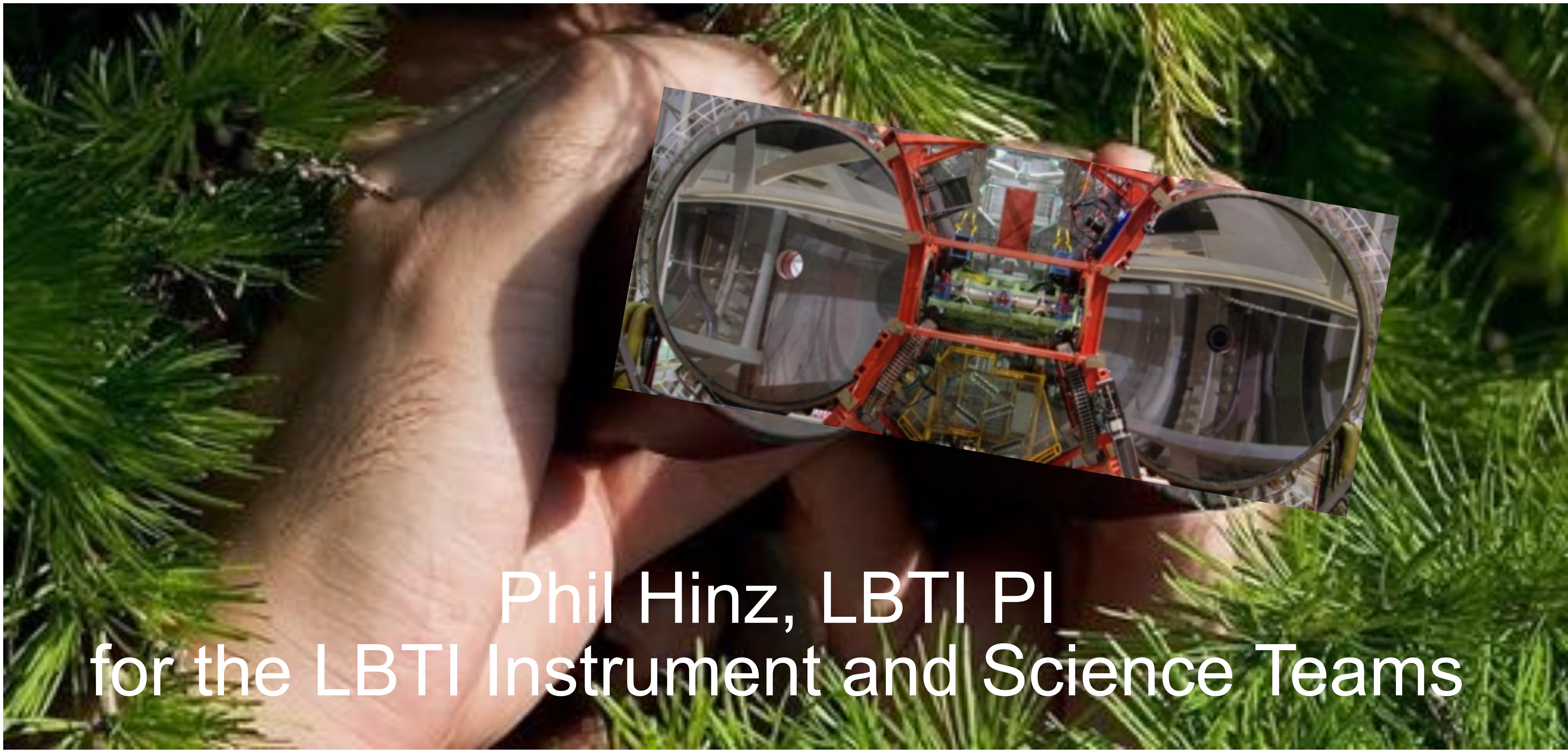
Exoplanetary Reconnaissance with LBTI

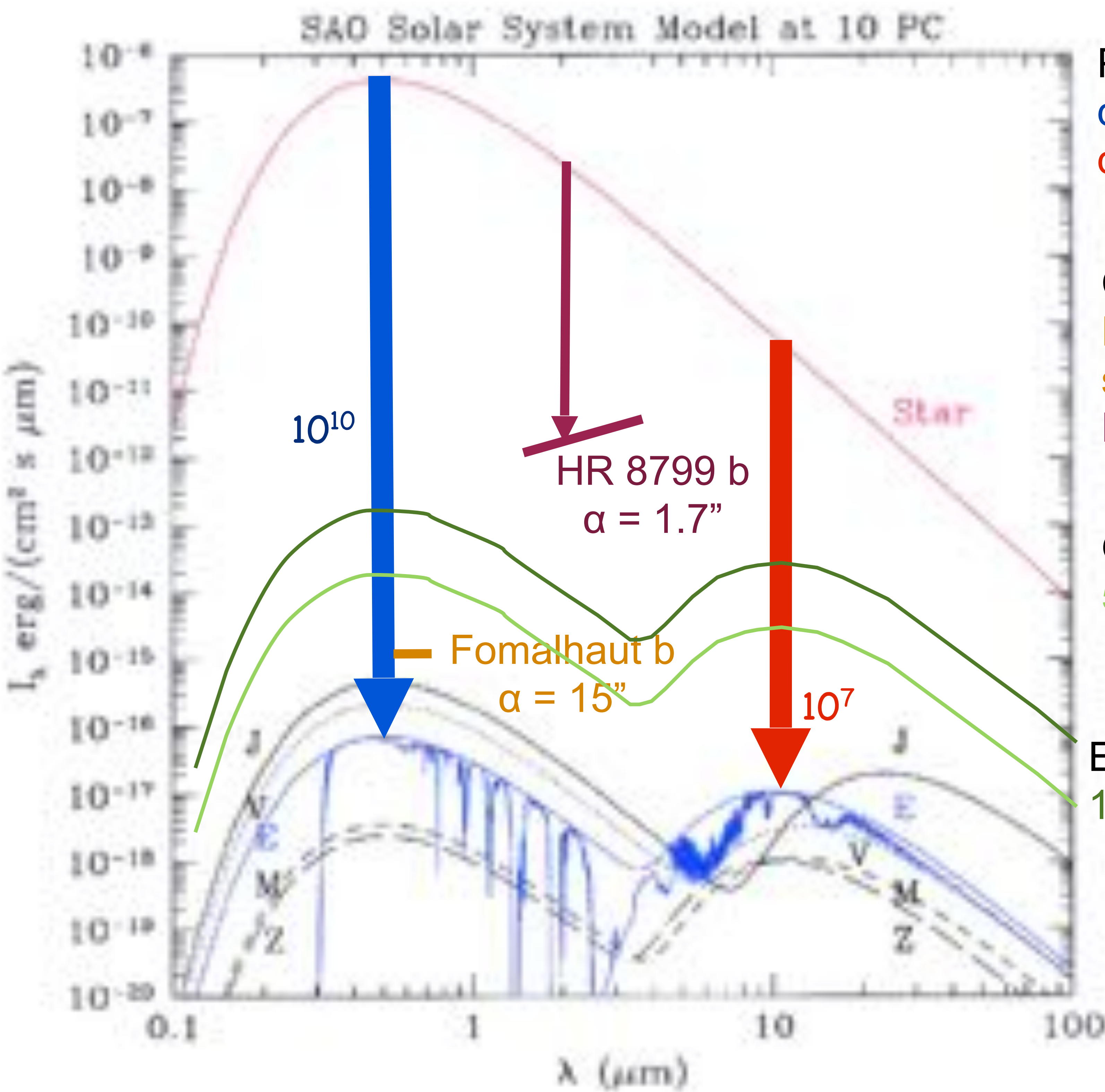


Phil Hinz, LBTI PI
for the LBTI Instrument and Science Teams

With specific contributions from

Denis Defrere, Andy Skemer, Alycia Weinberger, and Bertrand Mennesson

The Contrast Problem



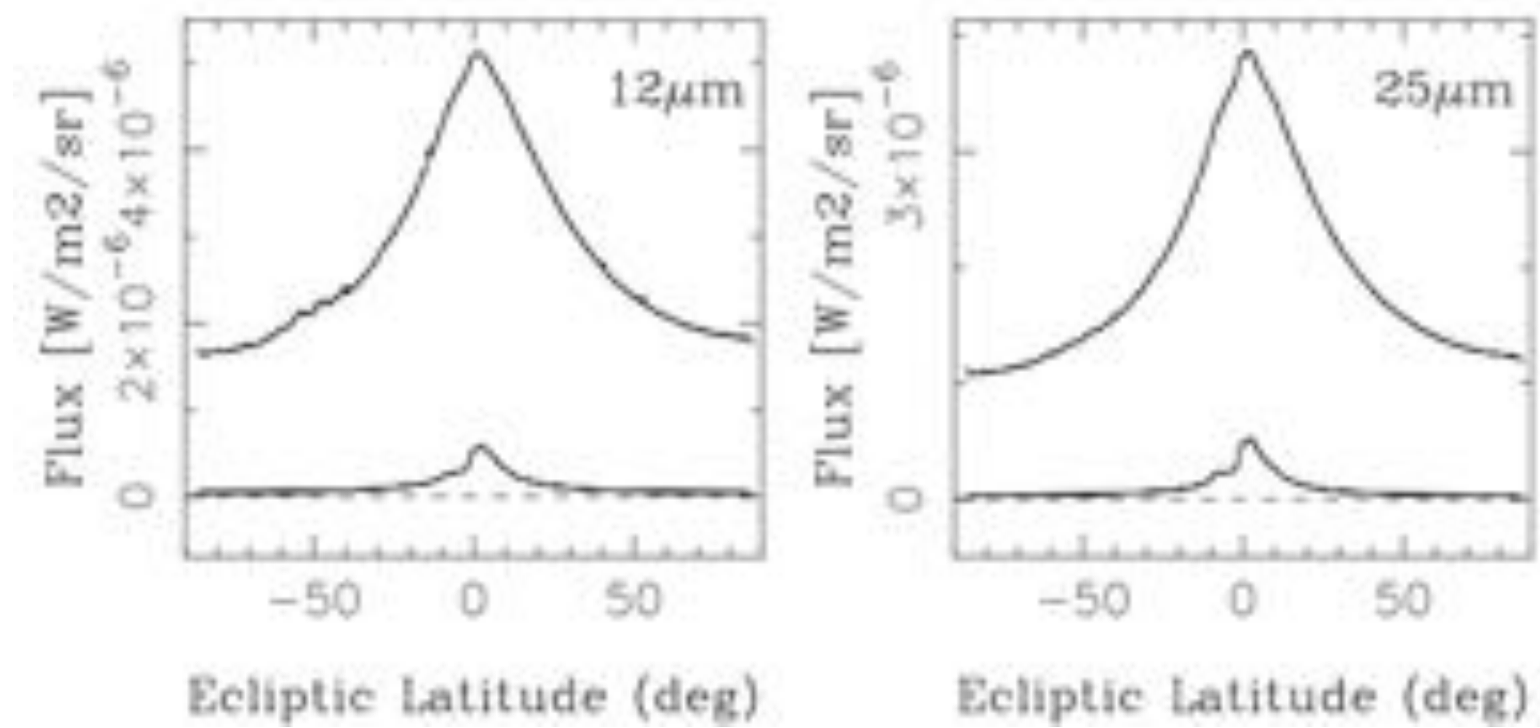
Planet Finding missions aim to:
detect Earths 10^{-10} fainter in visible.
detect Earth 10^{-7} in the IR.

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.

Zodiacal Dust



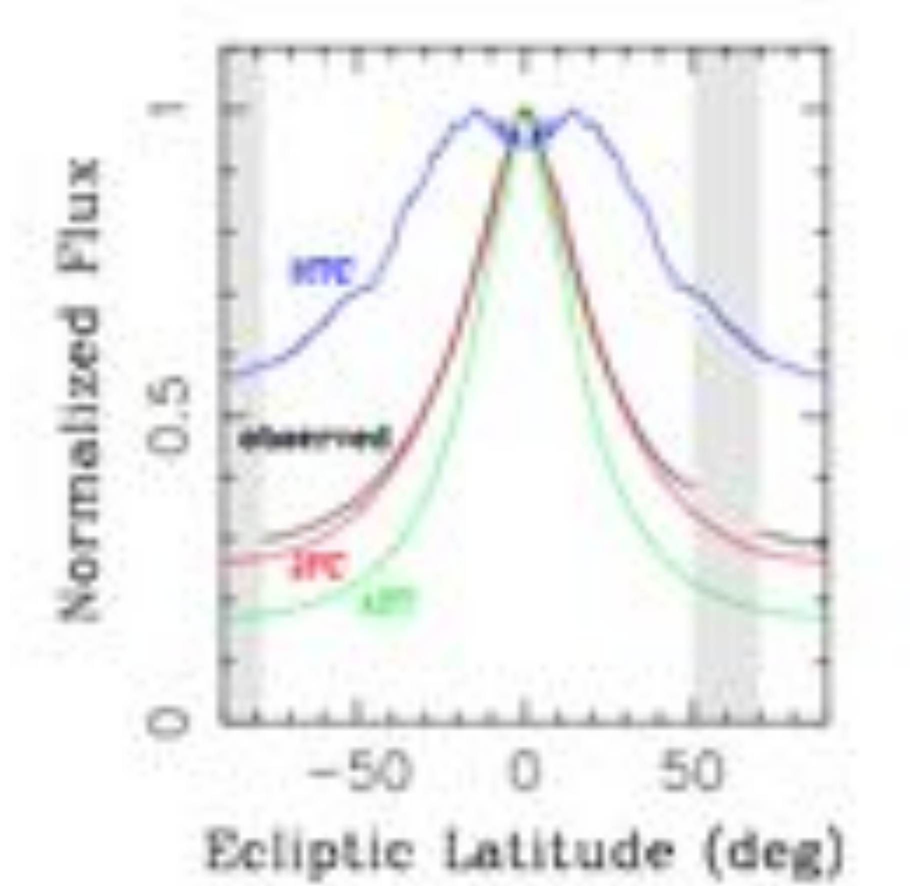
from Nesvorney et al. 2010

