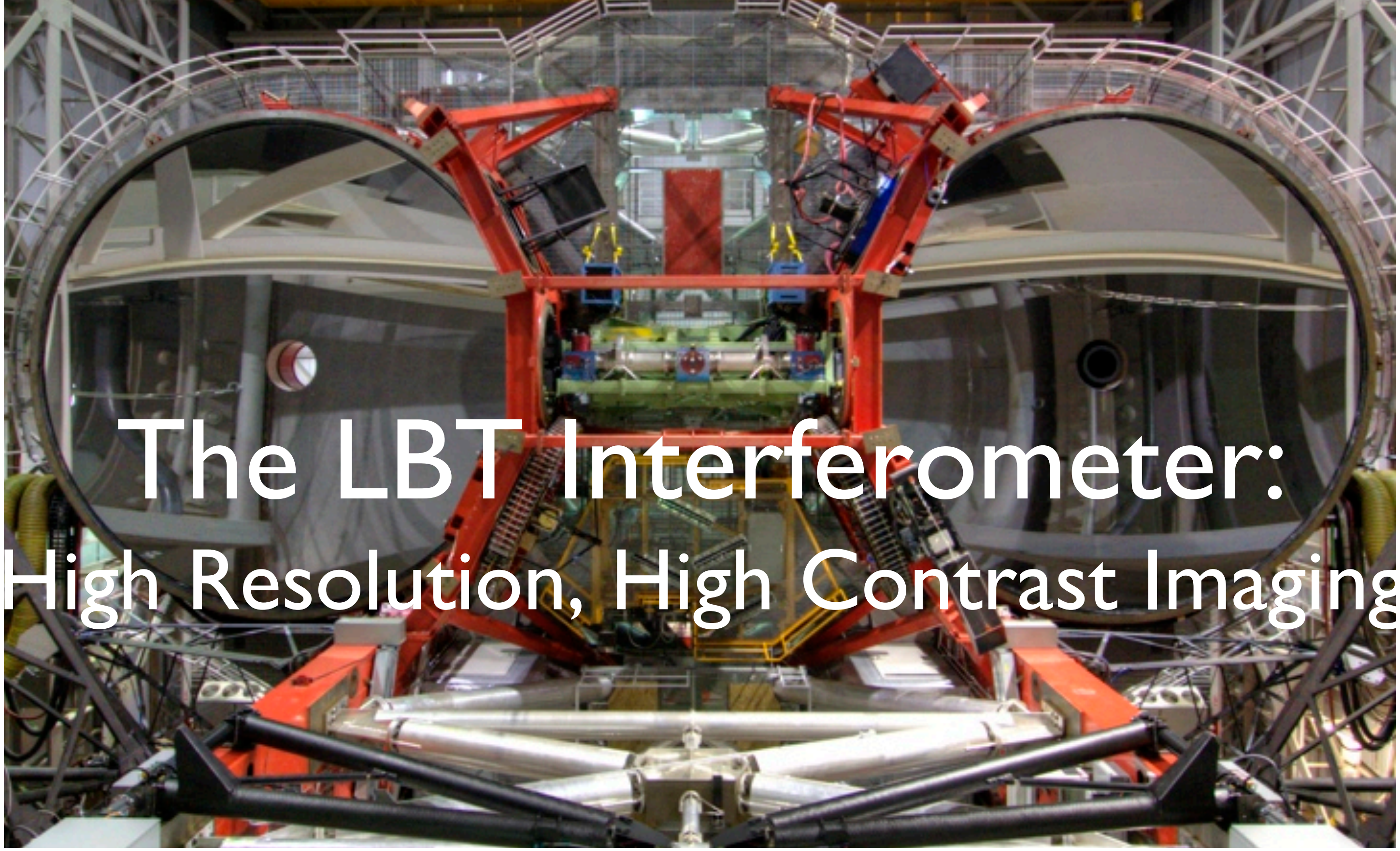


The LBT Interferometer: High Resolution, High Contrast Imaging

Phil Hinz

January 7, 2011

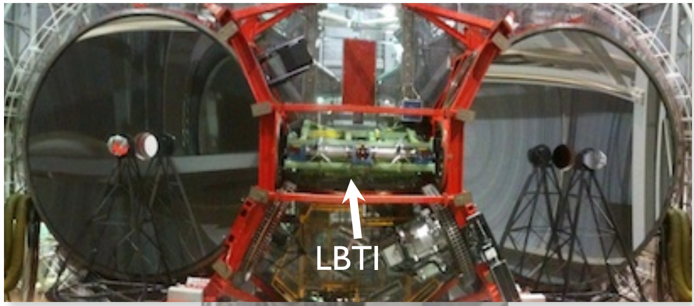
Outline:

- Instrument Overview
- On-sky testing and early science with LBTI
- Expected Capabilities and Plans

Key Parameters

Sensitivity

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

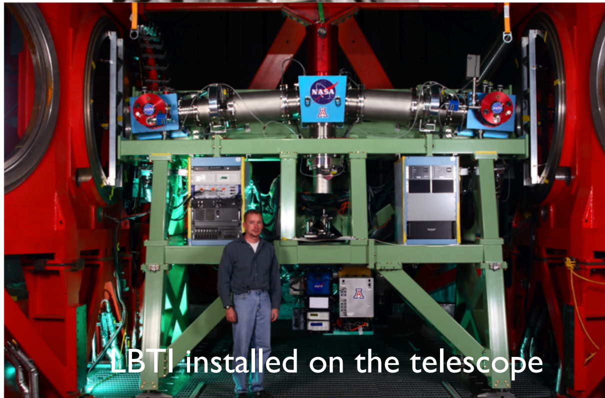


High Contrast

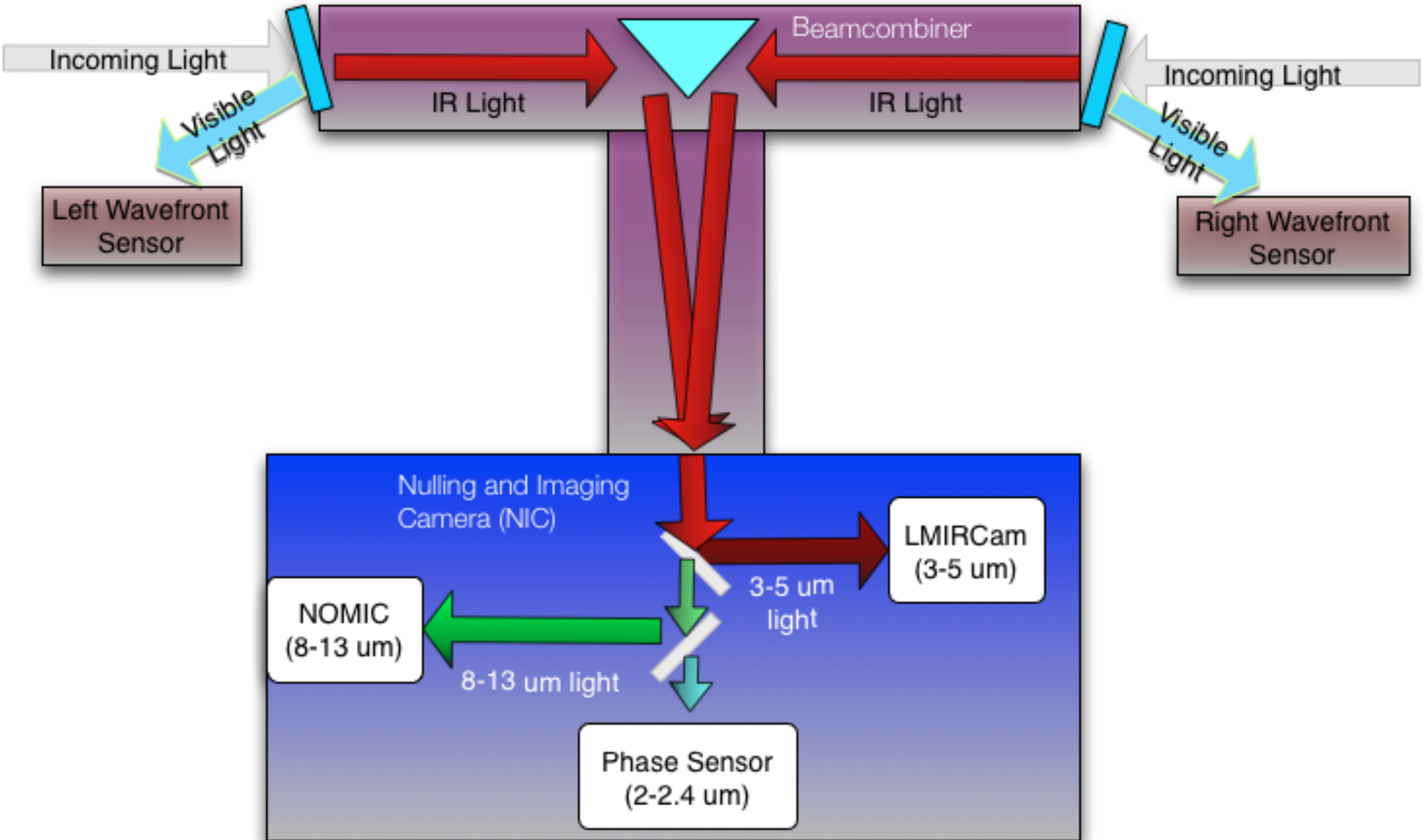
The AO system creates an image with a Strehl of >95% at 3.8 μm.

