LBTI HOSTS Debris Disk Survey: Perspective from the Science Team

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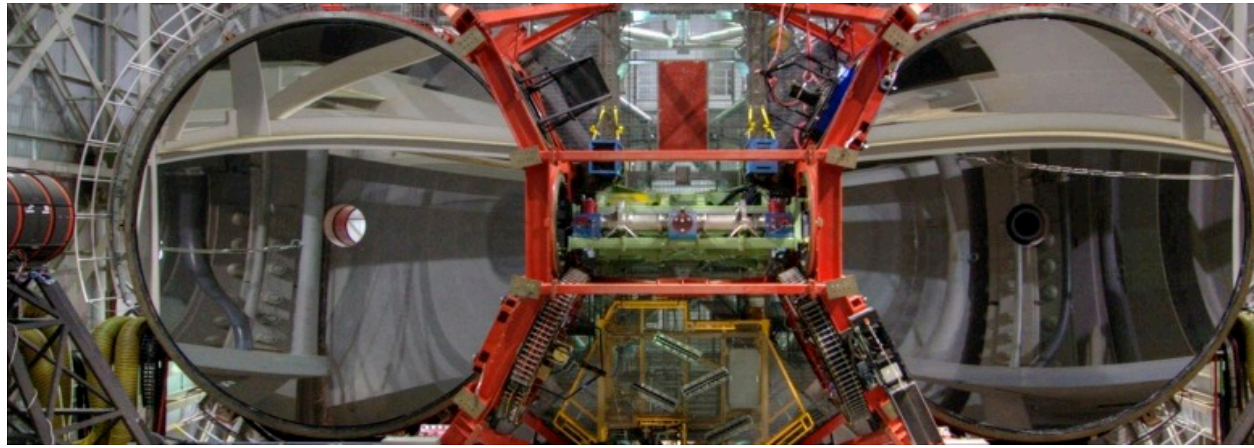
D. Defrère, U. Arizona

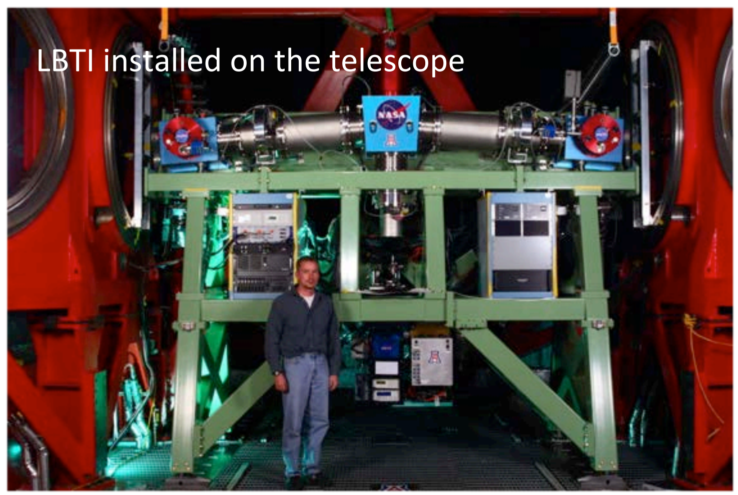
19 March 2013

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.

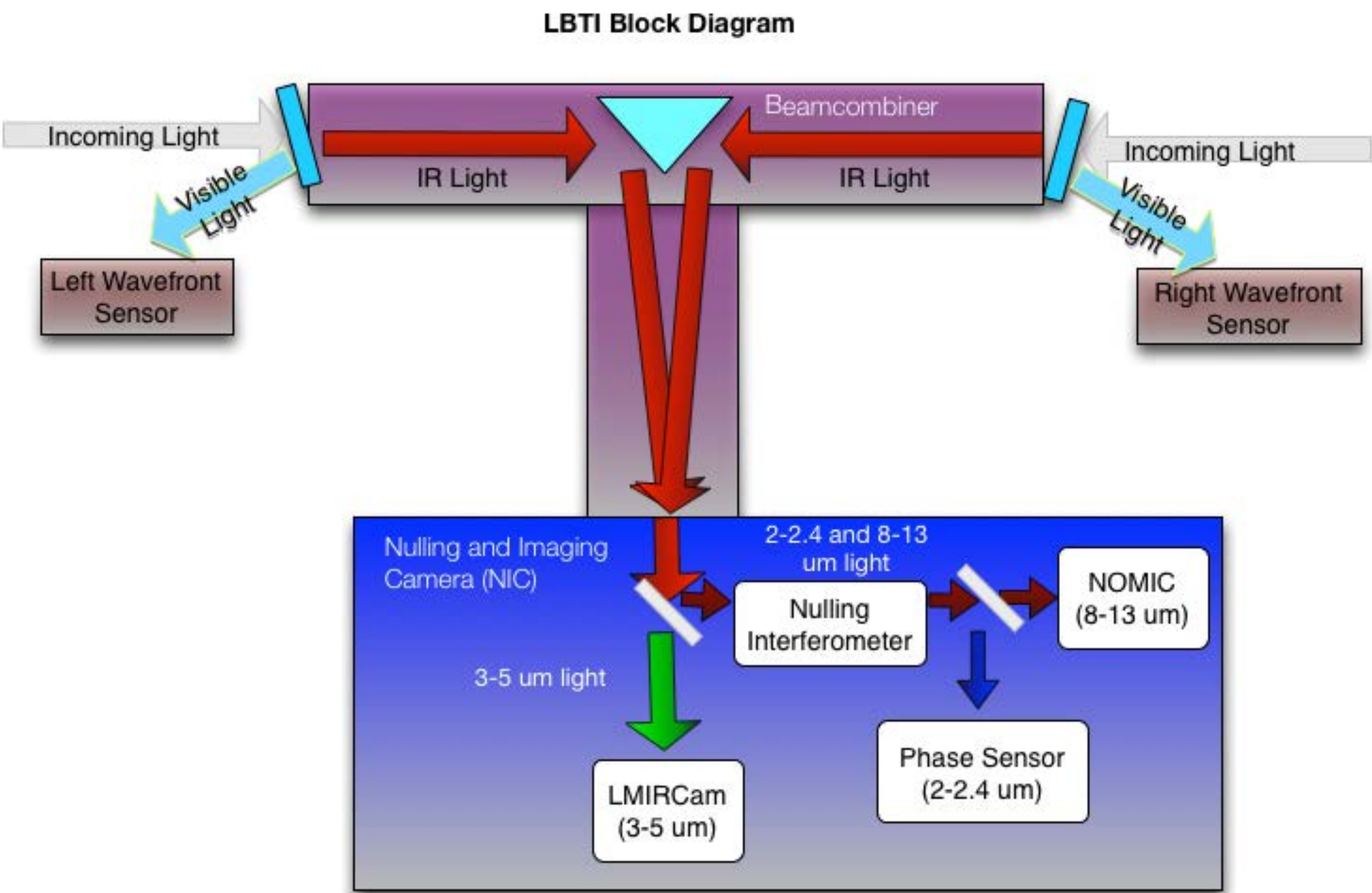


LBTI installed on the telescope

LBT Deformable Secondary Mirror

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

LBTI Layout


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

LBTI 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’