- Scattered light in ecliptic plane.
- Infrared emission first seen by IRAS.

Origin of Zodiacal Dust

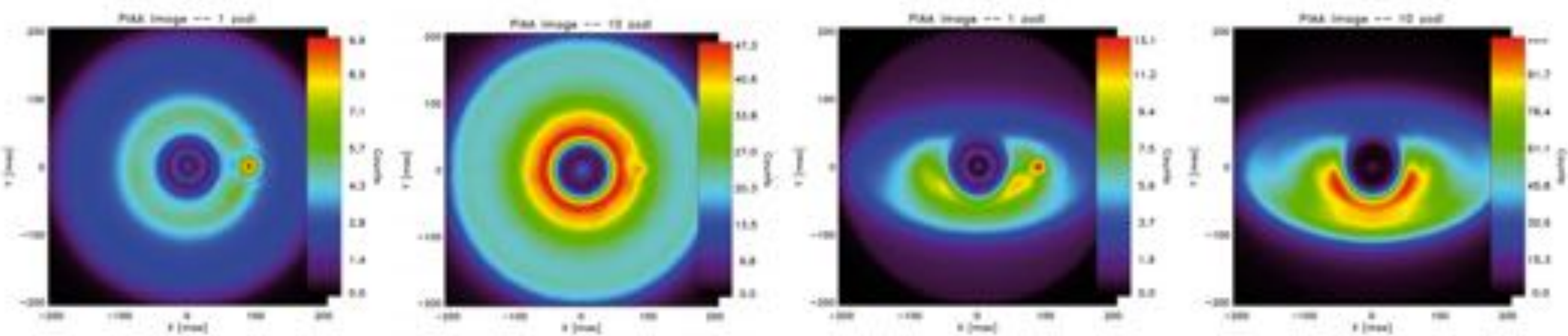
- Asteroid belt thought to provide much of the dust seen at Earth (Dermott et al. 2002).

- Recent Dynamical models (cf. Nesvorney et al. 2010) suggest Jupiter-family comets provide the majority of the dust for the zodiacal cloud.



from Nesvorney et al. 2010

The problem with exozodiacal dust



from Defrere et al. 2012

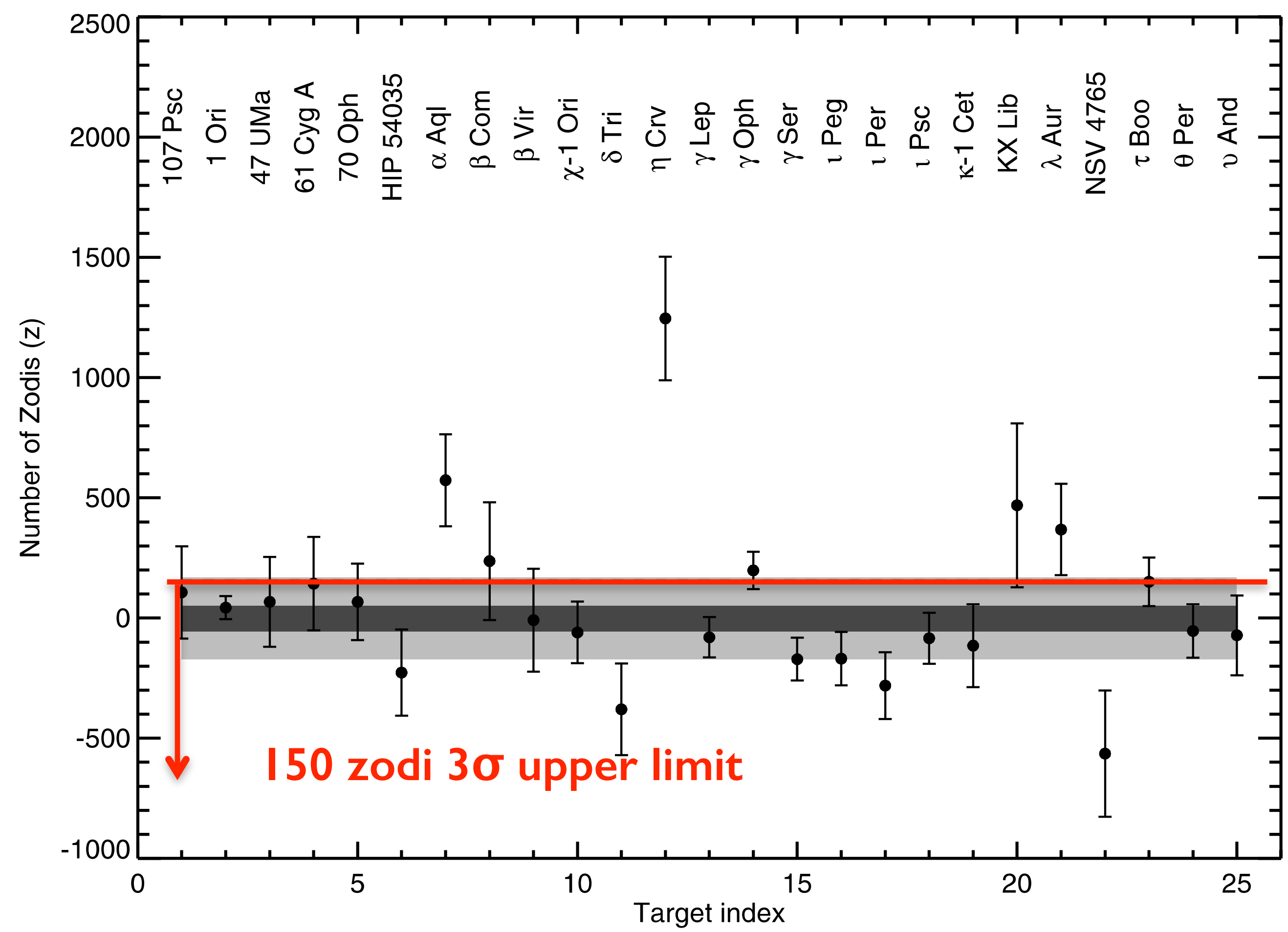
- Flux is problematic for any imaging mission.
- Clumpiness (resonances) complicates the detection.