Resolution

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



LBTI Layout



Beamcombiner
Incoming Light
IR Light
IR Light
Incoming Light
Visible Light
Visible Light
Left Wavefront Sensor
Right Wavefront Sensor
Nulling and Imaging Camera (NIC)
LMIRCam (3-5 um)
3-5 um light
NOMIC (8-13 um)
8-13 um light
Phase Sensor (2-2.4 um)

LBTI Overview

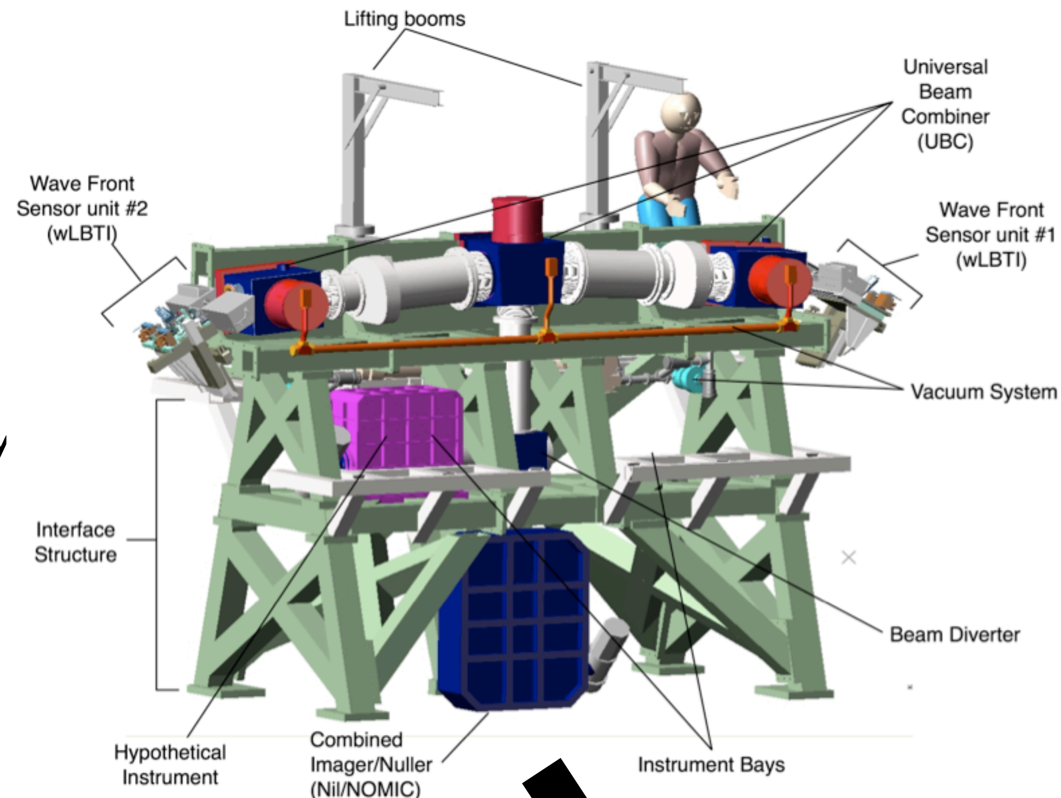
The LBT Interferometer:

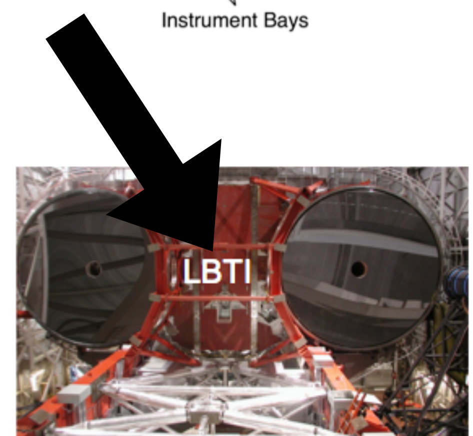
Combines light from the 2x8.4 m telescope to create a coherent 22.7 m imager.

•Leverages integrated deformable secondary mirror to achieve diffraction-limited wavefronts. (same WFS as well).

•Cooled optics beamcombiner allows high sensitivity at 3-13 μm wavelengths.

•Key science program to detect exozodiacal dust disks and exoplanets.





LBTI Cameras

	LMIRcam	NOMIC
Wavelength Coverage (μm)	2.9-5.1(1.5-5.1 capable)	8-14 (8-25 goal)
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	19.8 (3.4 μJy) @ L’	14.3 (70 μJy) @ N
Spatial Resolution	40 mas @ L’	100 mas @ N’