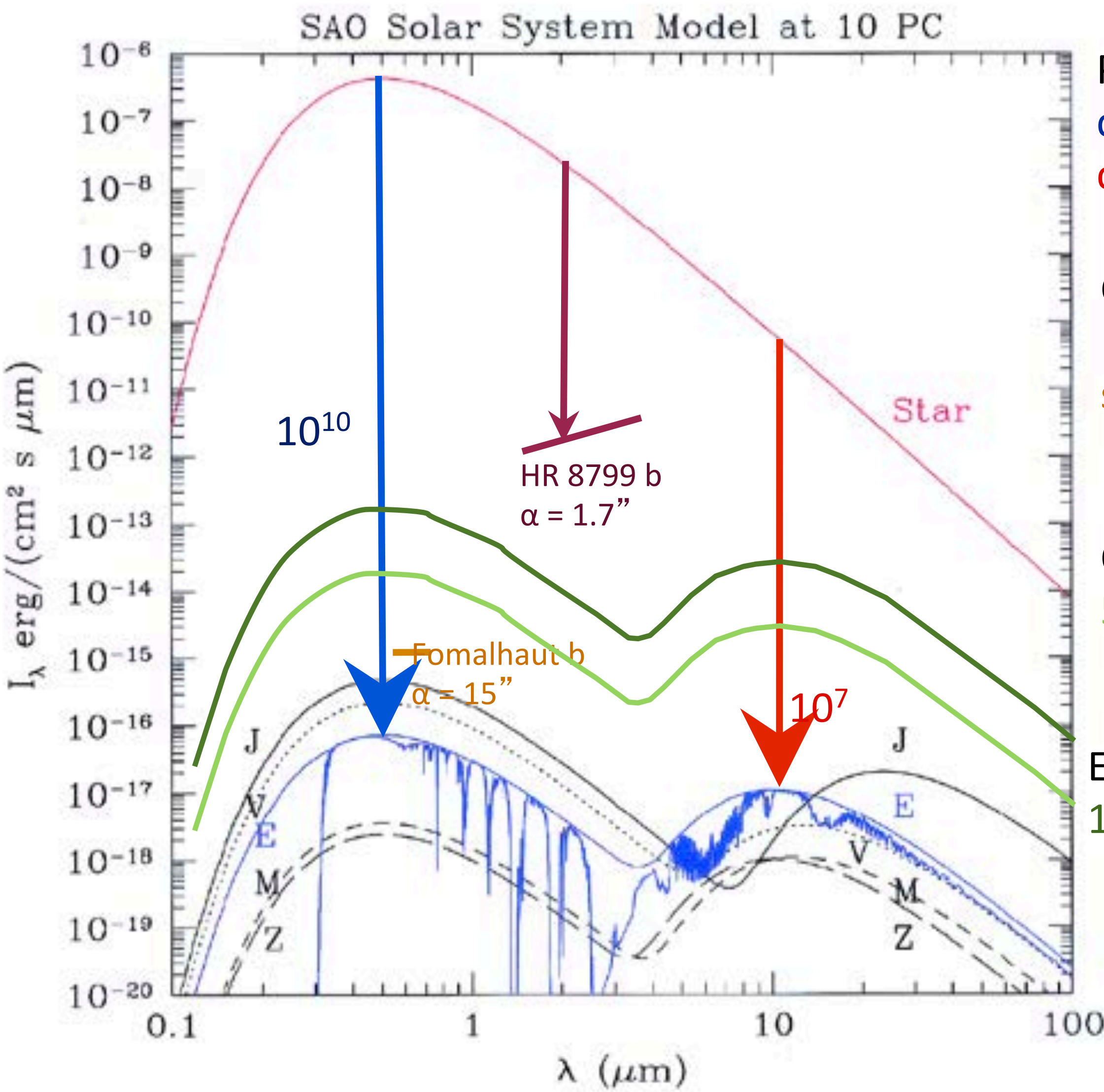
~2 M_J planet
at 1 Gyr

~1 zodi
debris disk

0.4 AU
at 10 pc

1 AU
at 10 pc

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.

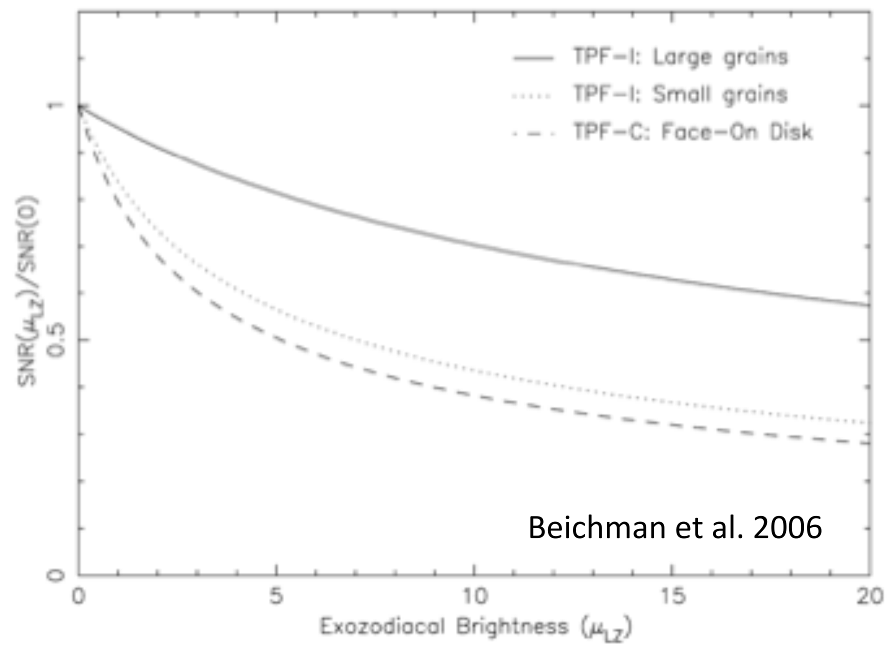
Exozodiacal dust becomes a problem:
10 zody or above.

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

Why is NASA interested in exozodiacal dust?