Present Status of ExoZodi Knowledge in the Habitable Zone

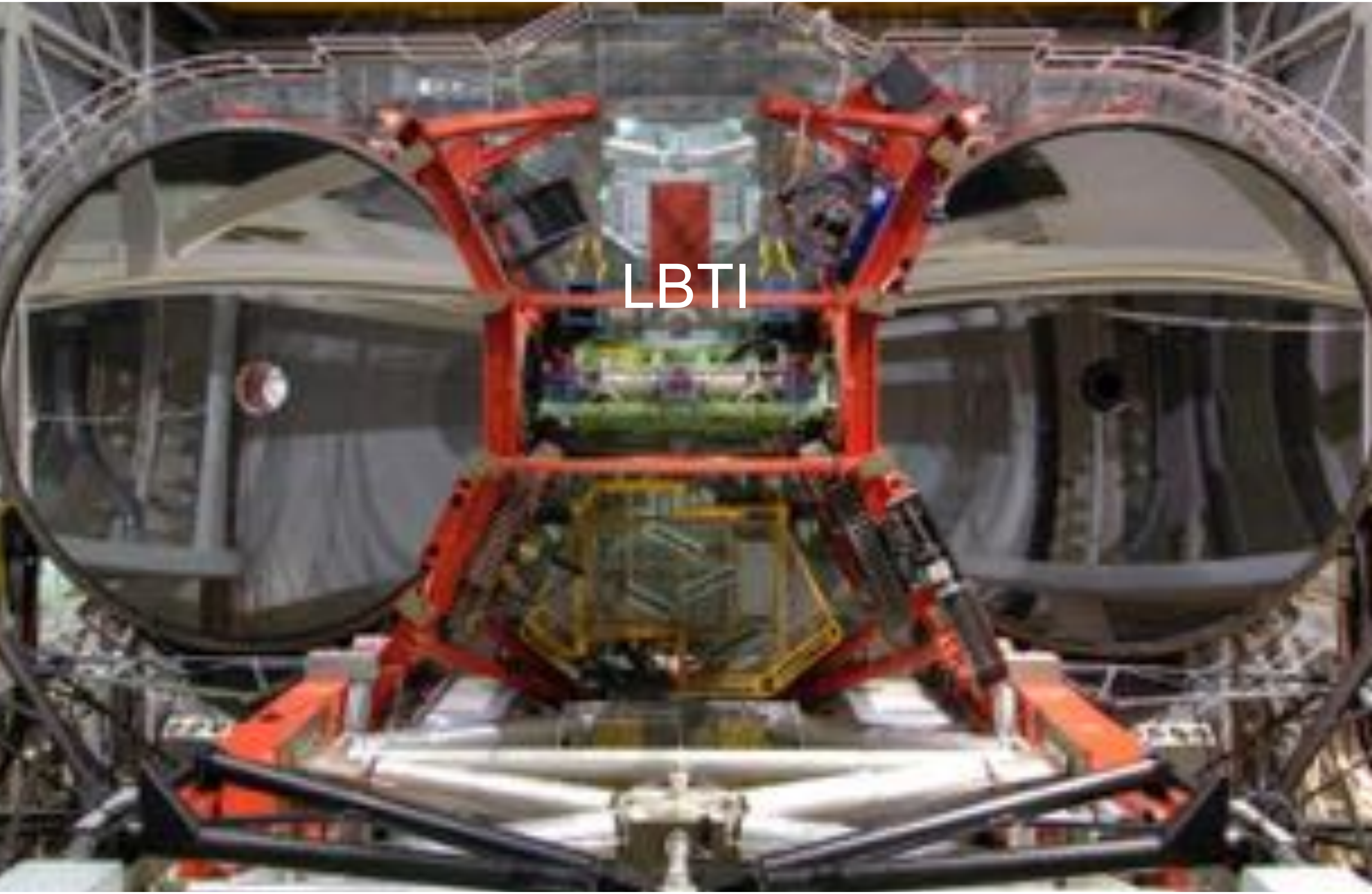
- **Spitzer/IRS (8-12 μm):**
  - 209 stars, most FGK .
  - 1% detection rate.
  - Average 1σ limit: 300 zodi.
  - Limited by ability to subtract stellar photosphere.
  - Beichman et al. 2006, Lawler et al. 2009.

- **MMT/BLINC (N-band, λeff = 11 μm):**
  - 6 stars, most early spectral types.
  - Average 1σ limit: 70-200 zodi.
  - Liu et al. 2009, Stock et al. 2010.

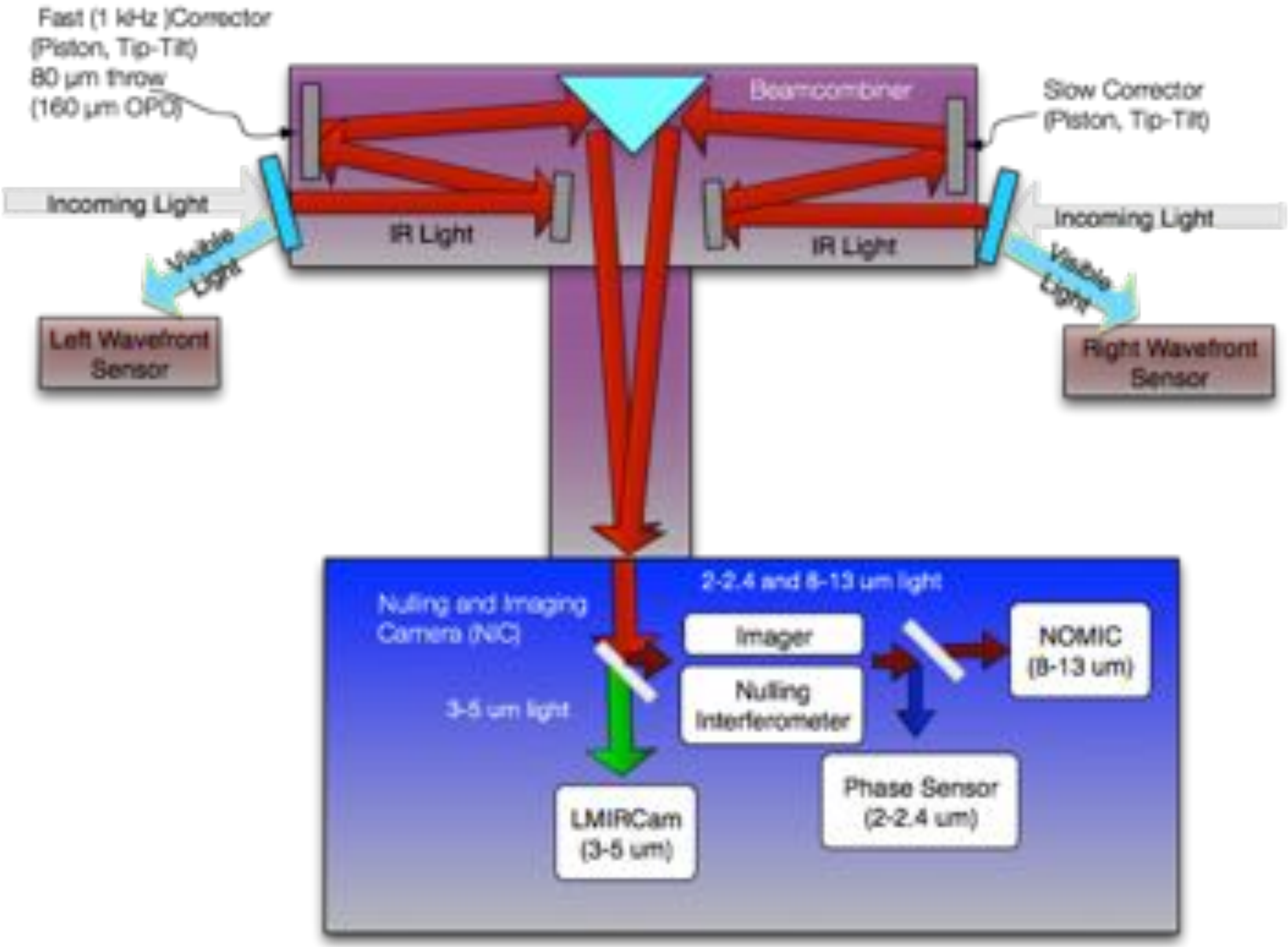
- **KI/Nuller (N-band, λeff = 8.5 μm):**
  - Results published (Millan-Gabet et al. 2011, Mennesson 2014)
    - 47 stars, most FGK. 1σ limit: 150 zodi.
    - Mean for the class: 0 ± 25 zodi.