2 M_J planet
at 1 Gyr

1/3 zodi
debris disk

0.4 AU
at 10 pc

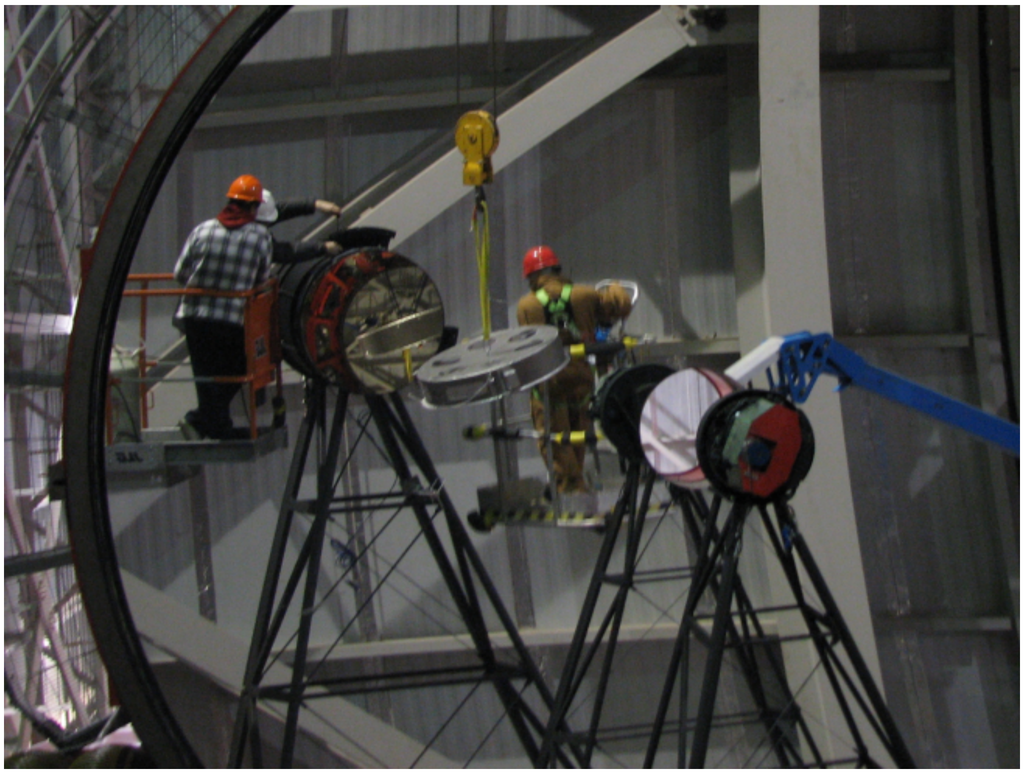
1 AU
at 10 pc

Adaptive Optics Commissioning

May-December 2010

FLAO system installation @ LBT

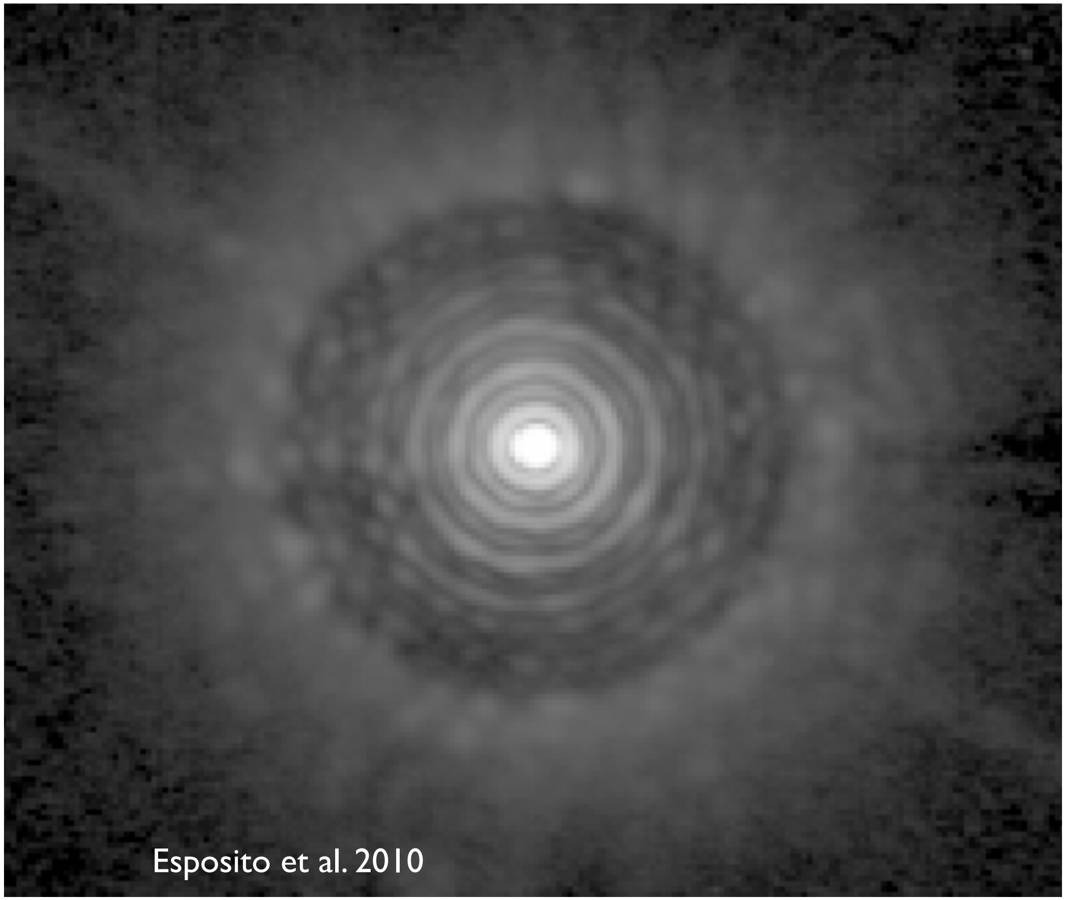
February 9th --March 17th 2010



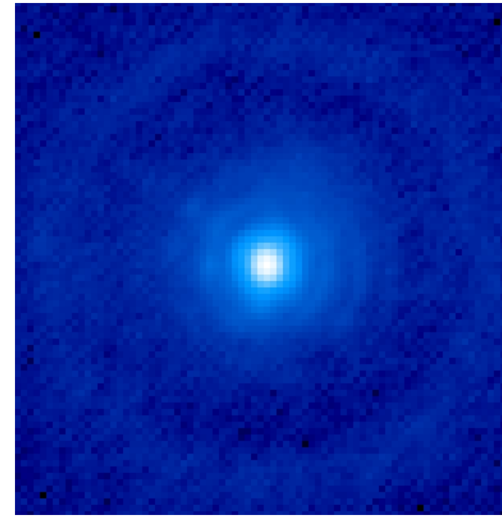
Pictures showing the deformable secondary mirror being mounted for the first time.

High Strehl images

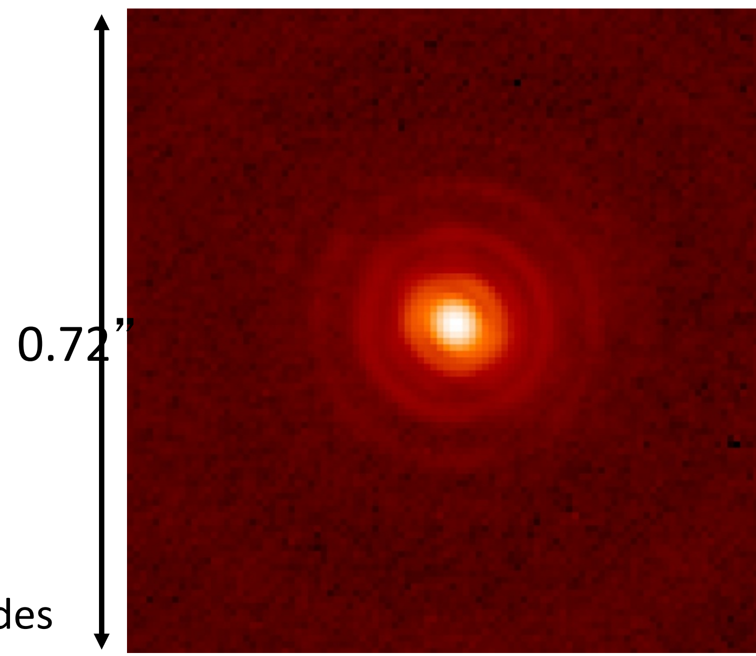
May-June 2010 First light results.
These are the highest Strehl images from a ground-based telescope!



The reference: HD175658, R =6.5, H=2.5
The atmosphere: seeing 0.9 arcsec V band
FLAO parameters: 1KHz, 30x30 subaps, 400 corrected modes