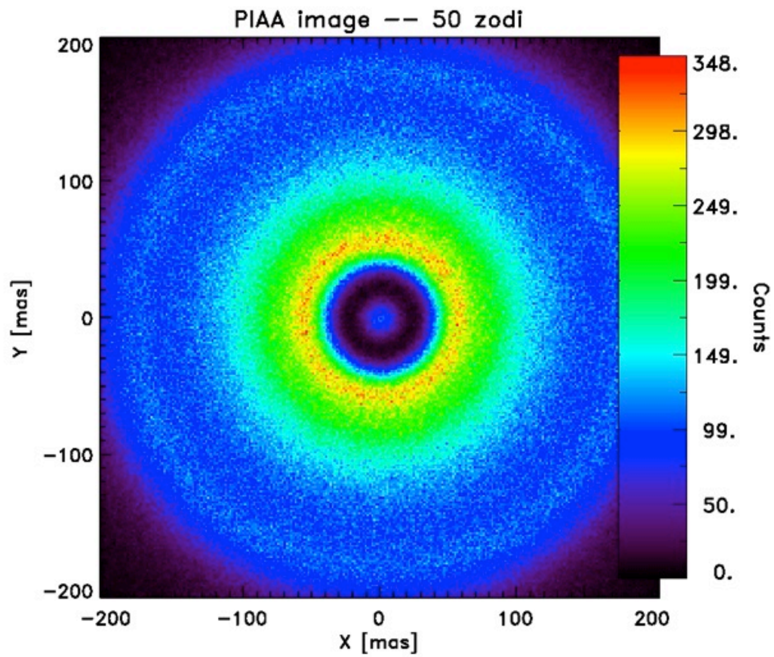
- Zodiacal dust around other stars can obscure flux from an exo-Earth. At 10 times our own density (10 zodies) the dust will impact the performance of exo-Earth imaging missions.
- LBTI is designed to probe for zodiacal dust at 10 µm down to 10 zodies. It is unique in being able to accomplish this task.

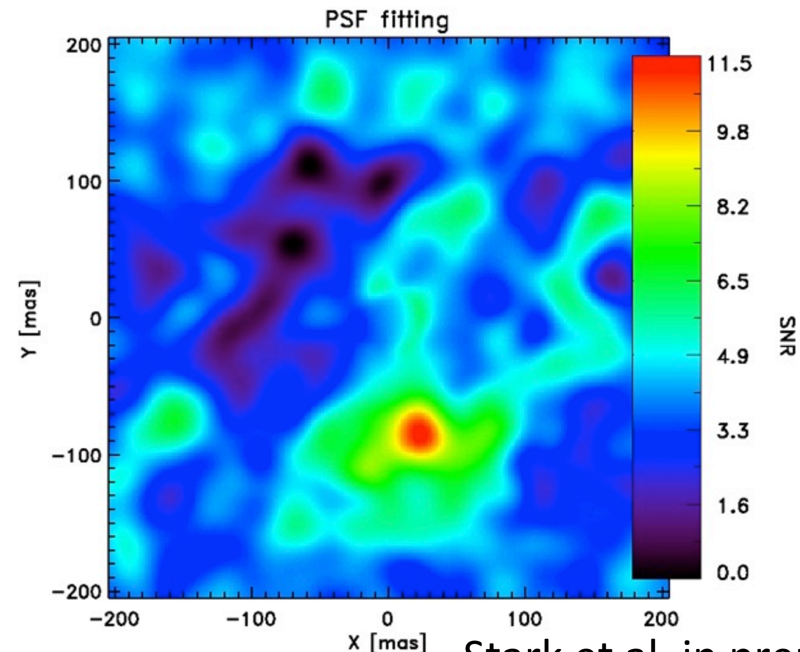
Estimate of signal-to-noise reduction for exo-Earth detection in the presence of increasing exozody brightness.



Why is NASA interested in exozodiacal dust?

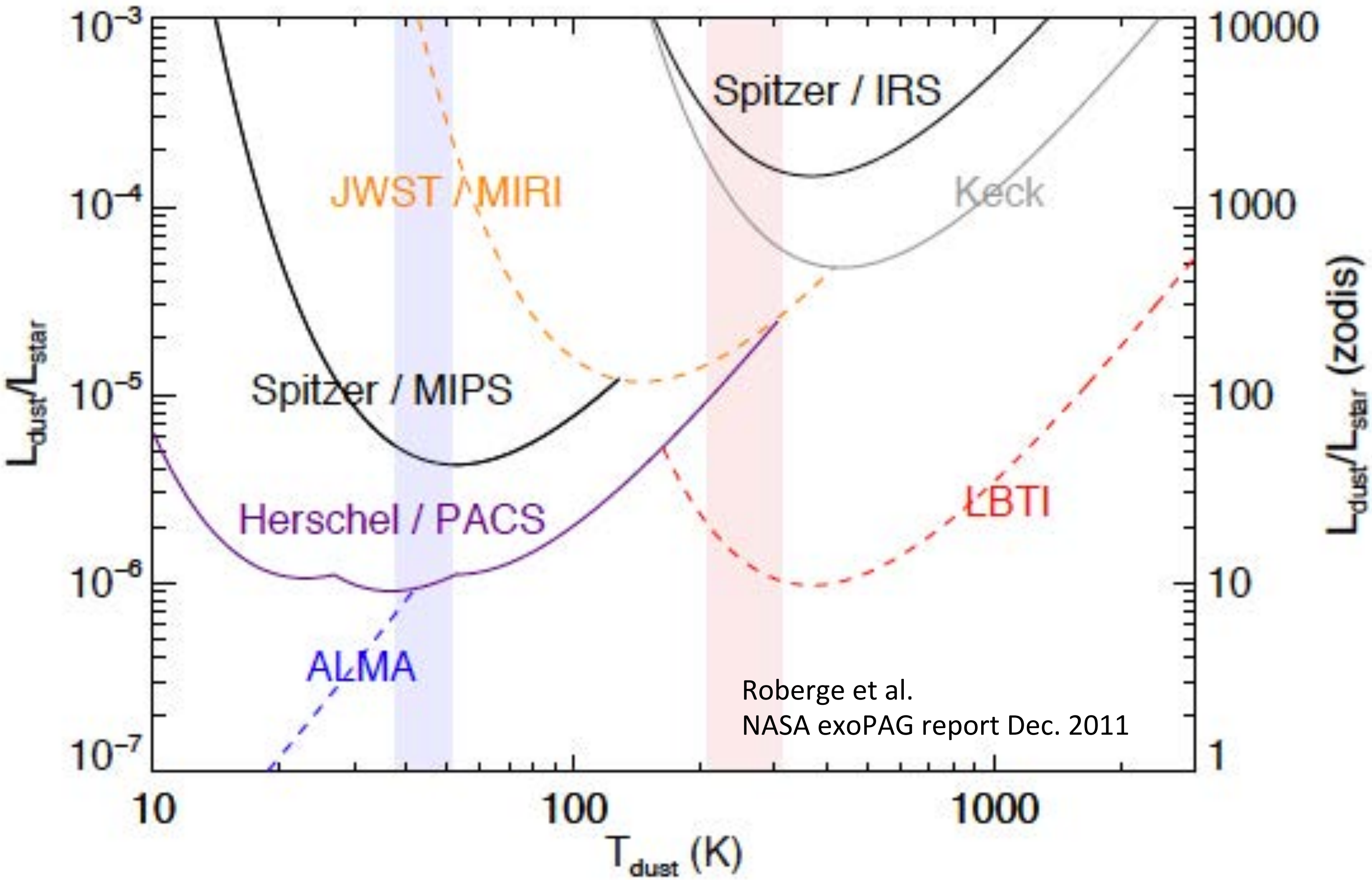
Where is the planet?