Need improve the sensitivity down by > 1 order of magnitude.


LBTI

LBTI: The Instrument



The LBTI Project

- LBTI is a NASA-funded instrument built to support exoplanet imaging missions.
- Nulling interferometry is used to measure the thermal emission of dust in the habitable zone at 11 µm (via NOMIC).
  - The project passed it's "Operational Readiness Review" in April of this year.
- Imaging is used to detect Jupiter-like planets at 4 µm (via LMIRcam)
  - The planet imaging survey is currently underway (Skemer et al. 2014).

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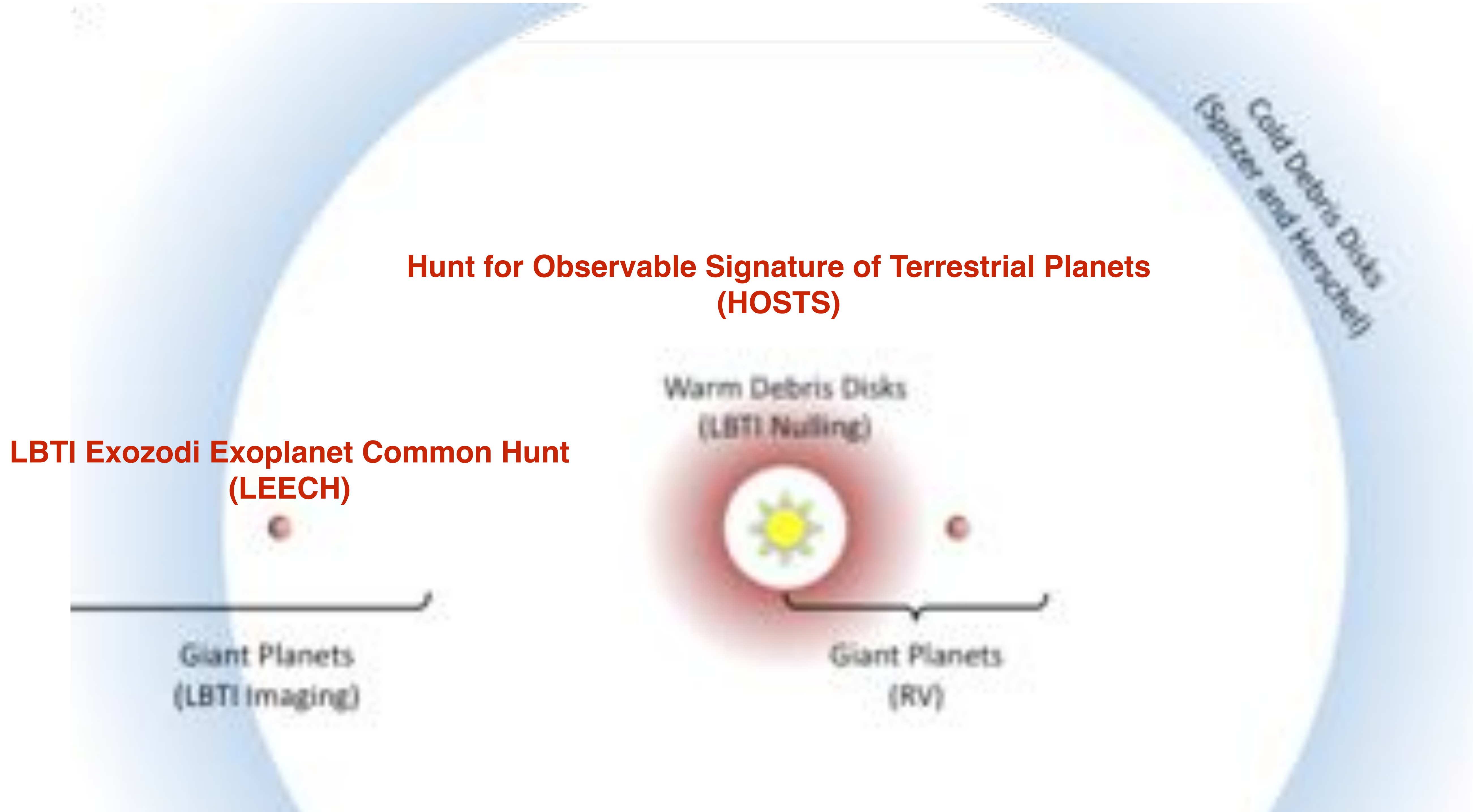
LBTI Reconnaissance



HOSTS Survey Plans

- Carry out HOSTS survey in the US FY16-17. We expect to be able to observe 32 stars during this time with a detection level of 400 ppm (12 zodies).
- Improve performance to Requirements level (150 ppm) during 9 month Science Verification Phase (SVP).
- Additional ~15-20 stars could be observed in FY18, funding permitting.

HOSTS Objectives

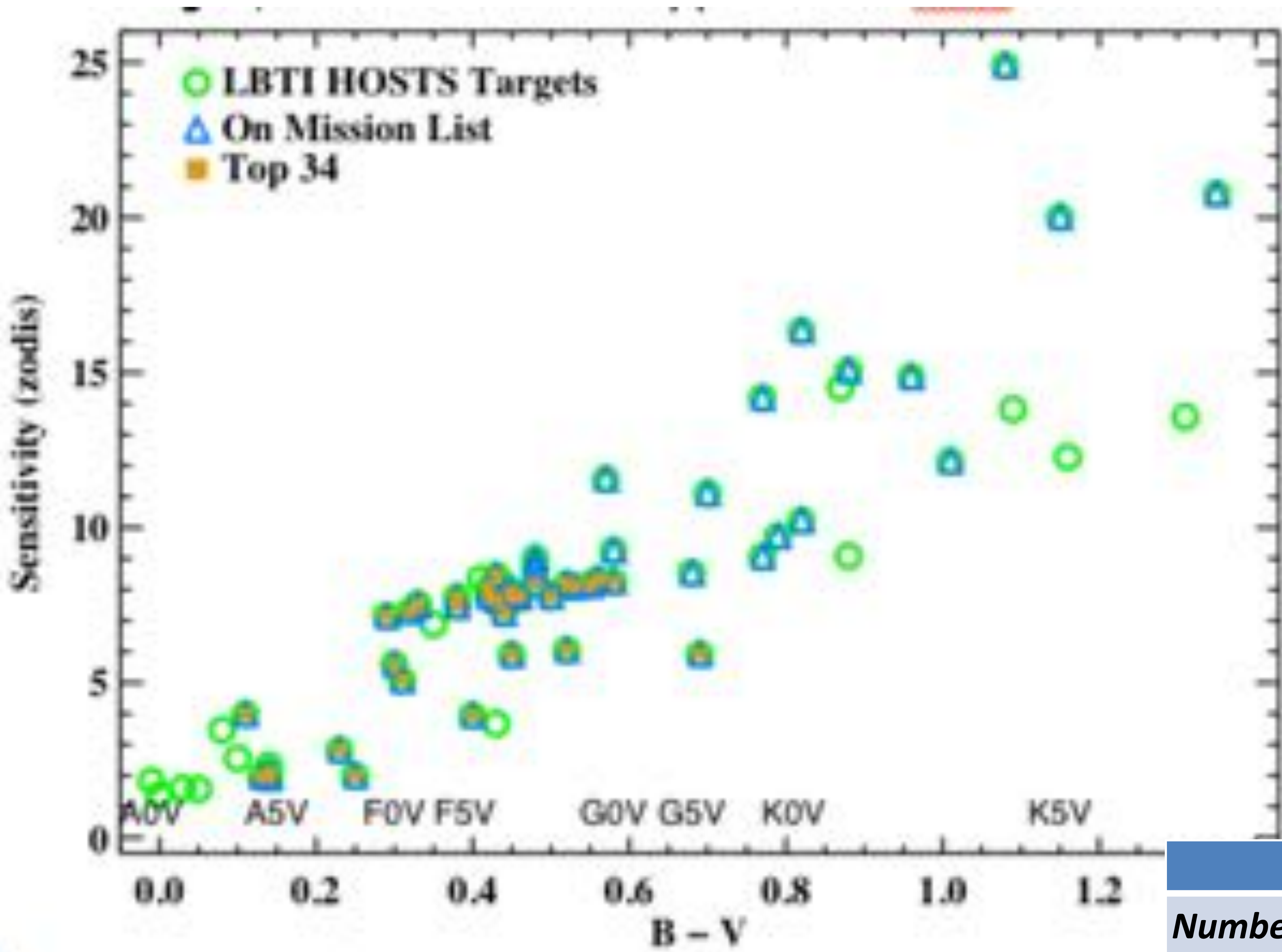
Satisfy:

1. Observe ACTUAL stars that would be good targets for a future direct imaging mission

2. Observe a SAMPLE of stars that enable sensible extrapolations to those stars that cannot be observed

LBTI Target Sensitivity

We can observe a subsample of 32 targets, all of which are good TPF targets, and achieve sensitivity per star < 9 zodis.