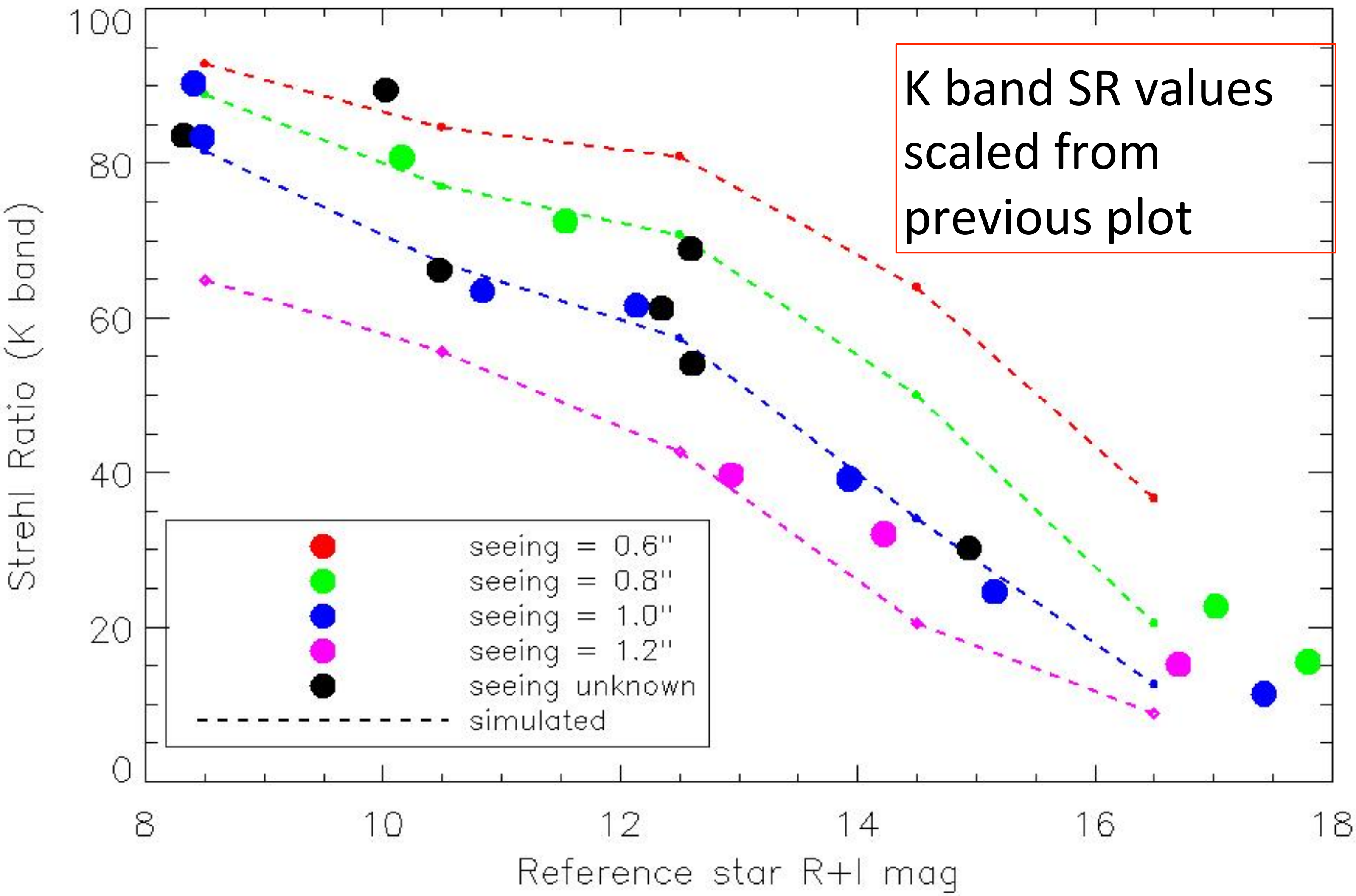


J Band 46.6% SR in 20 sec



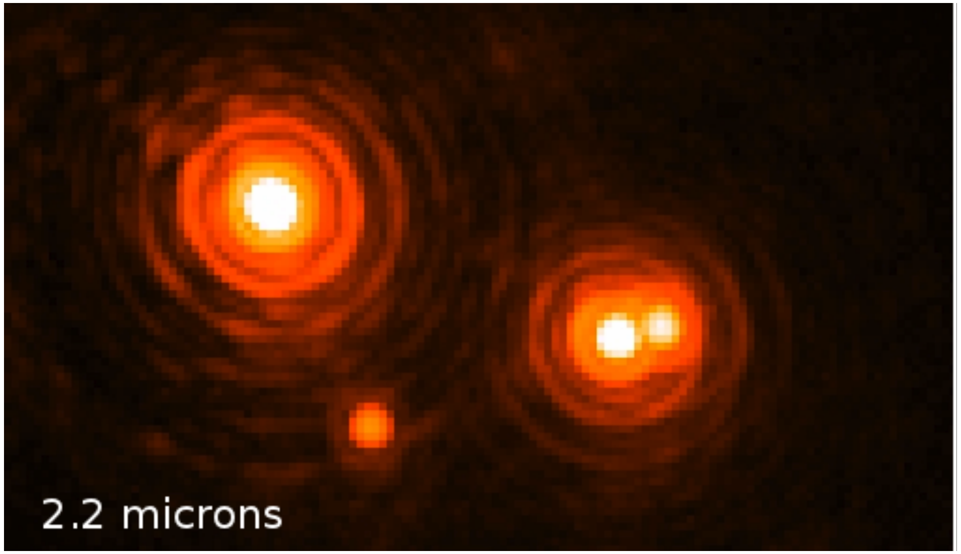
H Band 75% SR in 12sec

K band SR vs star mag & seeing

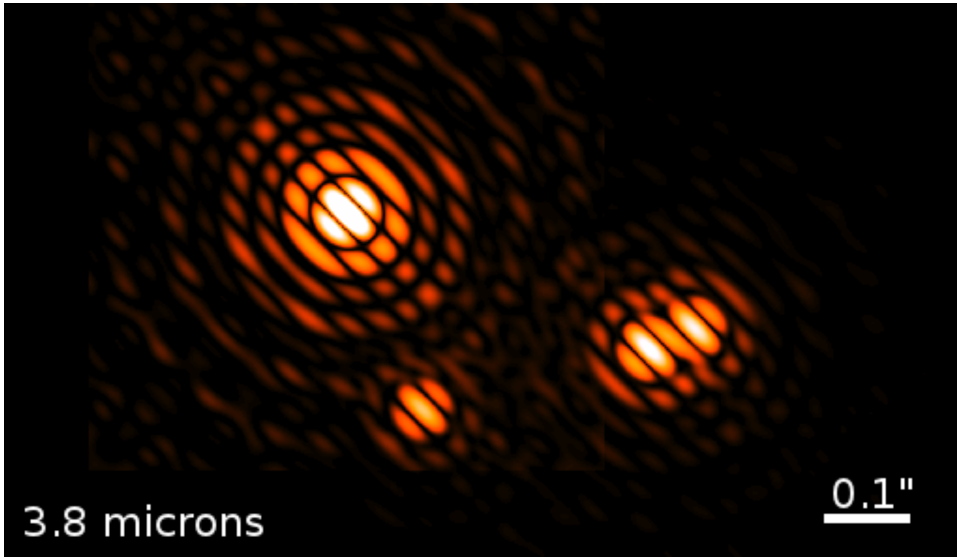


Ability to use faint guide stars will allow "all-sky" use of LBTI.

The Promise of LBTI



LBT AO Image of θ 1 Ori B At K band
90% Strehl



Simulated LBTI image at L' band

LBTI Installation and Commissioning

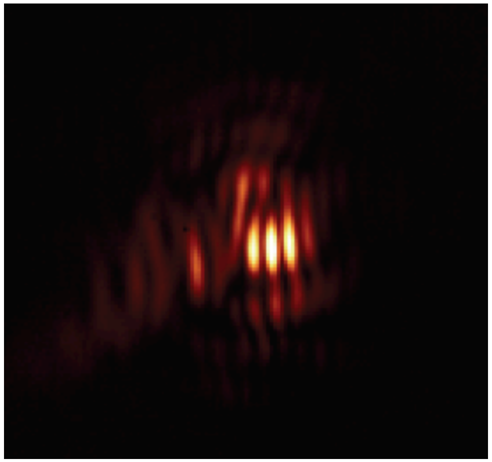
Beamcombiner:	Oct.-Nov. 2010
LMIRCam (3-5 μm) and AO:	May 2011
NOMIC(8-13 μm):	Nov-Dec. 2011 (cloudy)

LBTI was installed in September 2010

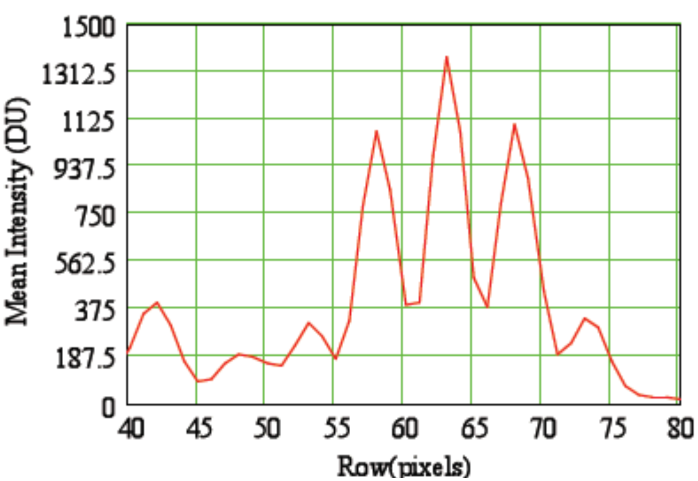
Sep. 2010

90 minutes later we are on the telescope!

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).