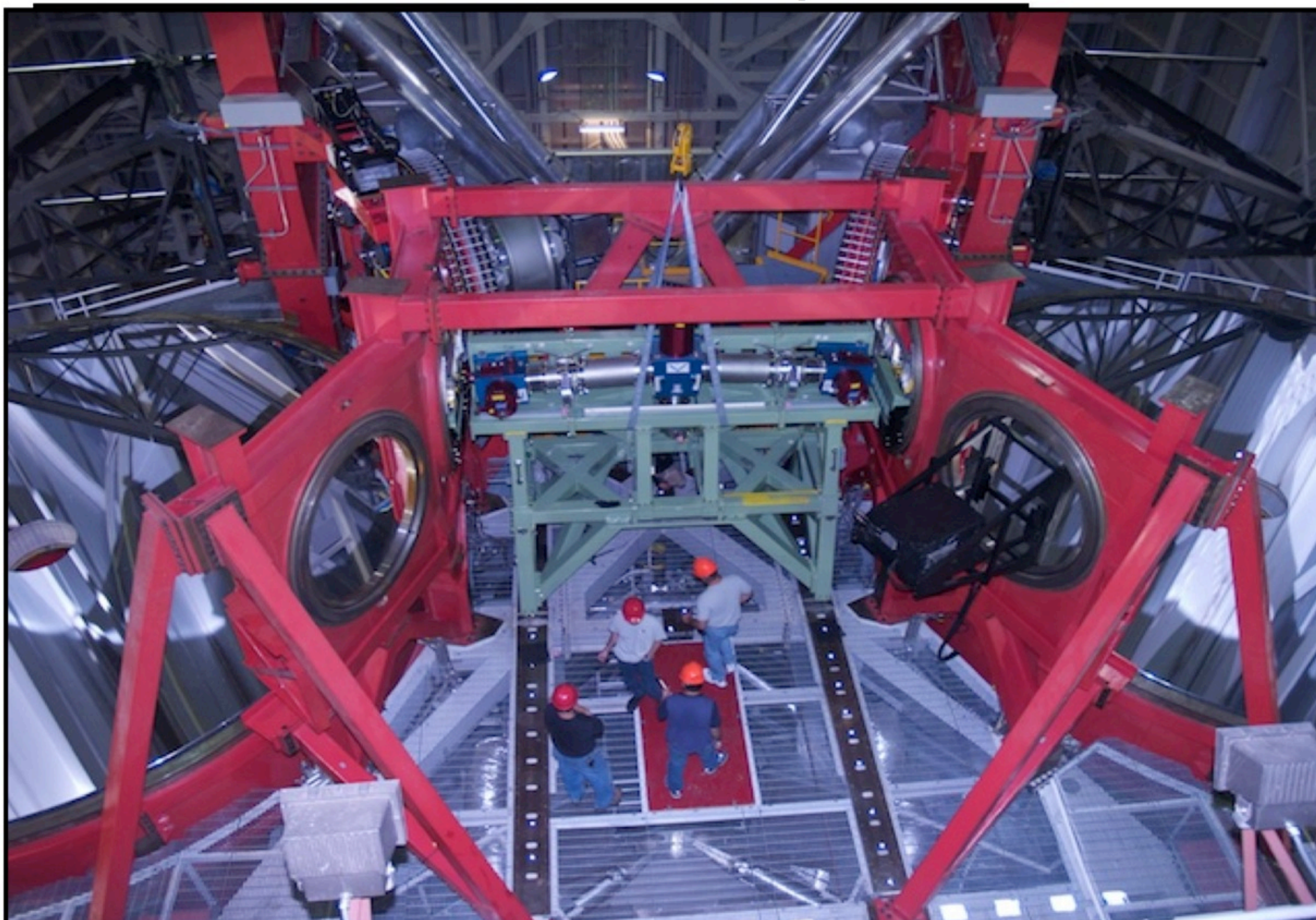
Stark et al. in prep

Sun-Earth system at 10 pc surrounded by a 50-zodi exozodiacal disk



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

LBTI was installed in September 2010



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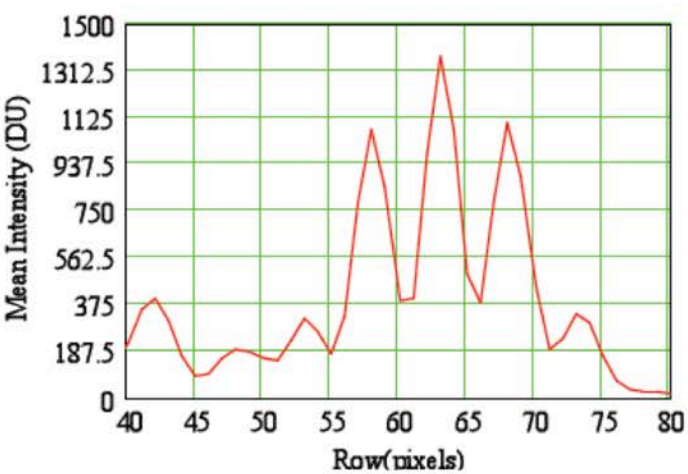
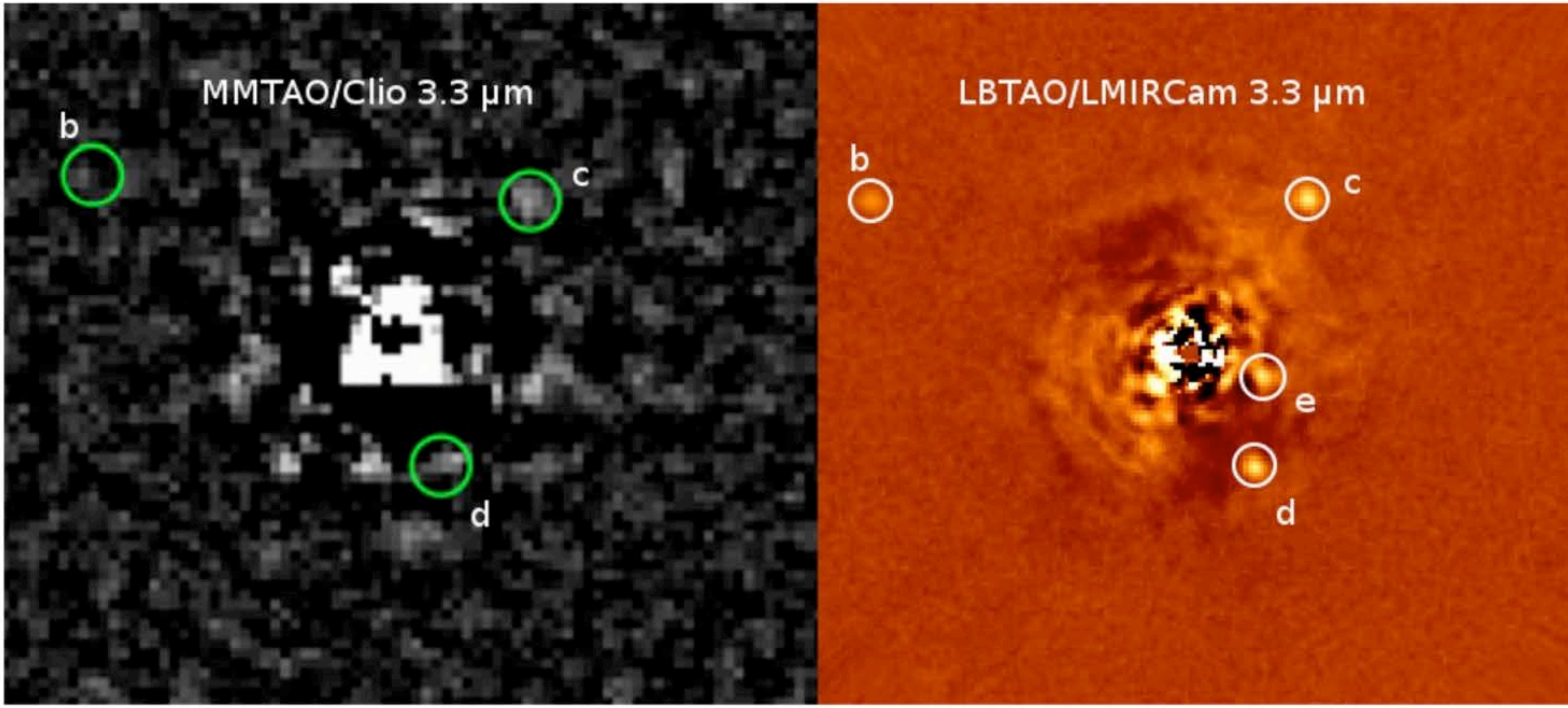
First Fringes!
(First night on sky: Oct. 14, 2010)