	A type	F type	G type	K type	Total
Number	*13*	*32*	*8*	*15*	*68*

Targets lists published in Weinberger et al. 2015, ApJS, 216:24

Additional Science Goals

Likely to require more than a 32 star sample to satisfy

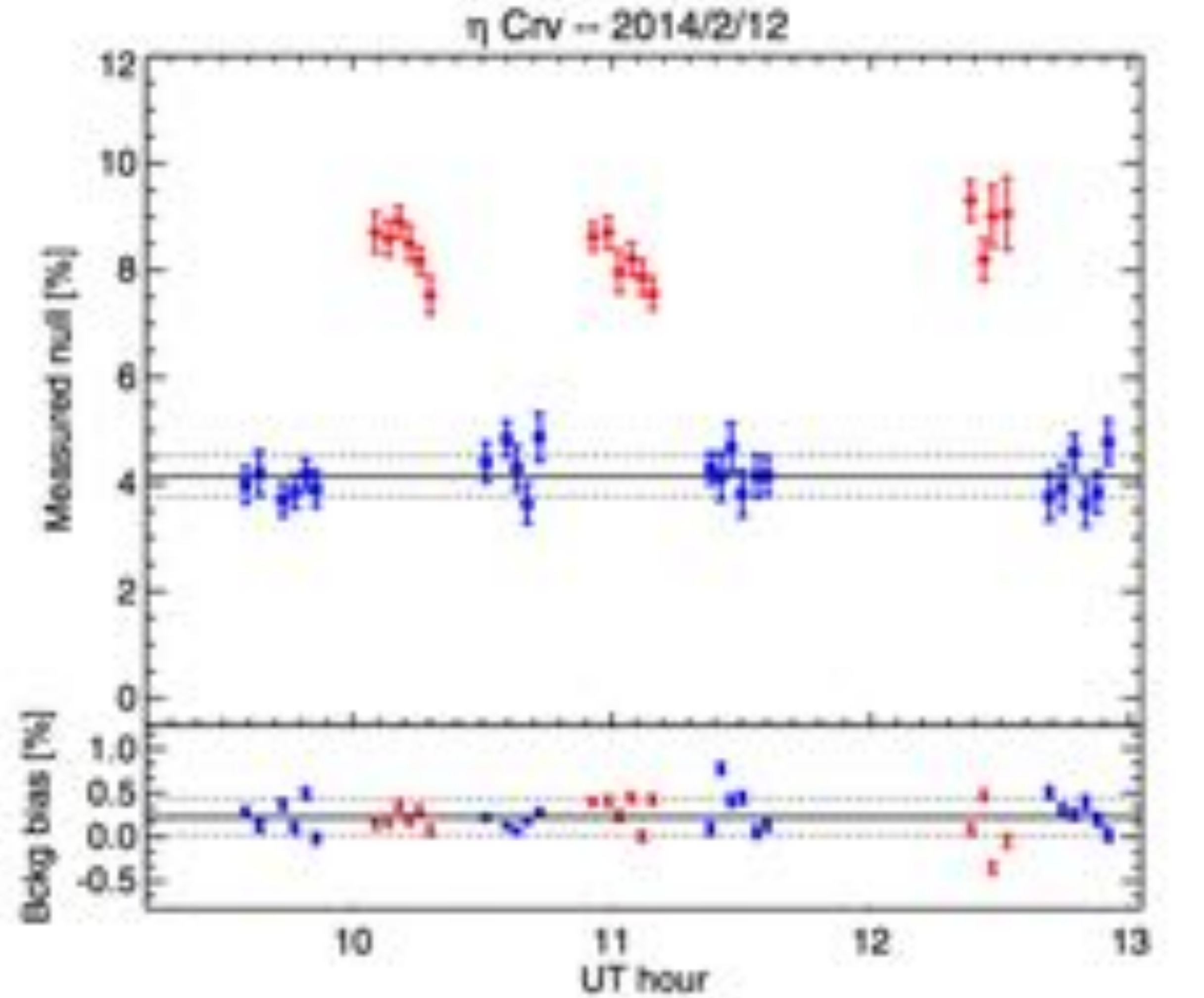
1. Do all mass/luminosity stars have the same exozodi brightness distribution?

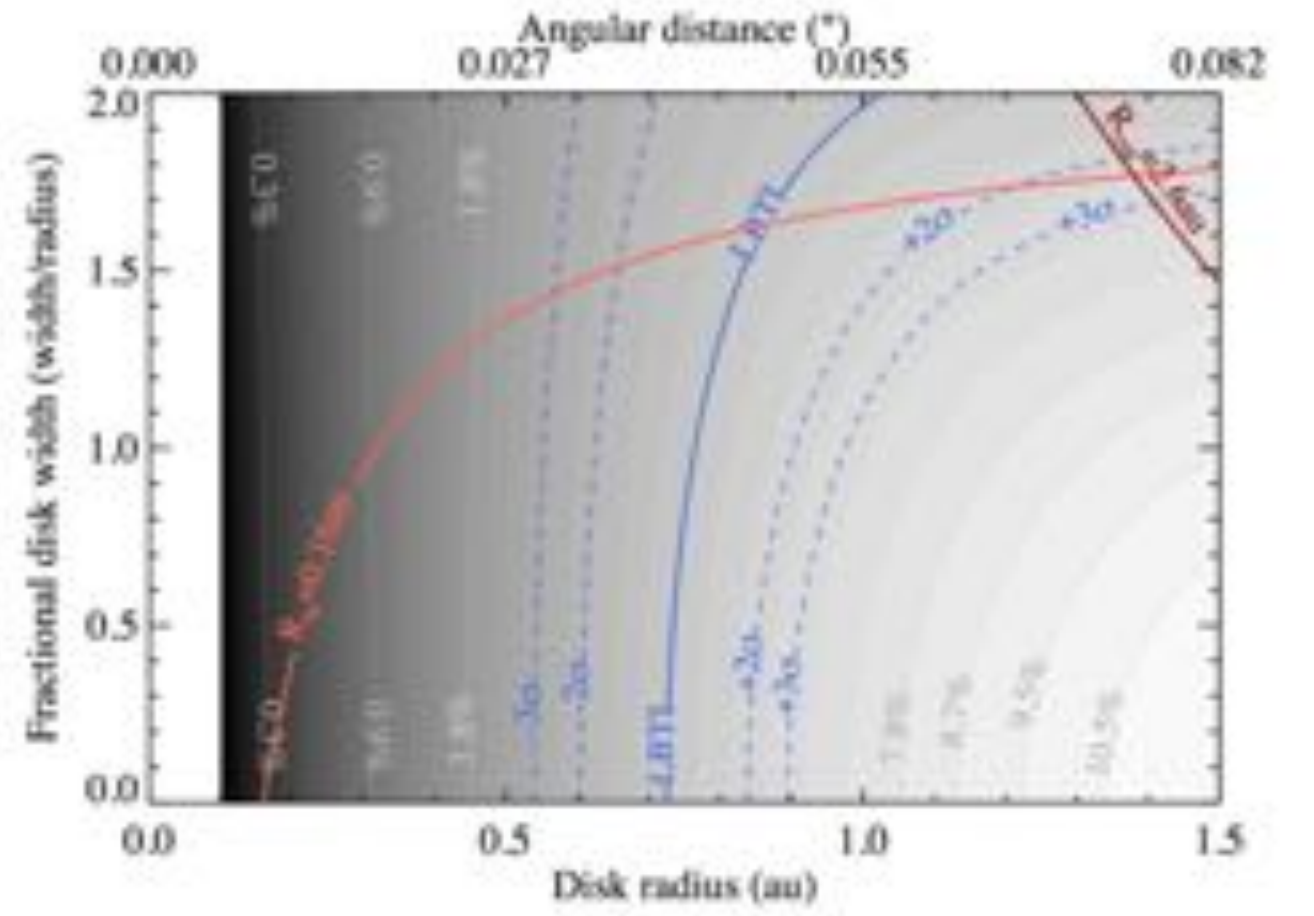
   → Observe stars of a range of spectral types
2. How correlated is the level of cold dust with exozodi level? (KIN showed a correlation, but not its distribution)
3. What is hot excess observed by near-IR interferometers?
4. How does dust luminosity change with age? (our target list is not designed for this)

If median exozodi level is high, we should consider an extended program to observe more actual TPF targets

LBTI nulling first light

- Commissioning tests on the star eta Crv detected a bright disk (Defrere et al. 2015).
- Modeling indicates dust is at < 1 AU (Kennedy et al. 2015).
- Data are consistent with a ~12000 zodi surface density in the habitable zone (although the model actually predicts most of the dust is closer).





