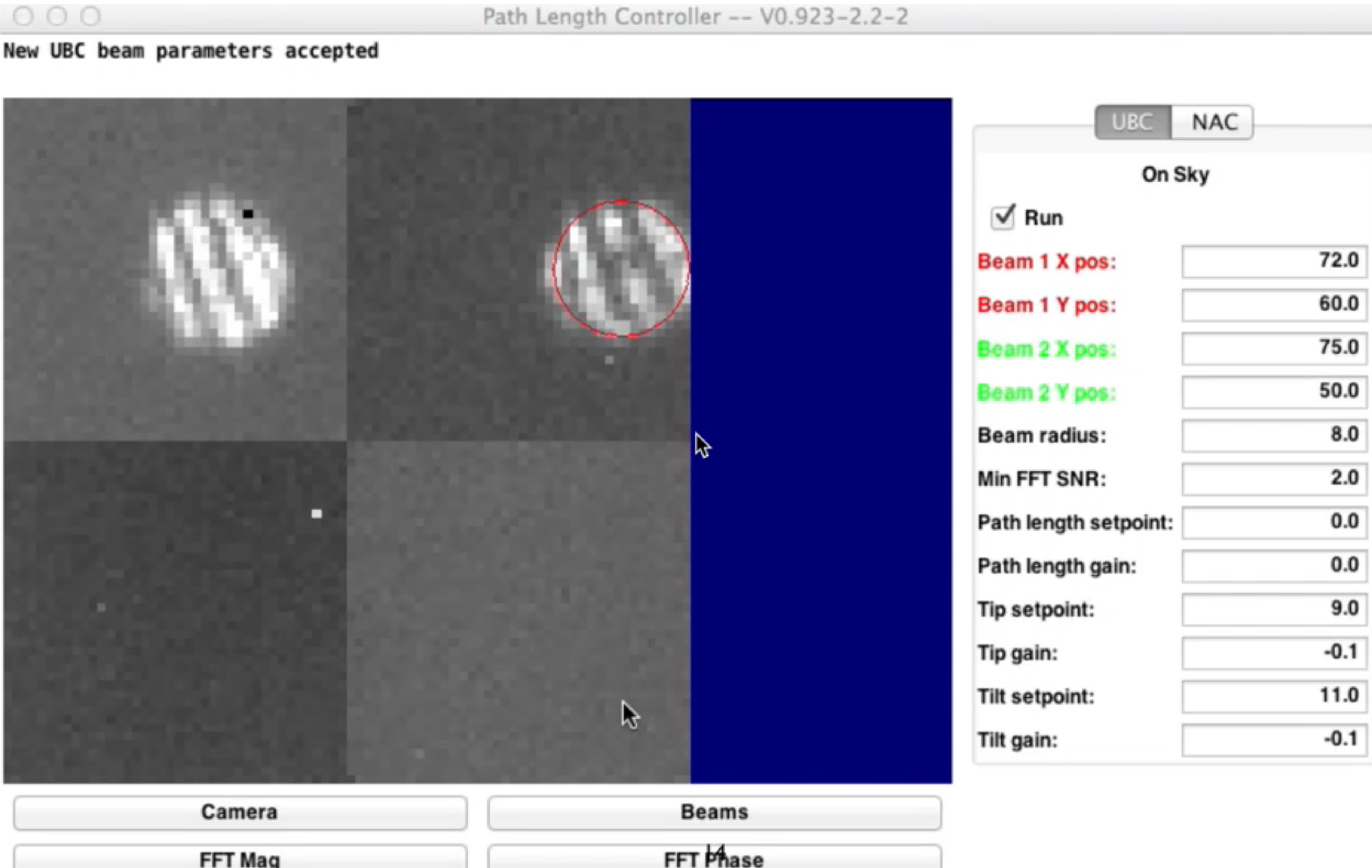


LBTI phasing algorithm



- Create small pupil images
- Introduce tilt difference.
- Fourier Transform provide three observables: Φ, θ_{tip}, θ_{tilt}

LBTI phasing algorithm



Status and summary

- Failure of right-side adaptive secondary for almost the whole semester
- Now back on the telescope
- Commissioning of the fringe tracker will resume in October
- Survey expected to start in Fall 2013
- Demonstrated good sensitivity and excellent background subtraction