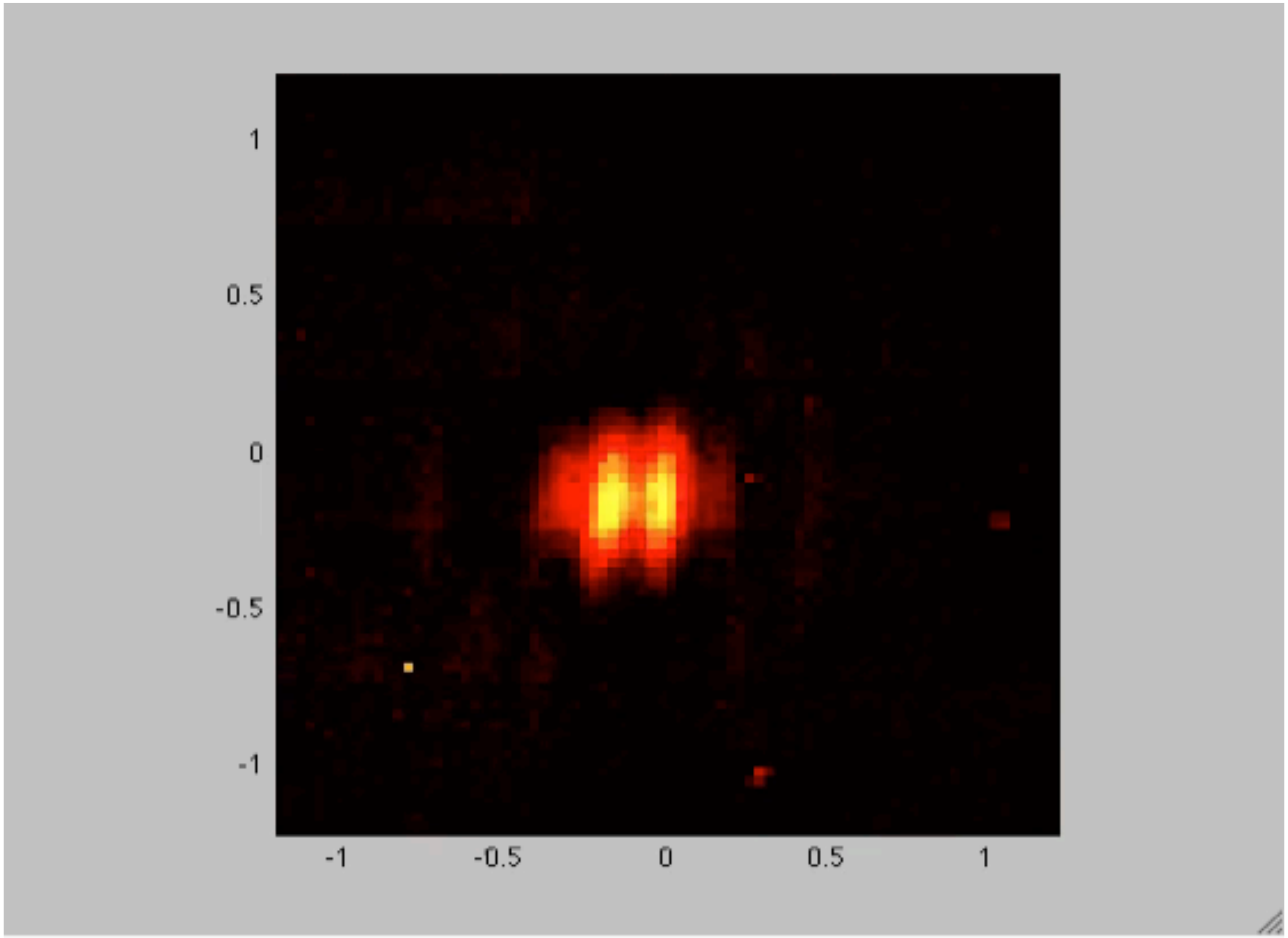
This image shows that:

- 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.

The First Light on-site team:
Tom McMahon, Oli Durney, Vanessa Bailey, Vidhya Vaitheeswaran, and Bill Hoffmann

with the expert help of John Hill

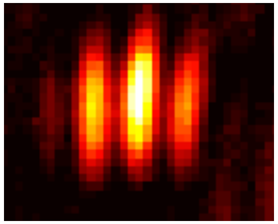
Interference with Turbulence



Frame rate is 10 Hz (displayed at 5 Hz).

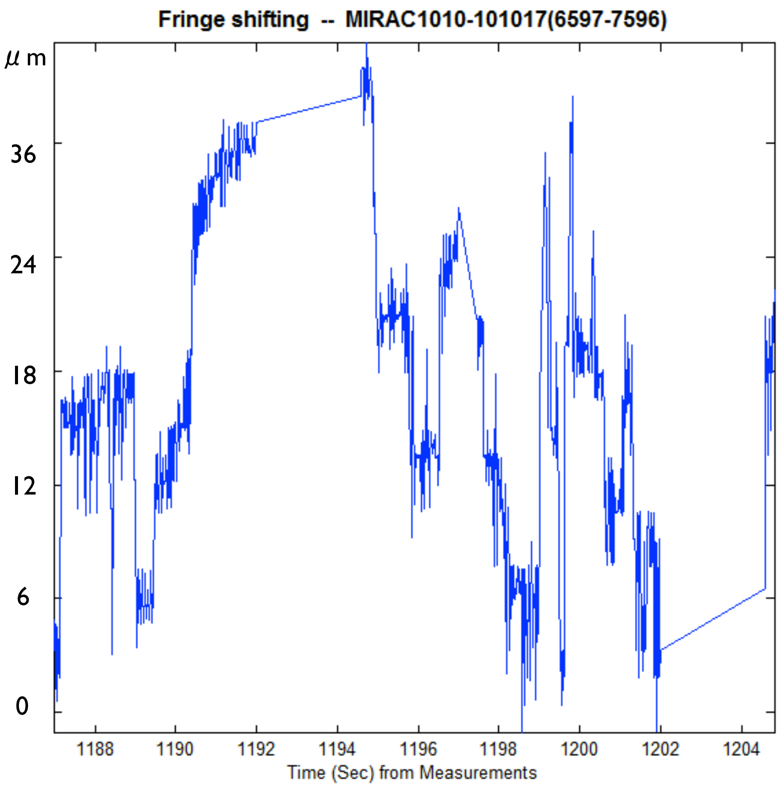
Wavelength is 12 μ m. AO loop is closed on one side.