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.

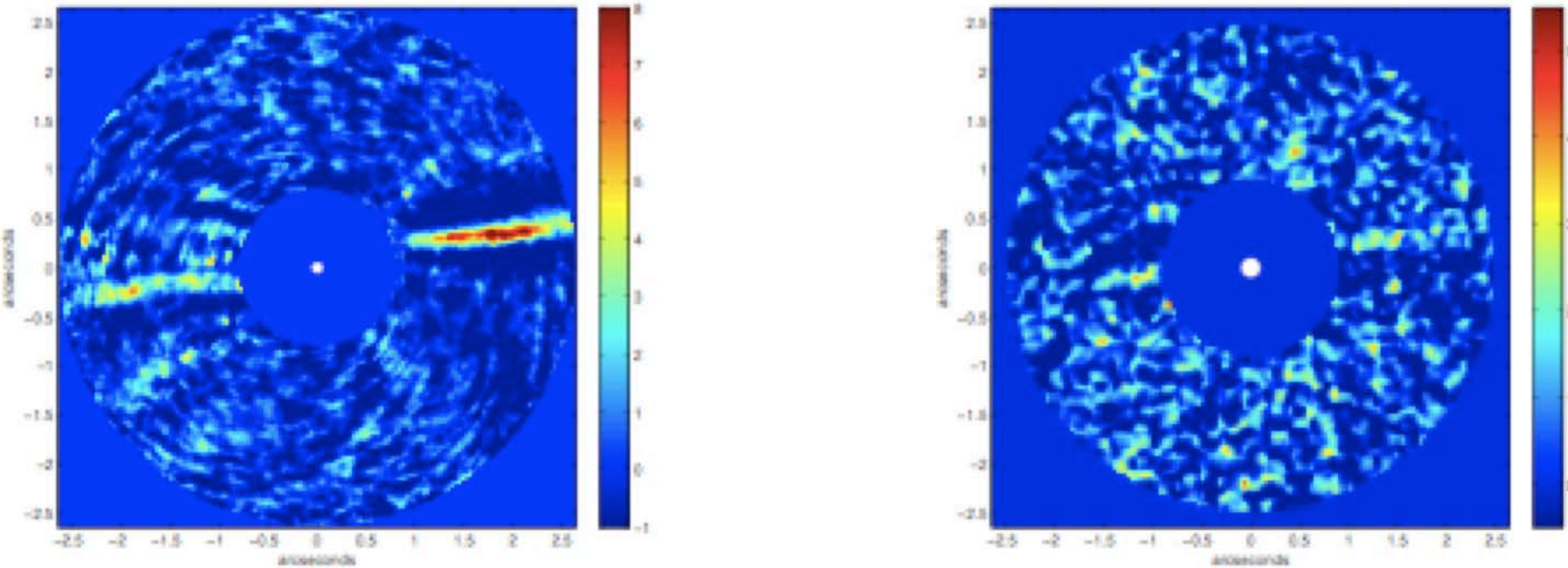


Early Science results



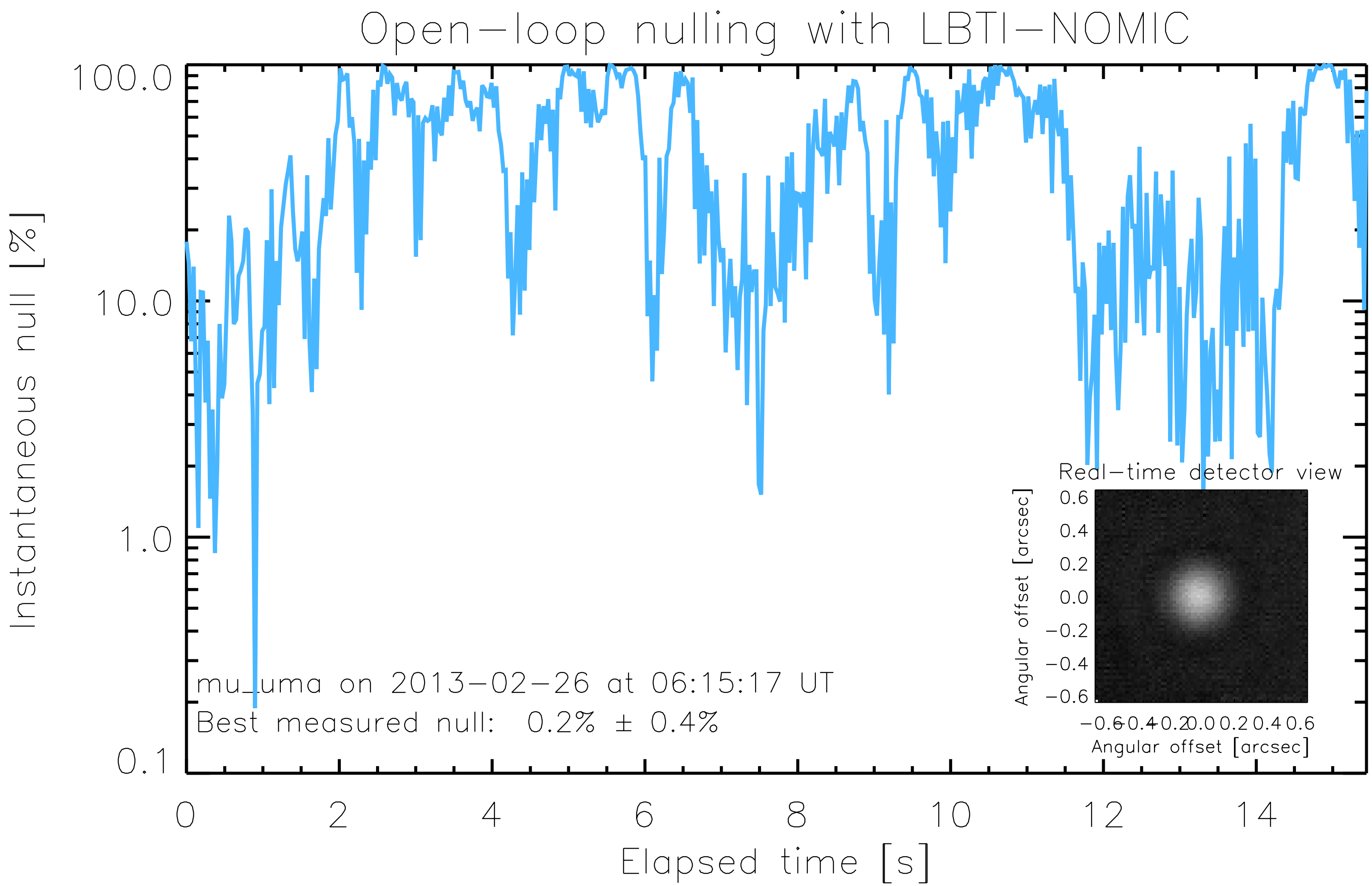
Skemer et al. 2012

Early Science results

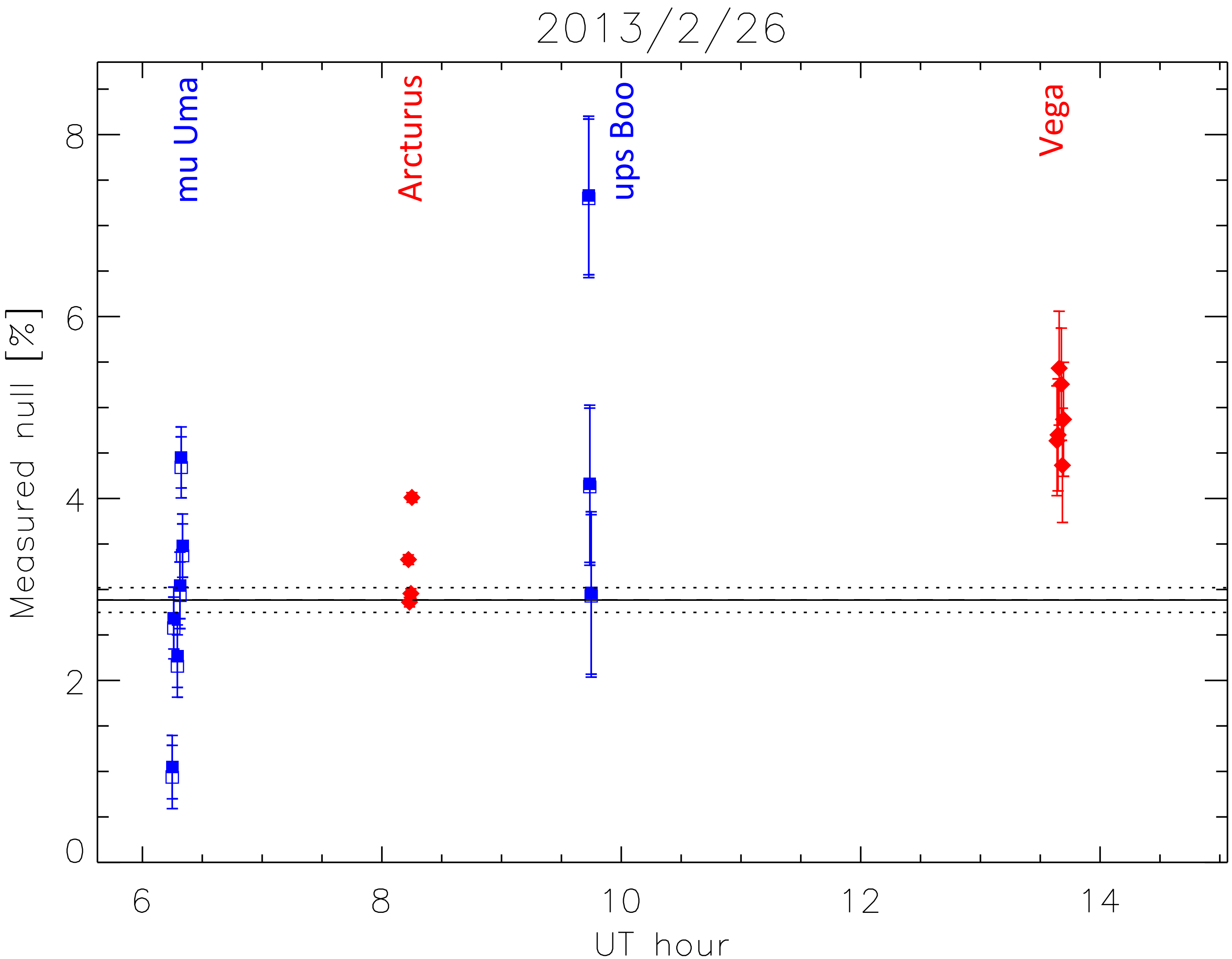


Rodigas et al. 2012

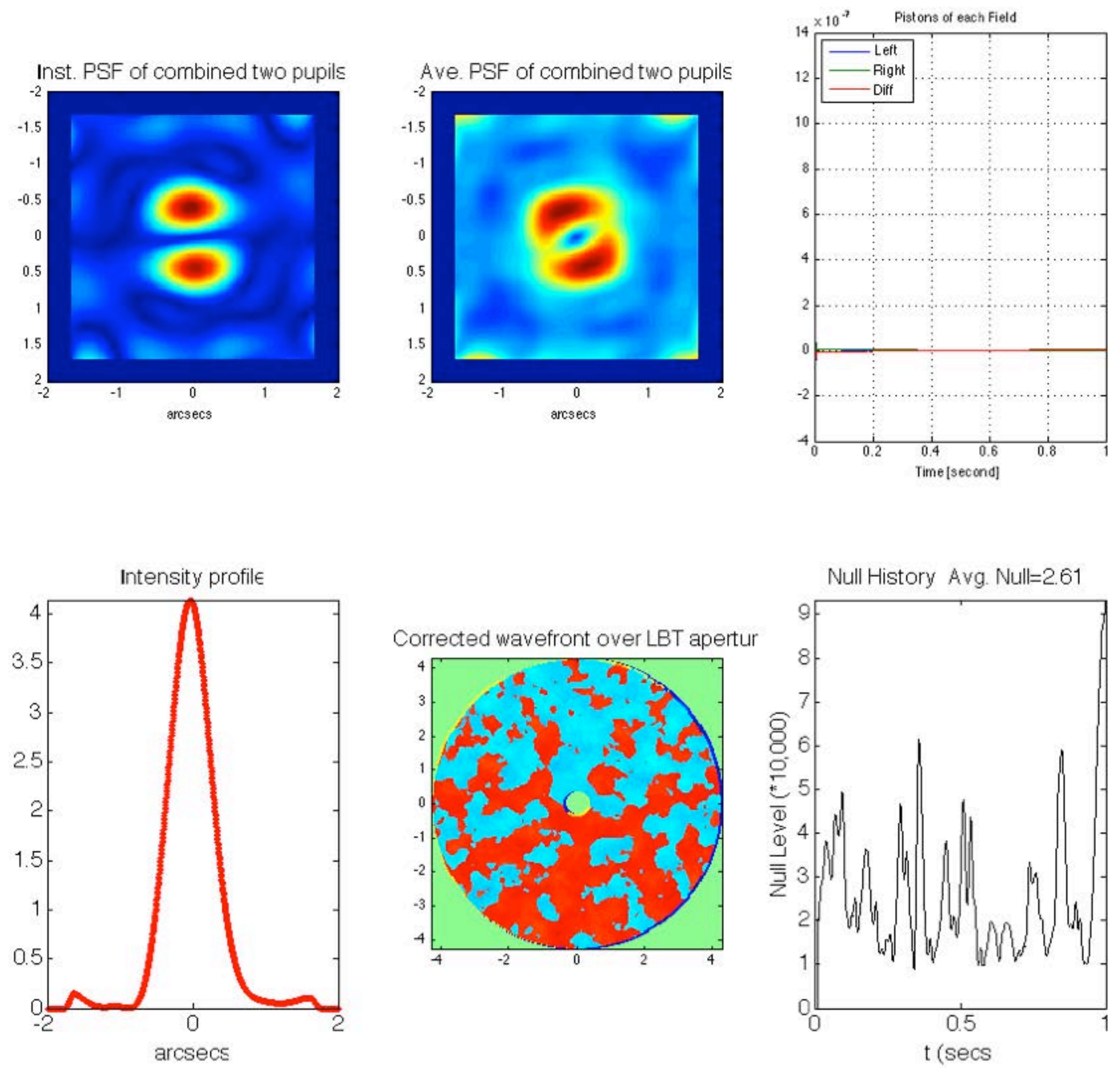
Open-loop null measurements



Open-loop null measurements



AO and Phasing Simulation

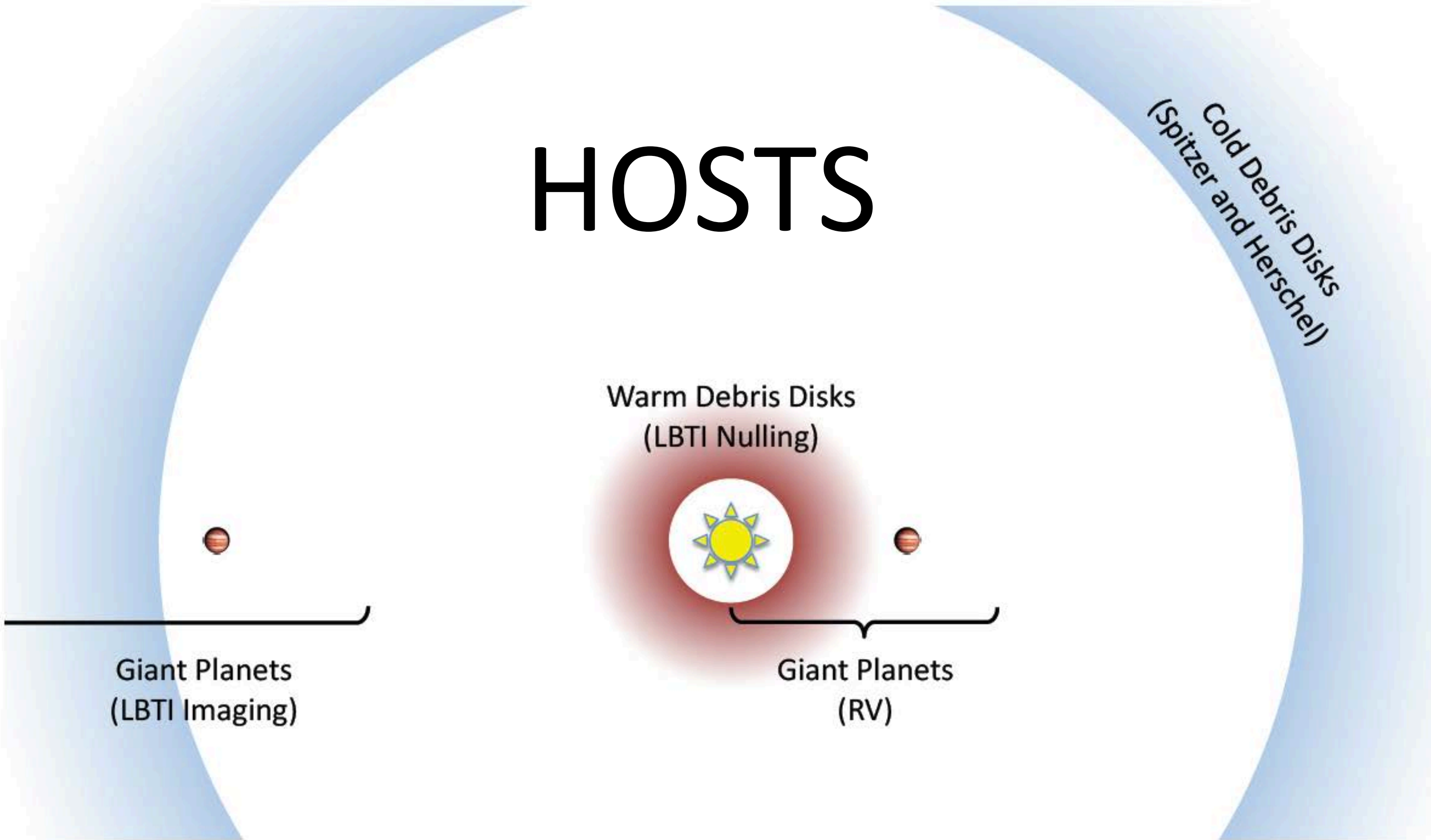


Matlab-based Monte Carlo AO code is being used to simulate nulling performance.

Null stability is seen to be ~5×10^{-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.

The Hunt for Observable Signatures of Terrestrial Systems



The HOSTS Program

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.

The HOSTS Team

- The HOSTS team is lead by Phil Hinz, with Instrument Scientists Andrew Skemer and Denis Defrère
- The NASA Exoplanet Science Center will archive data, and provide data support.
- An independent panel has selected astronomers from the exoplanet community to support the HOSTS program.
- Kickoff meeting was in September 2012.
- Team meeting during AAS Meeting in January 2013
- Monthly telecons and frequent e-mails

HOSTS Team Members

Geoffrey Bryden - Jet Propulsion Laboratory

Connecting LBTI to Previous Debris Disk Observations

Collaborator: F. Morales (JPL)

While the LBTI survey can be considered as a stand-alone result, comparison with related observations will undoubtedly aid with interpretation and understanding. The objective of this proposal is to use the combined LBTI/Spitzer/Herschel dataset to explore and quantify how observations at different wavelengths are related, how exozodiacal dust relates to cold outer debris, and how warm dust is related to neighboring planets.