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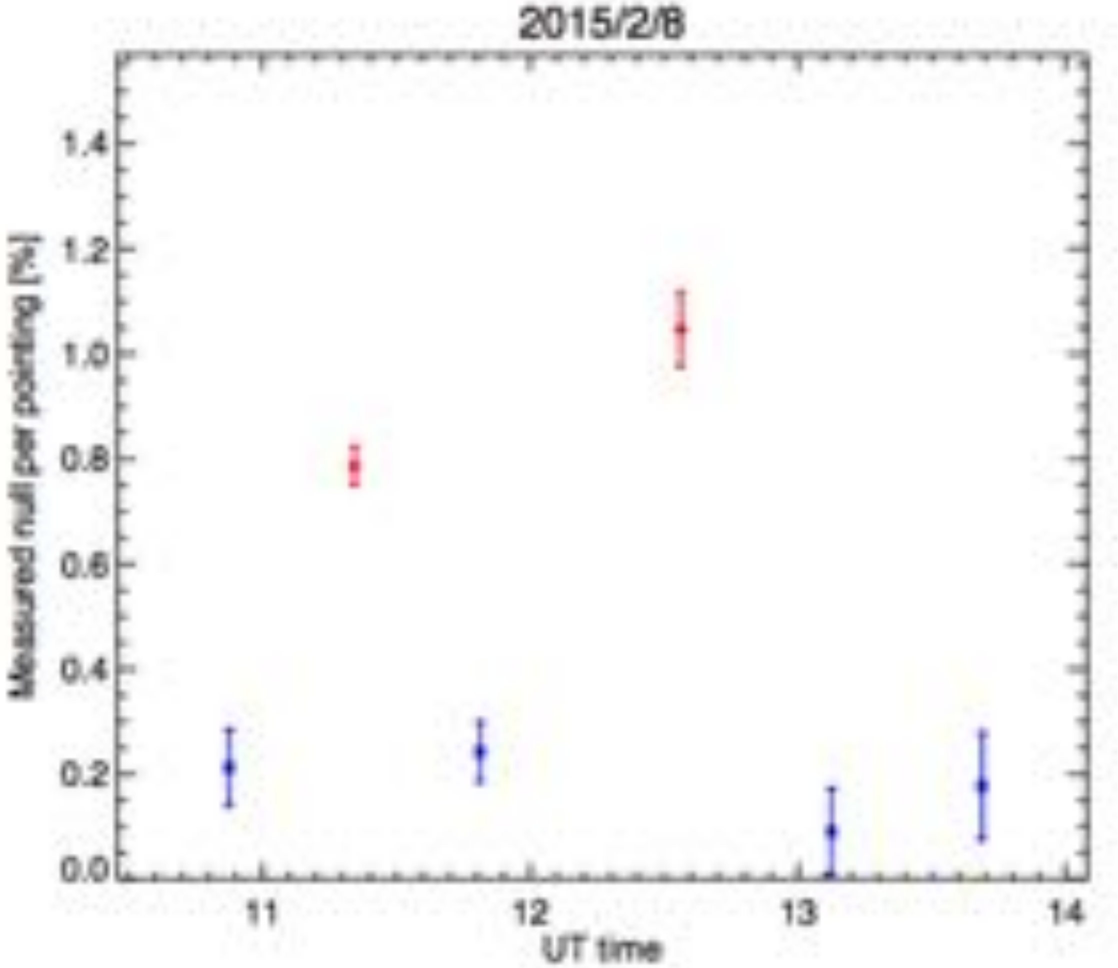
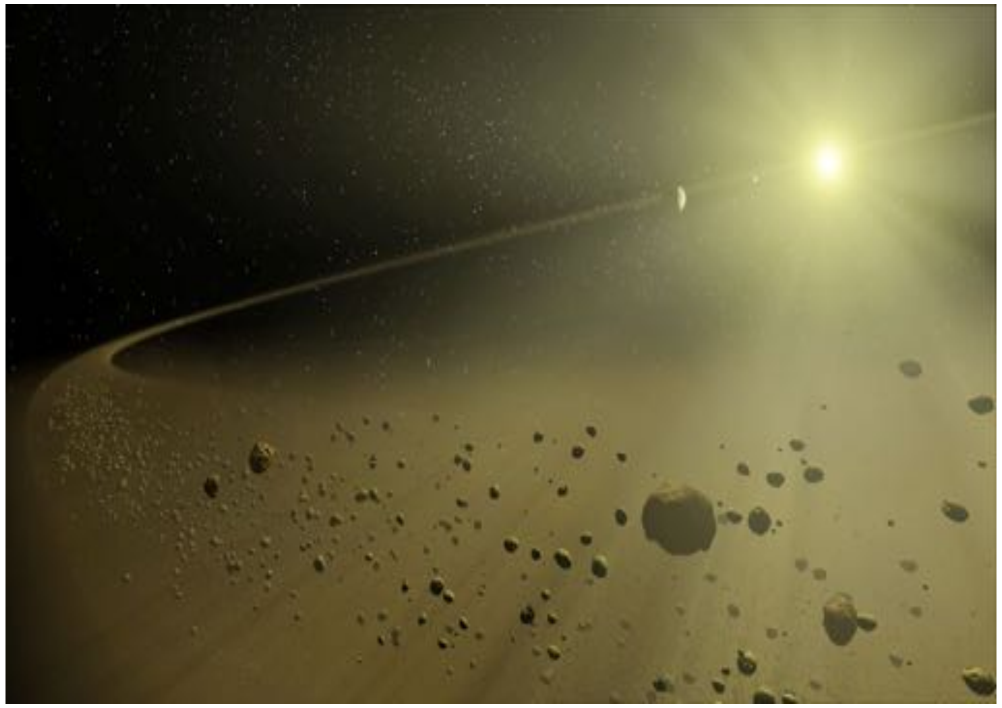
HOSTS Target 1: beta Leo





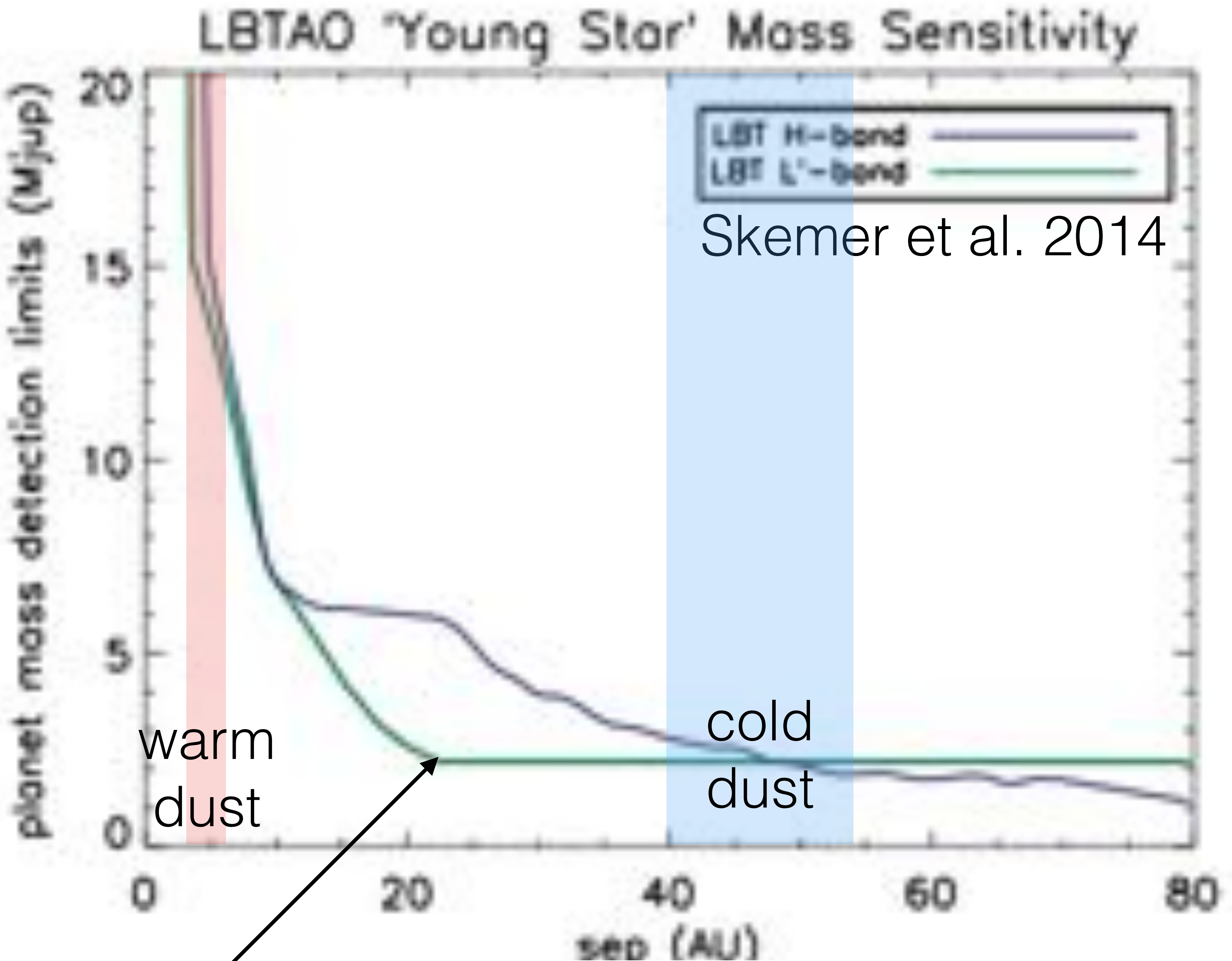
Commissioning tests on the star β Leo detected a disk at the level of 6000±500 ppm.