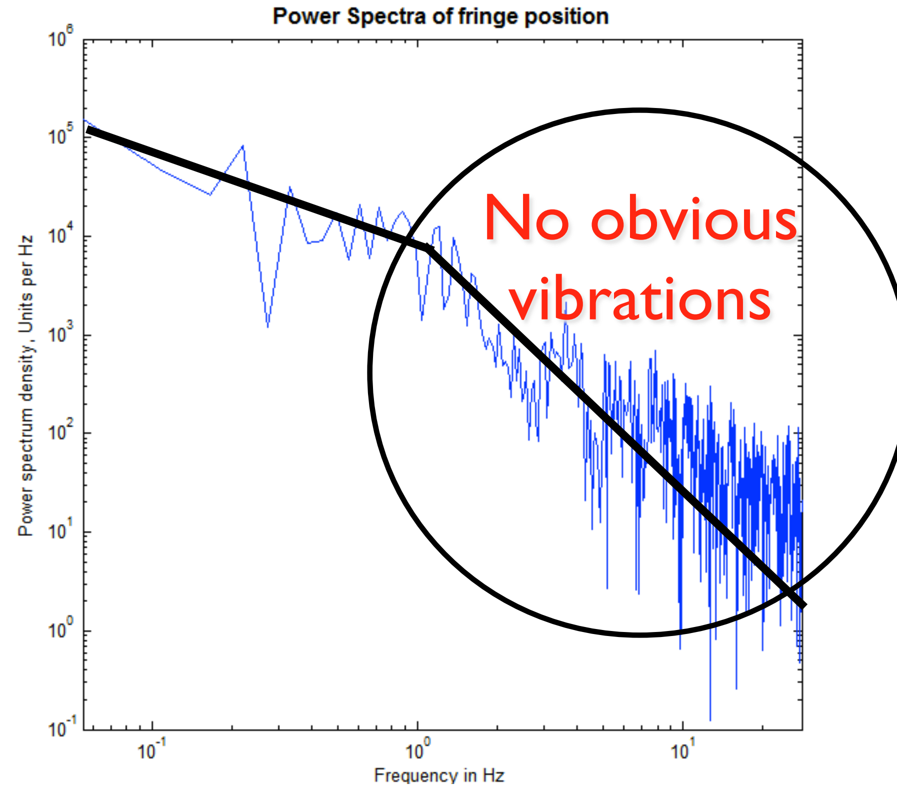
Fringe Sensing



First Fringes at 10 μm
Resolution of 22.6 m
telescope

Power spectrum shows expected shape for atmosphere variations



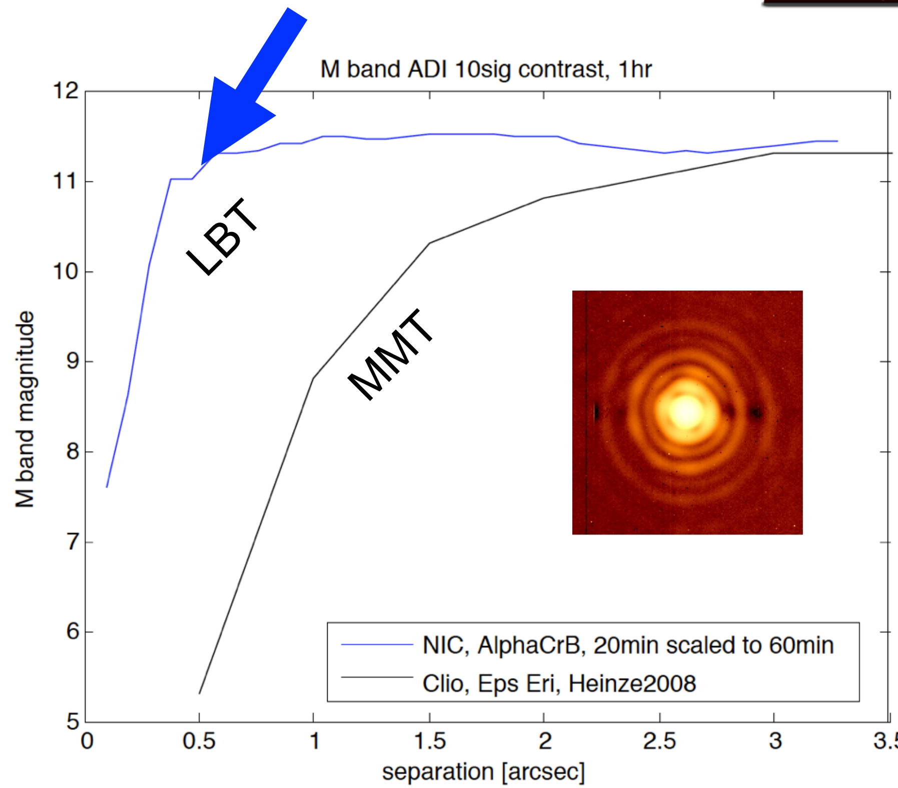


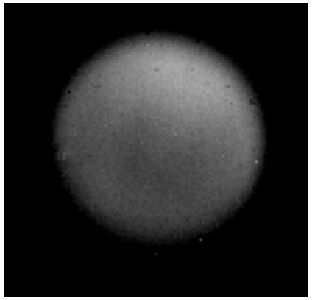
RMS = 10.5 μ m

May 2011 tests

- AO tests in May 2011 demonstrated 95% Strehl at M (4.8 μm, top right).
- Very stable PSF allows subtraction to the background limit outside of 0.3 arcsec.
  - This is dramatically better than M band observations with the 6.5 m MMT (Clio), primarily due to the better AO performance.
- Test images of Titan in NIR, shows good image quality of detector.
- Several technical issues were identified and fixed for fall observing(light leak, electronics excess noise, static aberration).

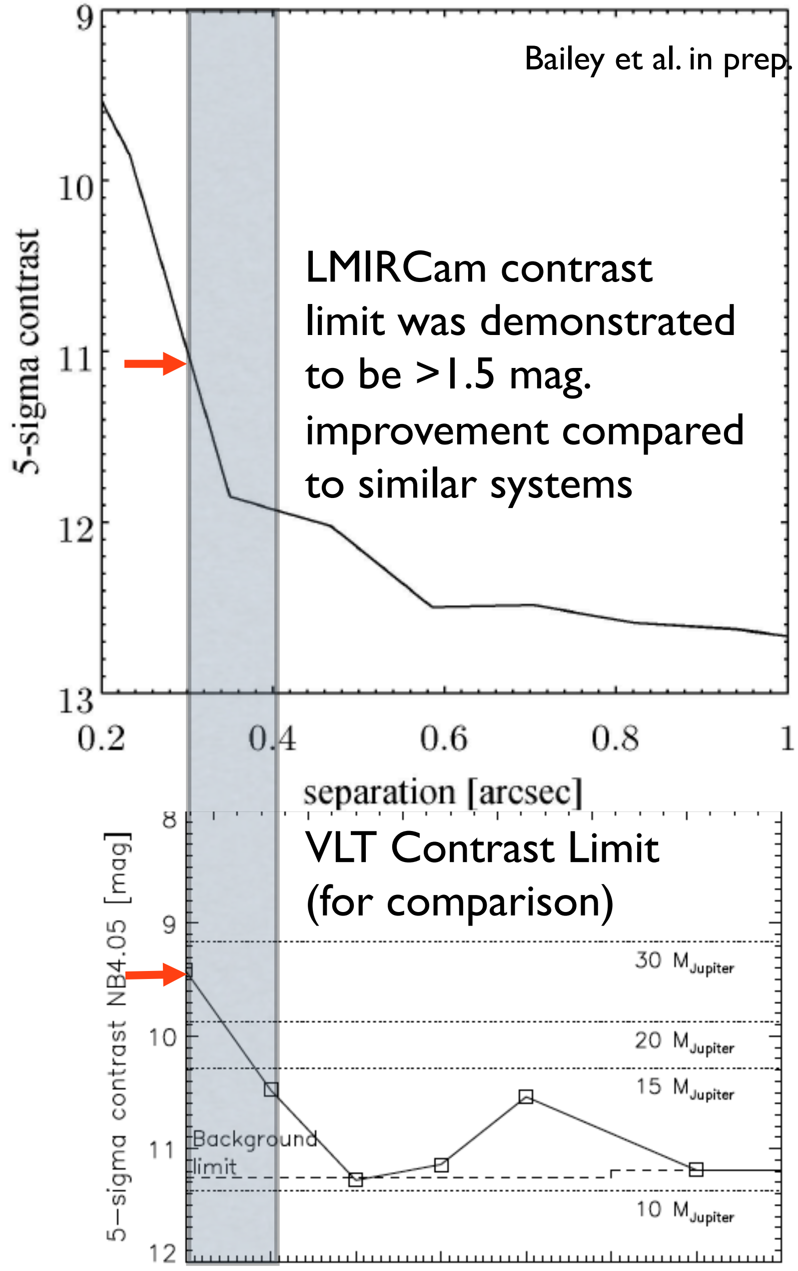
Contrast sufficient to detect 2 MJ planet around eps Eri at 1 AU