William Danchi - Goddard Space Flight Center

Strategies to maximize the Science Return and Minimize Risk for the Large Binocular Telescope Interferometer

I propose a set of strategies to maximize the science return and minimize risk for the LBTI, covering the following areas: (1) Instrument performance verification and optimization of observational efficiency; (2) Source selection for a "pilot" survey and high value early science targets; (3) Calibration, Pipeline, preliminary data analysis, and modeling; and (4) Source selection for the "complete" survey.

Bertrand Mennesson - Jet Propulsion Laboratory

High Accuracy Null Depth Measurements of Nearby Main Sequence Stars with the LBTI

Collaborator: G. Serabyn (JPL)

Measuring individual star exozodi emission levels -or upper limits- down to the 10 zodi level, a factor 30 better than the current state of the art, is the challenging and exciting task awaiting the LBTI team. With that ultimate goal in mind, we propose here to assist with 5 key aspects of the LBTI Exo-zodi Key Science survey: (i) the optimization of the nulling interferometry instrumentation, (ii) the selection of LBTI target stars, (iii) the high accuracy calibration of null data (in particular the exploration of systematics), (iv) the "inversion" of null data, and (v) follow-up observations of a subset of the targets.

Karl Stapelfeldt - Goddard Space Flight Center

Exozodiacal Dust in Context: Scientific and Programmatic Connections to Current and Future NASA Missions

I propose to contribute to the LBTI Exozodi Key Science project in the areas of target selection, observation planning, modeling of detected emission, and scientific interpretation. My experience studying disks with Hubble, Spitzer, Herschel, and WISE has given me unique knowledge of existing datasets. I am eager to assess the implications of median exozodi levels on the science requirements for the 2020s "New Worlds" exoplanet imaging mission.

Alycia Weinberger - Carnegie Institution of Washington

Signal and Noise: Debris Disks and Exozodiacal Dust

Collaborator: Aki Roberge (GSFC)

We offer extensive experience observing disks with a wide variety of techniques, telescopes, and wavelengths. We will provide our insights into target selection, from the perspective of both the science and of the exoEarth mission requirements. We also propose to tackle the critical Science Team function of correctly connecting the LBTI observables to dust parameters that actually affect direct exoEarth observations. Finally, we propose to incorporate LBTI measurements of warm habitable zone dust into whole system architectures.

Mark Wyatt - Institute of Astronomy, University of Cambridge

Modeling the Structure, Origin and Populations of Exozodis of Nearby Stars

Collaborators: C. Haniff, G. Kennedy, O. Panic, A. Shannon (Cambridge)

In addition to contributing to the survey definition, my primary contribution will be to the topic of theoretical modeling and interpretation. Particular emphasis is placed on: (i) extracting model independent constraints on the dust distribution, (ii) modeling disk structure of individual sources to identify perturbing planets and to explore alternative exozodi origins, (iii) modeling of the 10 micron exozodi population with a view to extrapolating to the faintest levels that are important for a terrestrial planet finding mission.

Preliminary Survey Plans

- Three-pronged approach:
  - Shallow survey of 60-80 FGKM stars
  - Survey of ~10 well-known dusty systems to characterize distribution, strength, etc.
  - Survey 5-10 best candidate stars for future exoplanet missions to achieve the optimal sensitivity.
- Will benefit from a parallel LBTI Exozodi, Exoplanet Common Hunt (LEECH)
  - L band direct imaging of system carried out via the LMIRCam on LBTI.
  - Sensitive to ~Jupiter-mass planets

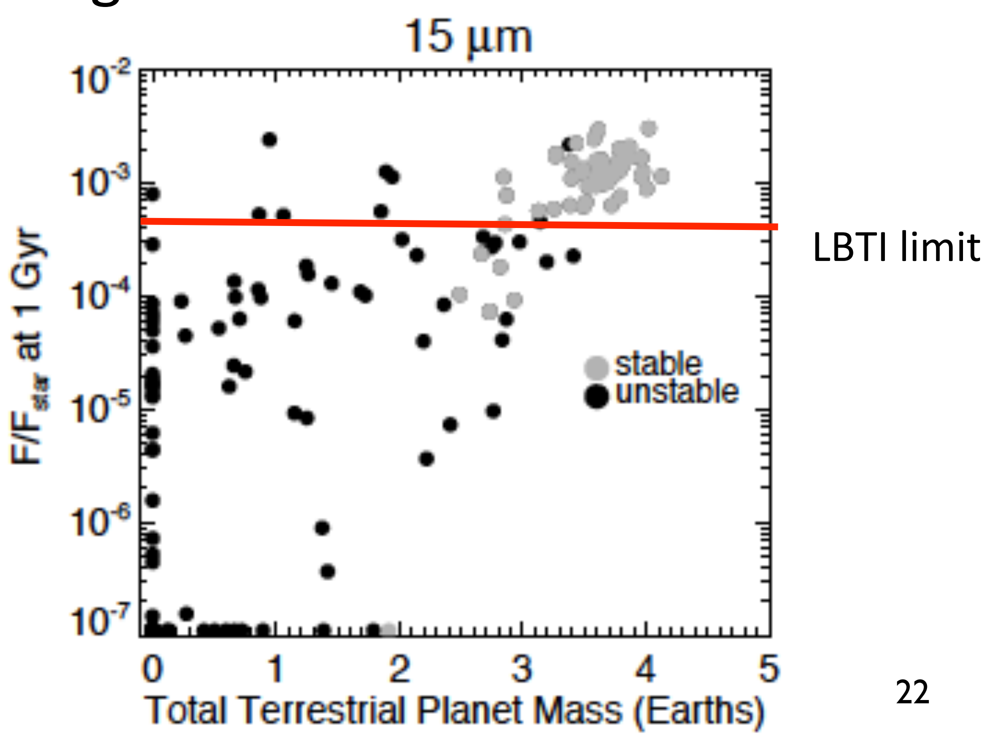
Ingredients for Master Sample List

- Stars need to be:
  - Bright enough to have their habitable zone resolvable by LBTI:
  - zodiacal dust above the photometric sensitivity of LBTI:
    - 40 pc for A stars. 21 available
    - 24 pc for F stars. 105 available
    - 14 pc for G stars. 28 available
    - 8 pc for K stars.   14 available
    - 3 pc for M stars. 2 available.

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.

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Summary

- The LBTI project has demonstrated coherent imaging with dual AO operation.
- Single aperture and nonredundant mask science observations have begun with the system (3 publications).
- Nulling commissioning is ongoing and started in fall 2012.
- The HOSTS and LEECH surveys will probe for dust disks and planets starting in Summer/Fall 2013.

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