This corresponds to a disk that is **90 ± 8 zodi.**

Cold disk known from Herschel to be at R=40 AU.

11 μm emission detected by LBTI is likely at ~4 AU.

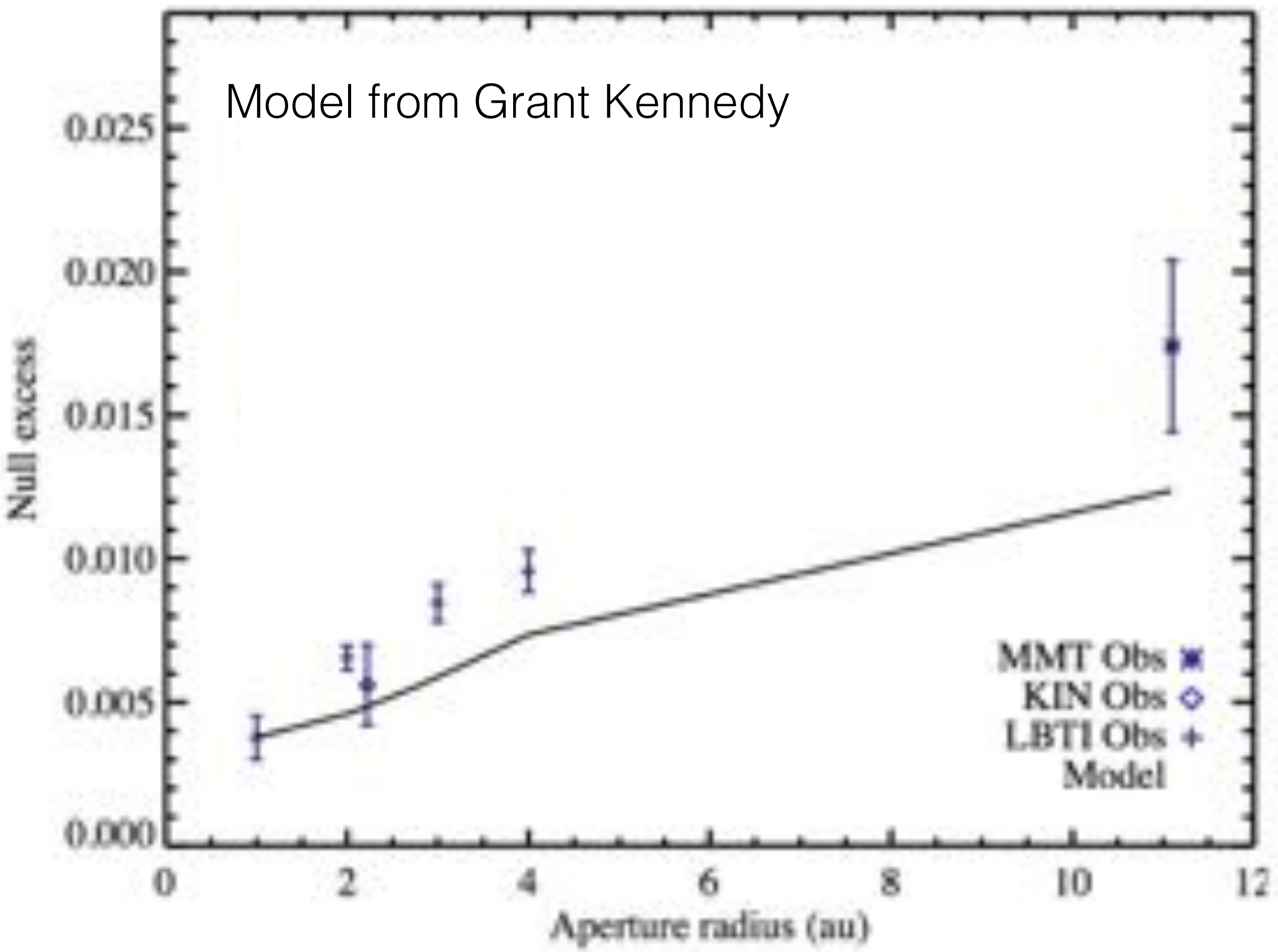
Limits to planets around beta Leo



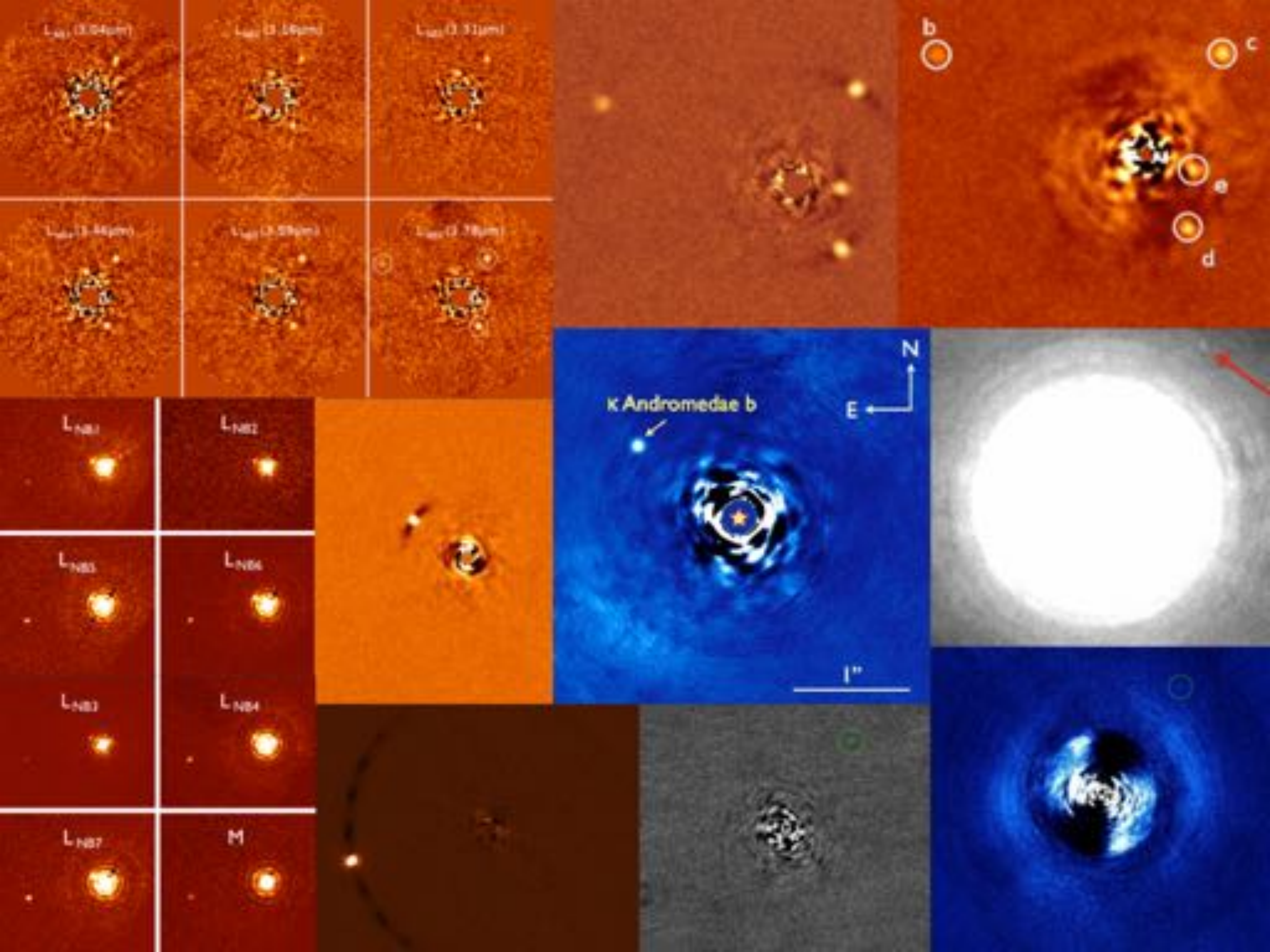
no planet detected down to ~2 M_J

The beta Leo planetary system

- Warm dust can be predicted from a parent body belt using analytic models (Wyatt et al. 2005, Kennedy and Piette 2015)
- P-R drag from this reservoir appears to be consistent with the warm emission



Combined, the data are all consistent with a single parent body belt at 40 AU, creating **both** the warm and cold dust, and **no giant planets** capable of clearing out the intervening material.