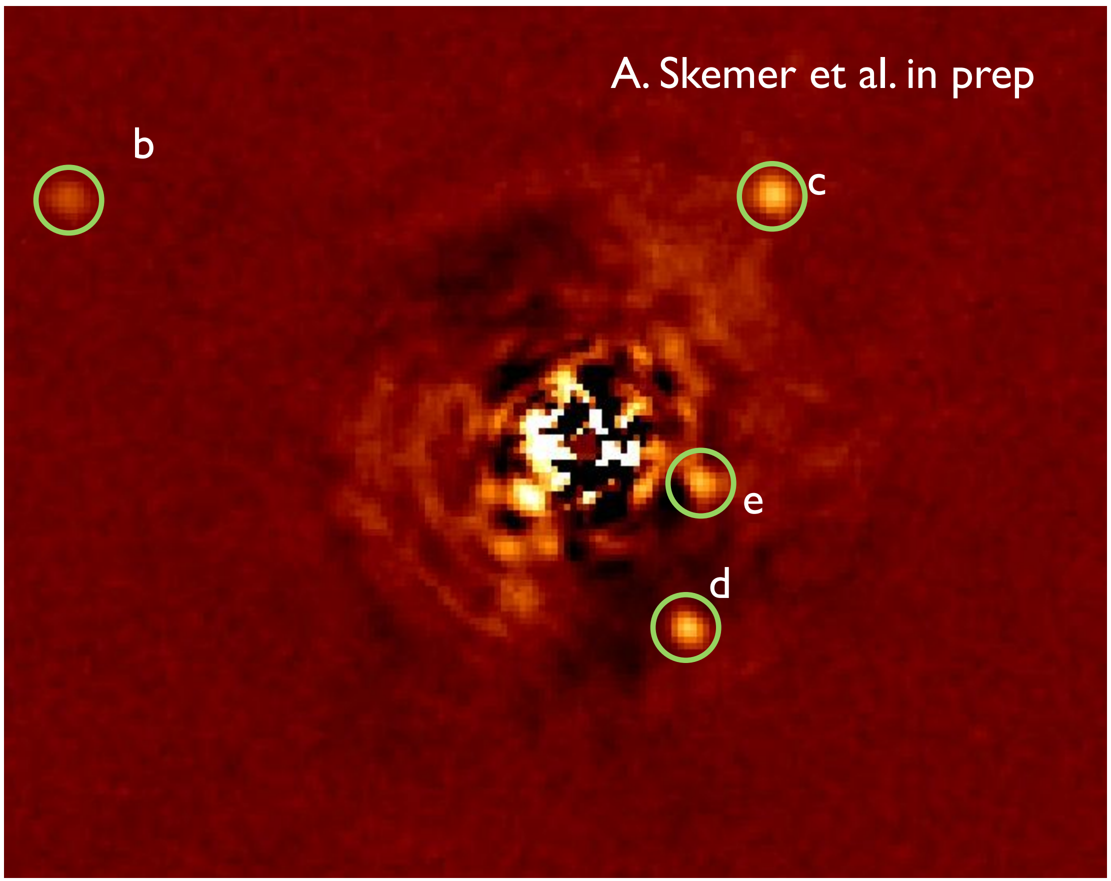
Titan imaged by LBTI May 2011

Exoplanet Imaging: Contrast Comparison



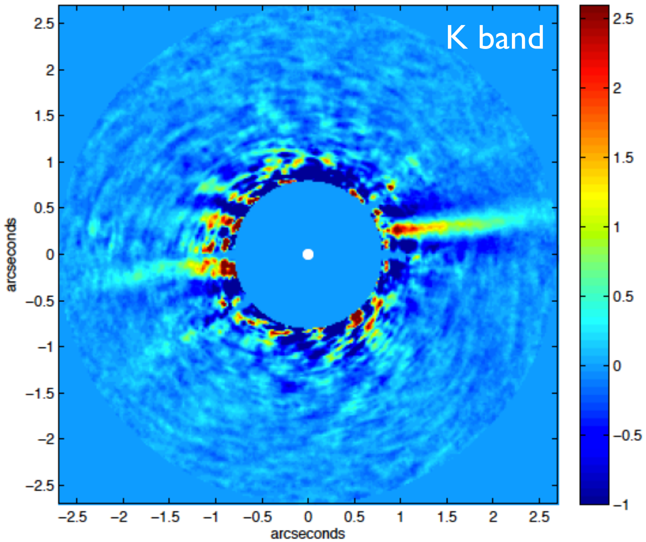
LBTI Fall Science Topic 1: Exoplanet Atmospheres

First Detection of 4 planets around HR 8799 in methane absorption (3.3 μm)

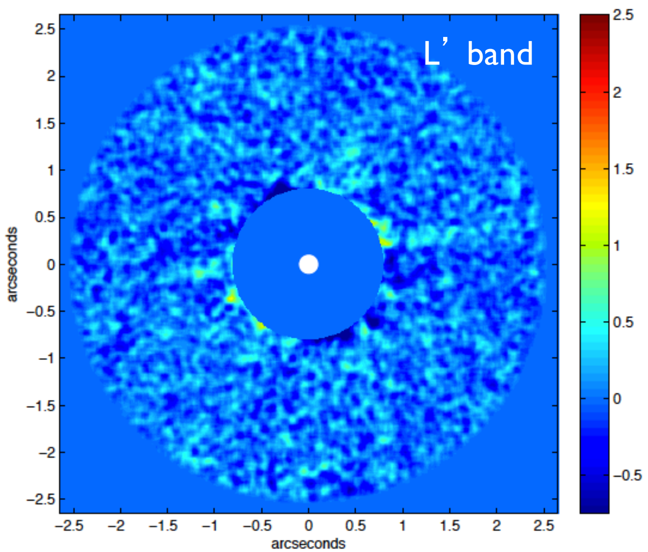


- LBTI imaging enabled a deep exposure of the HR 8799 planetary system.
  - Atmosphere models suggest that the planets (especially b) should be very dark at 3.3 μm.
  - Observations contradict this.
    - Discrepancy will help improve searches for cooler (lower mass) planets around other stars.

LBTI Fall Science Topic 11: Probing a young Debris Disk



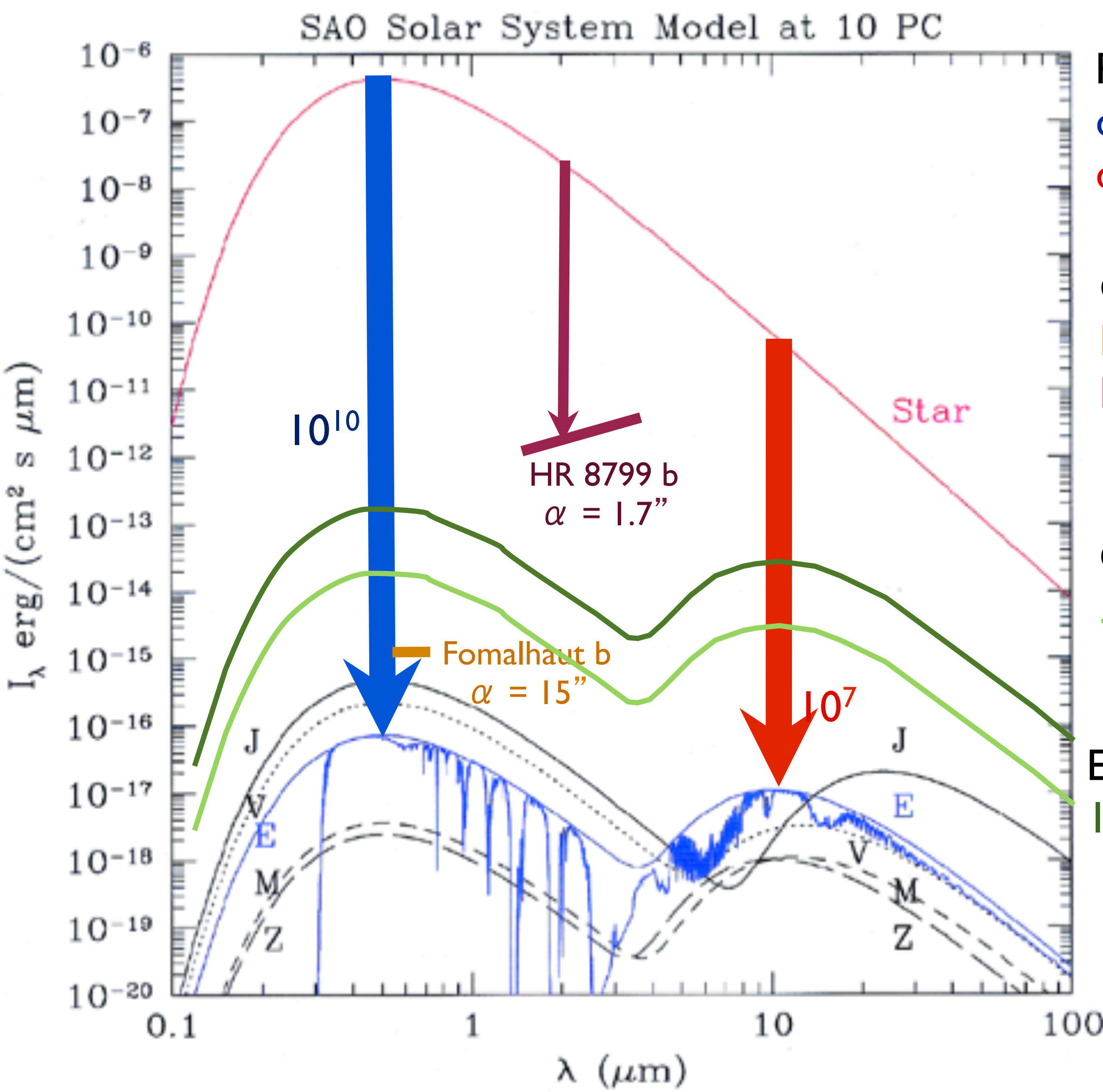
T. Rodigas et al. in prep



- Scattered light was detected at K and L' bands from an edge on disk a nearby young star.
    - Detection at L' suggests that the dust particles are relatively large.
    - Disk is asymmetric at K, due to interaction with ISM. L' is tracing the bound dust population.
- Evidence for an inner gap in the dust structure.

LBTI Capabilities

The Contrast Problem



Planet Finding missions aim to:
detect Earths 10^{-10} fainter in visible.
detect Earth 10^{-7} in the IR.

Current state of the art:
Fomalhaut b: 10^{-9}, but 150x separation.
HR 8799b: 10^{-4} but 17x separation.

Our own Zodiacal dust:
5x 10^{-5} at 10 μm =1 zody.