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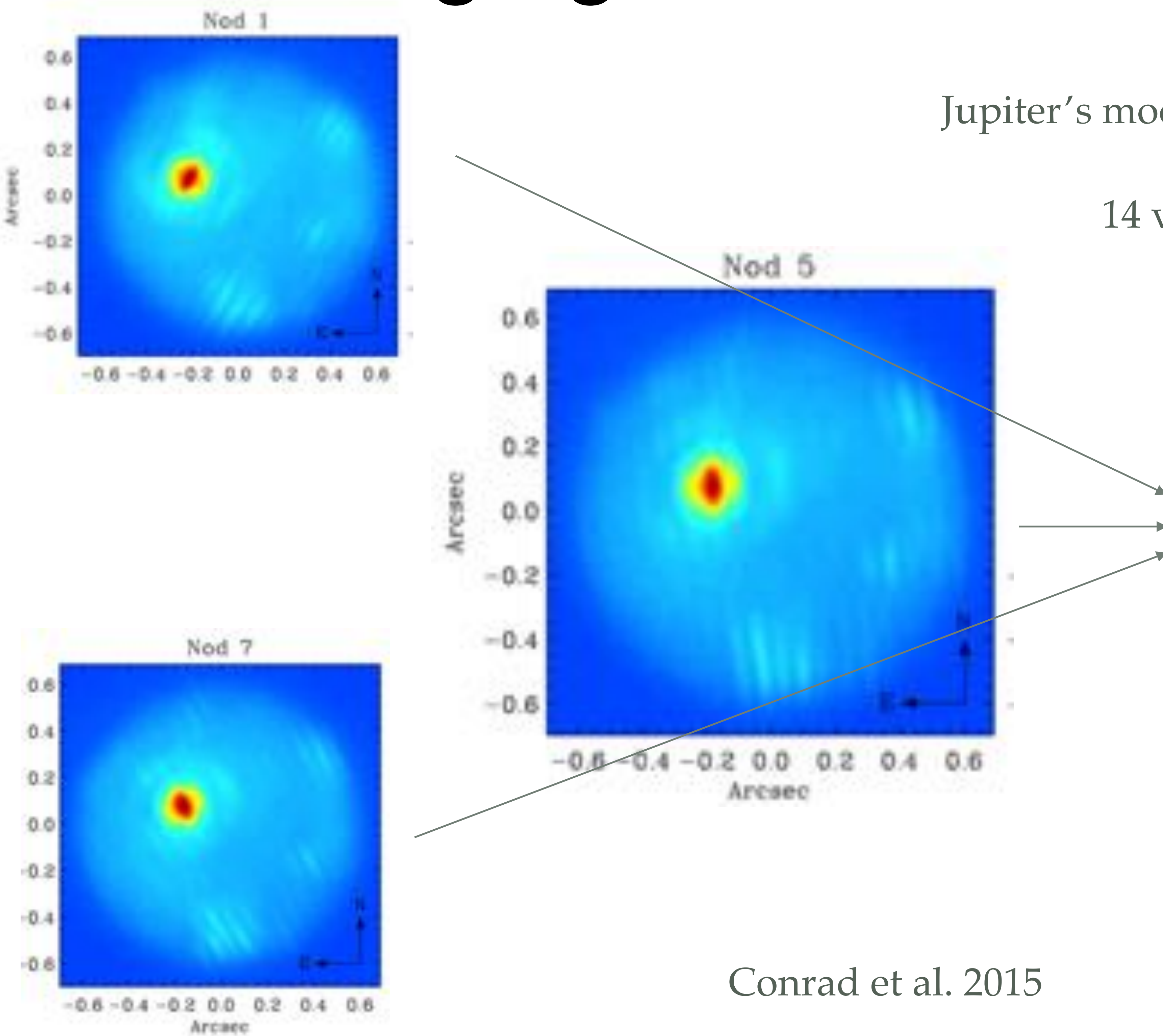
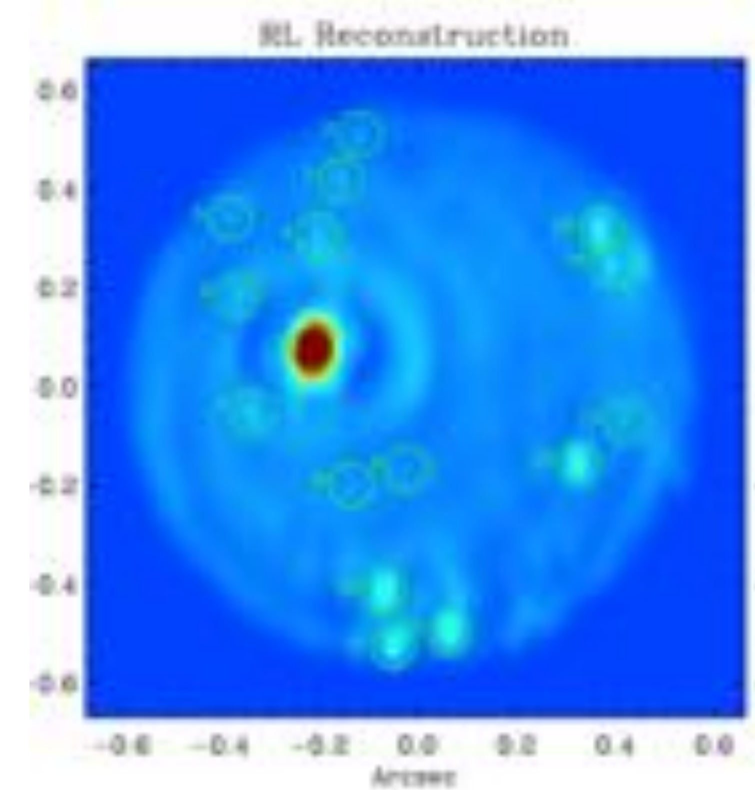
Other LBTI Capabilities: Imaging at 23 m resolution



Jupiter’s moon Io, at 4.7 μm wavelength

14 volcanoes resolved

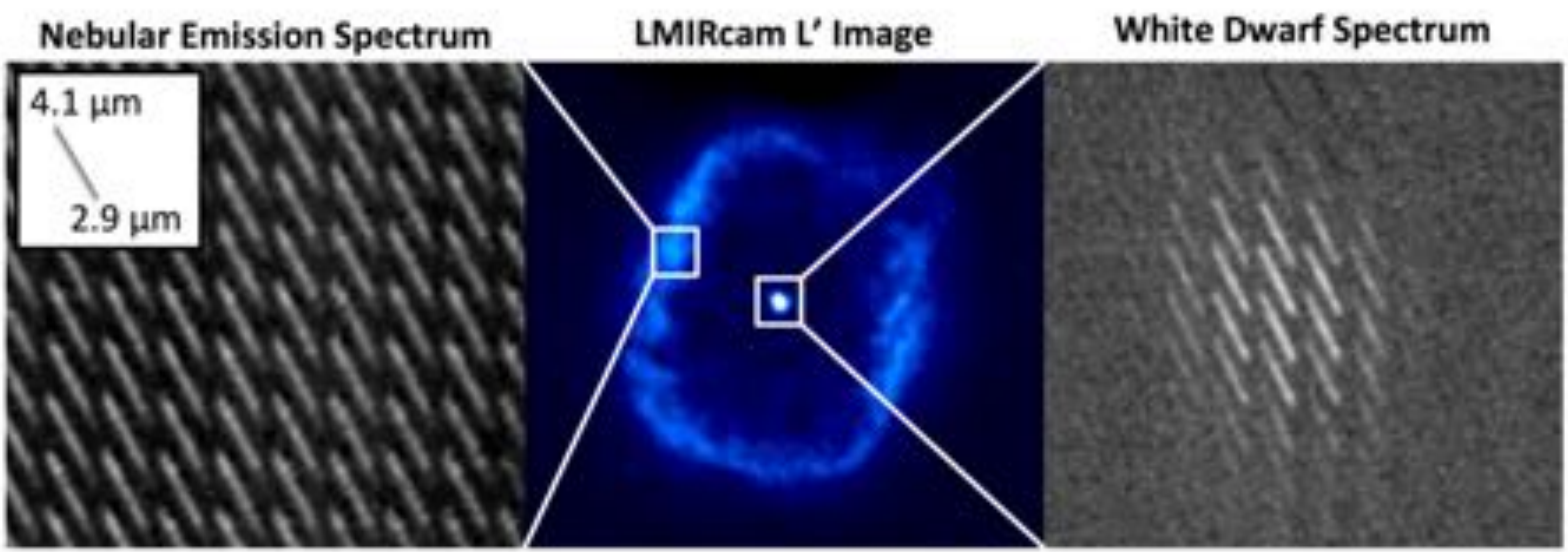


43 mas resolution on a complex structure

Conrad et al. 2015

Other LBTI Capabilities 2:
An IFU for exoplanets at 3-4 µm

- First tests of system carried out on June 1-3.
  - spaxels are 25 mas.
  - FOV is 1.3” (to be upgraded to 2.6”)



Summary

- The LBTI HOSTS survey for dust is beginning this fall.
    - Typical sensitivity is 11 zodies in the habitable zone.
- LBTI is observing nearby stars for giant planets with the LEECH Survey.
    - Typical sensitivity is 1-5 MJ at 5-20 AU.
- Results from these surveys will provide helpful context and input for future exo-Earth imaging missions.