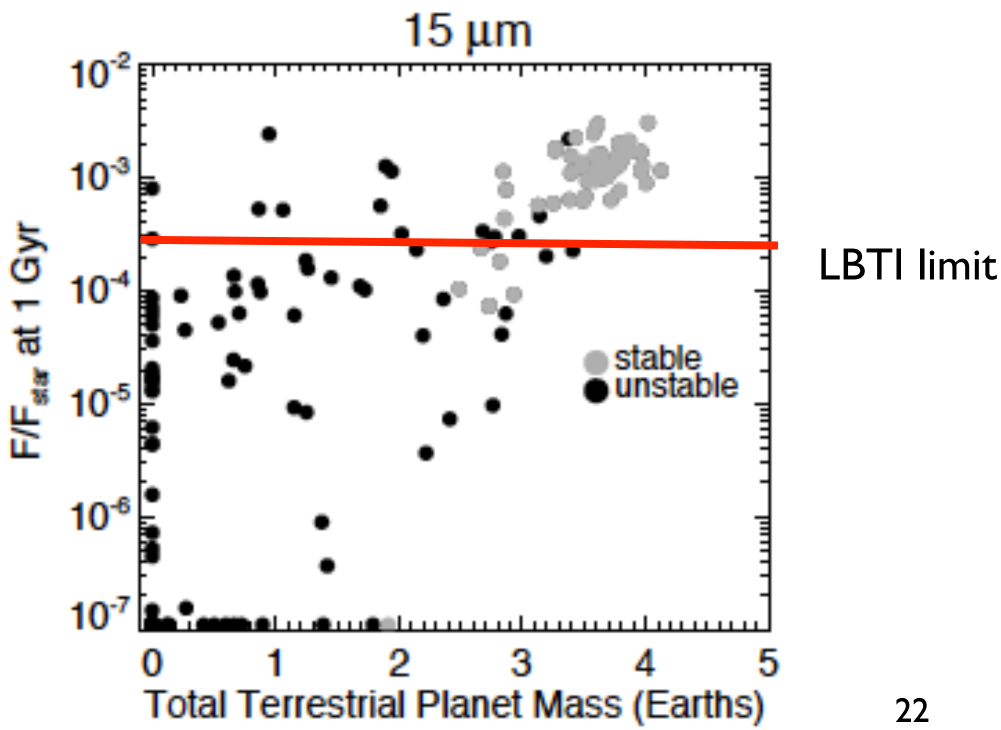
Exozodiacal dust becomes a problem:
10 zody or above.

LBTI can show us what exists (planets or dust disks) at faint levels around nearby stars.

Dust Detection: What might we expect?

- Raymond et al. (2011) have carried out an N body simulation of debris disks that predicts dust brightness as a function of final planet architecture.

- Results suggest that systems with stable giant planets will have bright debris disks.



LBTI can test these (and similar) predictions to lower risk in planning future exoplanet missions.

LBTI Performance

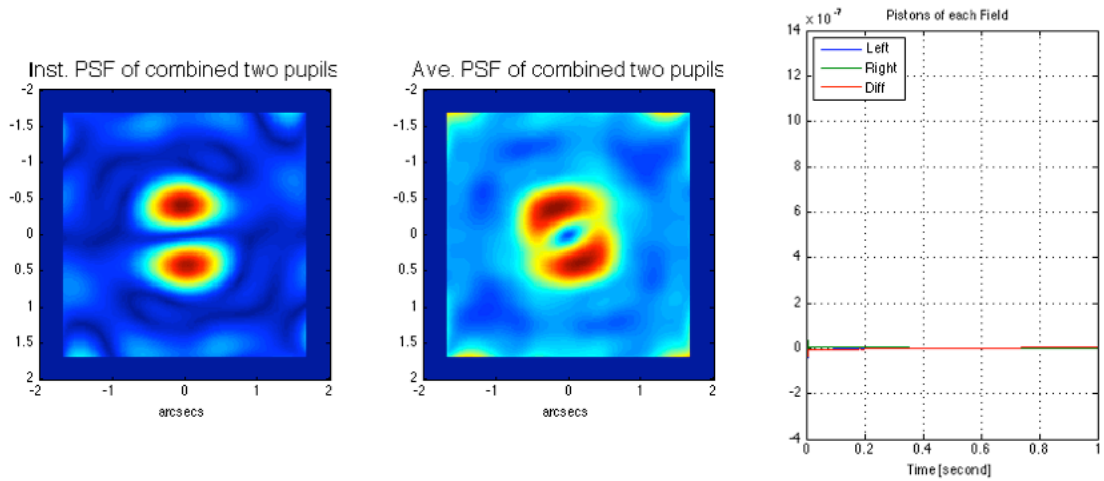
Identifier	Metric	Requirement	Tracking Metric	Impact	Current Status
T1	**Telescope Vibration**	Disturb Null by <10^{-4}	Monitor vibration on critical optics	Increased zody limit	Telescope subsystems are below vibration threshold.
T2	**Observing Efficiency**	>50% open shutter time	Data provided by LBTO	Increased Observing Time	Single Aperture efficiency is 60% (Nov. 2011).
T3	**Telescope Background**	<10%	MMT Comparison/Measure with LBTI	Increased Observing Time	Currently measured at 11% (May 2011)
A1	**AO System Wavefront error**	<220 nm	Simulate/ MMT AO system as prototype	Increased zody limit	On-sky performance is 120 nm RMS
A2	**Residual Image Motion**	<1 mas	Simulate/Prototype	Increased zody limit	To be measured.
L1	**Nulling Stability**	<0.1%(MMT) <0.01%(LBT)	BLINC prototype BLINC->LBTI scaling is 8-17x	Increased zody limit	MMT/BLINC performance is <0.2%. Simulation shows acceptable stability
L2	**Null Depth**	<0.1%	BLINC prototype	Increased zody limit	BLINC lab tests have shown 0.03%
L3	**Contrast Curve**	10^{-6} at 3 l/D	Clio prototype / LMIRCam	Increased planet limit	First light with LMIRCam shows performance at ~< 10^{-5} at 3 l/D
L4	**N Band Noise Performance**	100 uJy	MIRAC prototype	Increased Observing Time	MMT sensitivity is consistent.
L5	**L band Noise Performance**	2 uJy	Clio prototype	Increased Observing Time	MMT sensitivity is consistent.
L6	**Instrument Background**	<2%	Clio/MIRAC prototype	Increased Observing Time	To be measured.
L7	**Throughput**	>0.2	Clio/MIRAC prototype	Increased Observing Time	To be measured.

Green = Requirement Satisfied

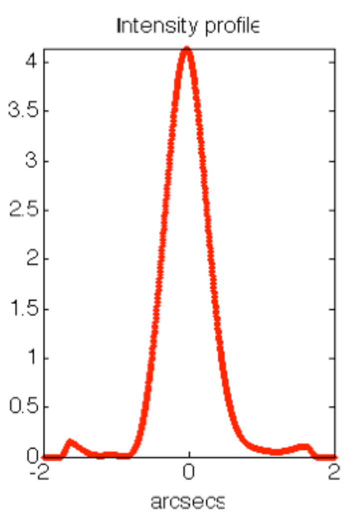
Yellow = Requirement has been measured, but not met.

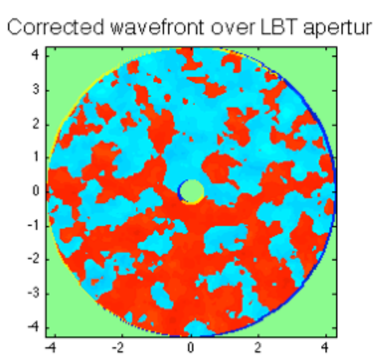
Blue = Requirement has not been measured.

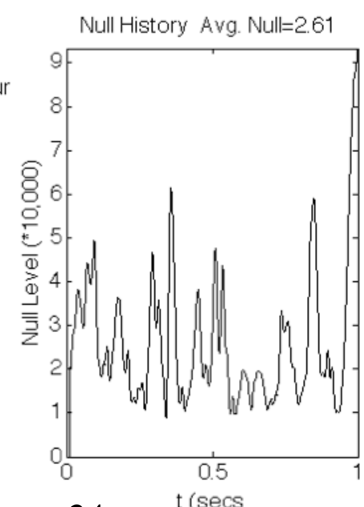
AO and Phasing Simulation



Matlab-based Monte Carlo AO code is being used to simulate nulling performance.







Null stability is seen to be ~5x10^{-5} for 30% variation in seeing between science object and PSF. This corresponds to approximately 3 zodies.

Suggests careful (and frequent) calibration procedures will be important.

LBT/LBTI Schedule

- LBTO Engineering
  - AO Unit #1 is complete.
  - AO Unit #2 has begun calibration. On-sky testing will be carried out January-May 2012.
  - An accelerometer-based OPD monitoring system is being deployed in 2012.

- LBTI Engineering
  - January 21-24, 2012 will be used to test NOMIC and start dual aperture operation.
  - April 14-17, 2012 will be used to test phase sensing and nulling operation.
  - An additional Summer 2012 run (to be scheduled) will be the first on-sky complete system testing of LBTI.