Recent Progress and Results from LBTI

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Artist concept of Kepler-16b
Credit: NASA/JPL-Caltech/T. Pyle

Talk Outline

- Motivation
- Measurement Technique
- Survey Status
- Preliminary Results

Motivation

Zodiacal Dust in the Solar System

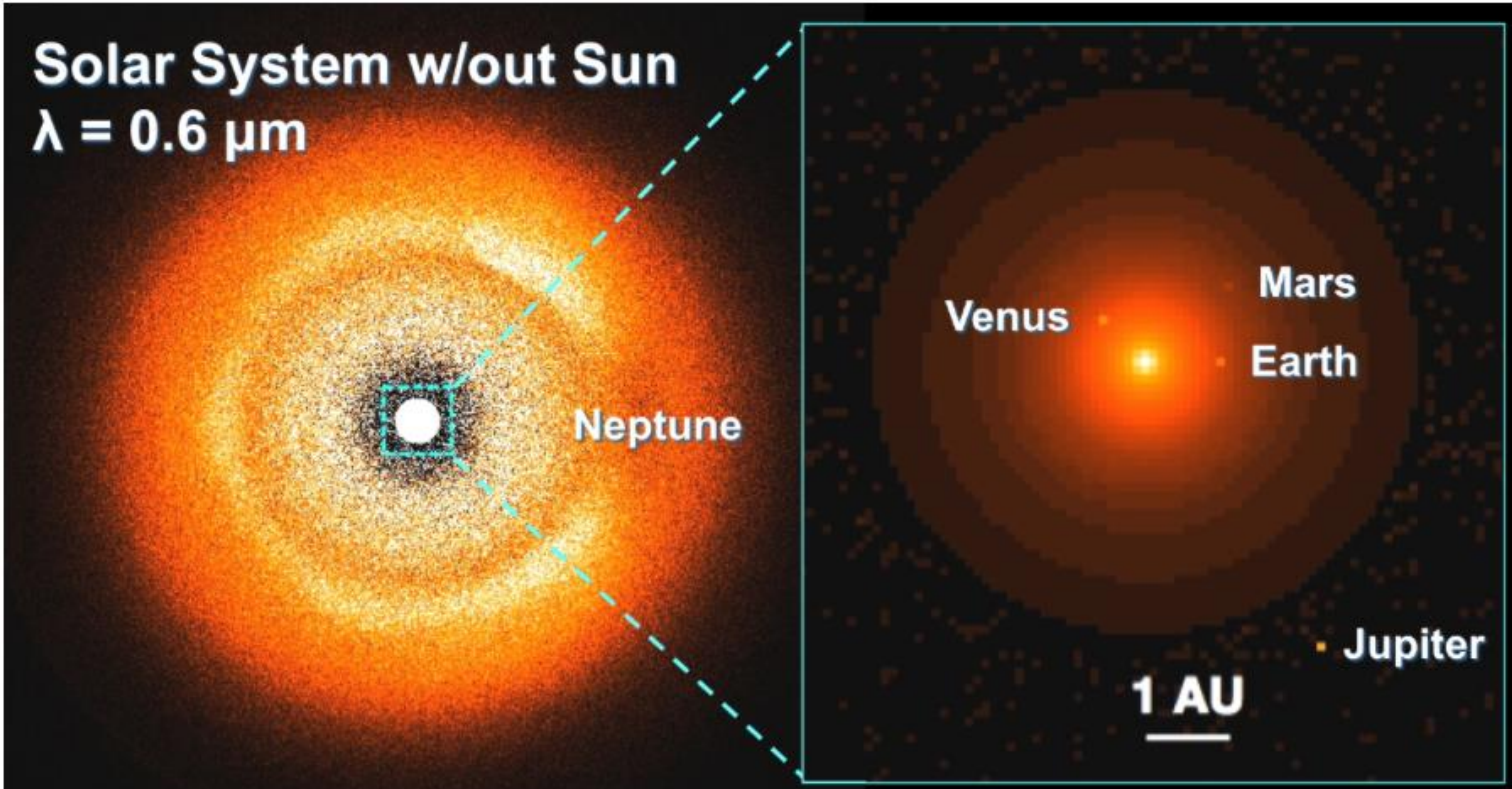
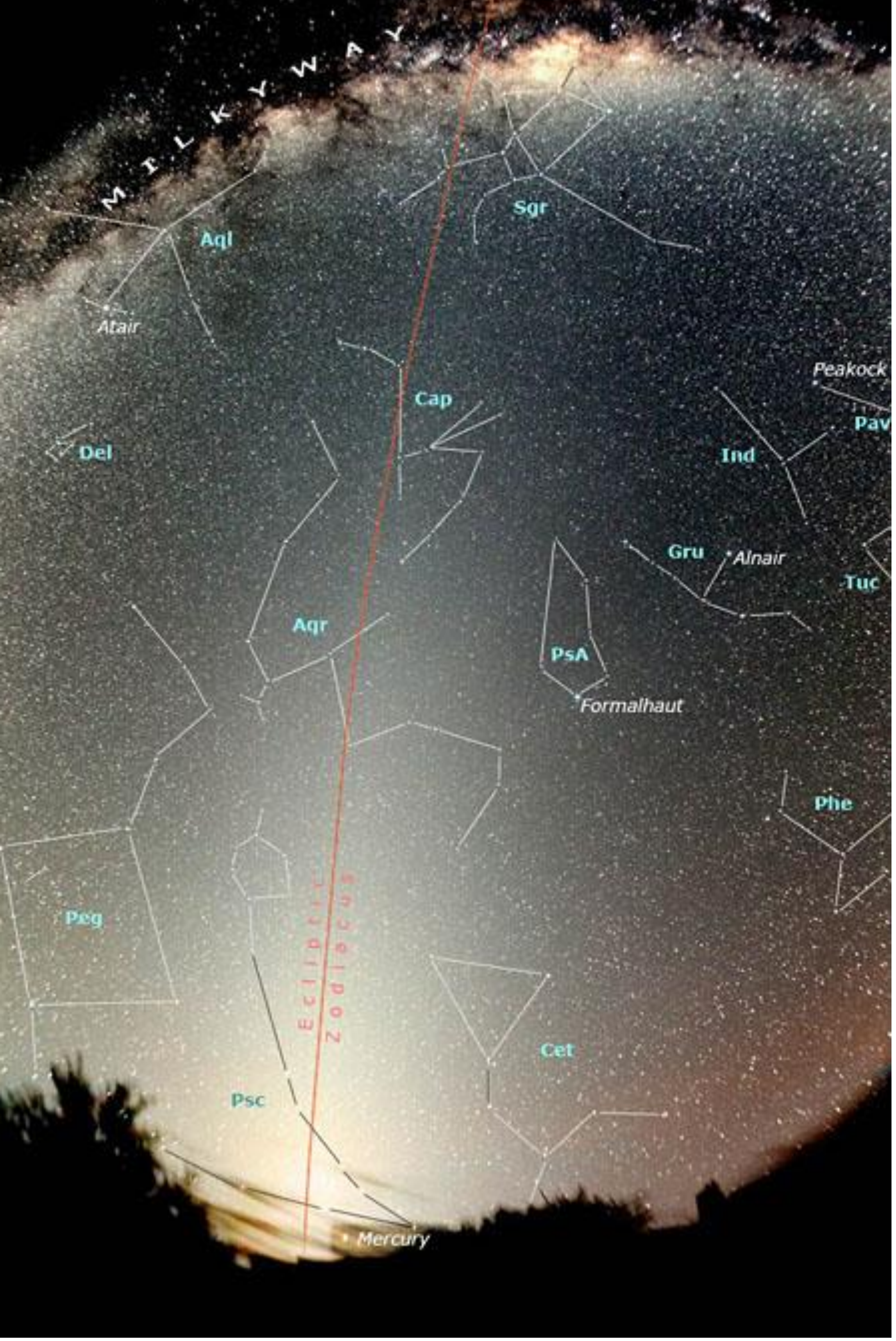
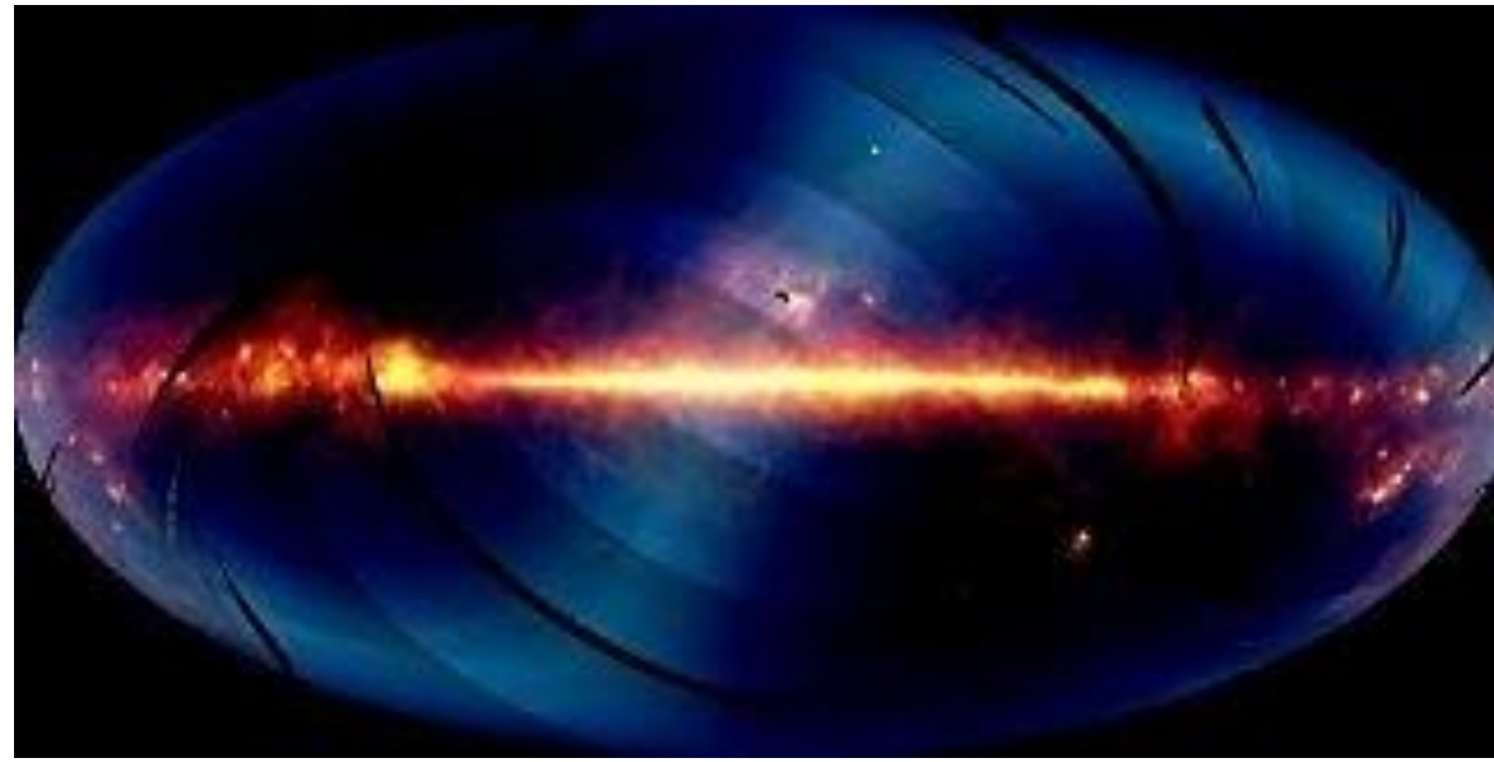
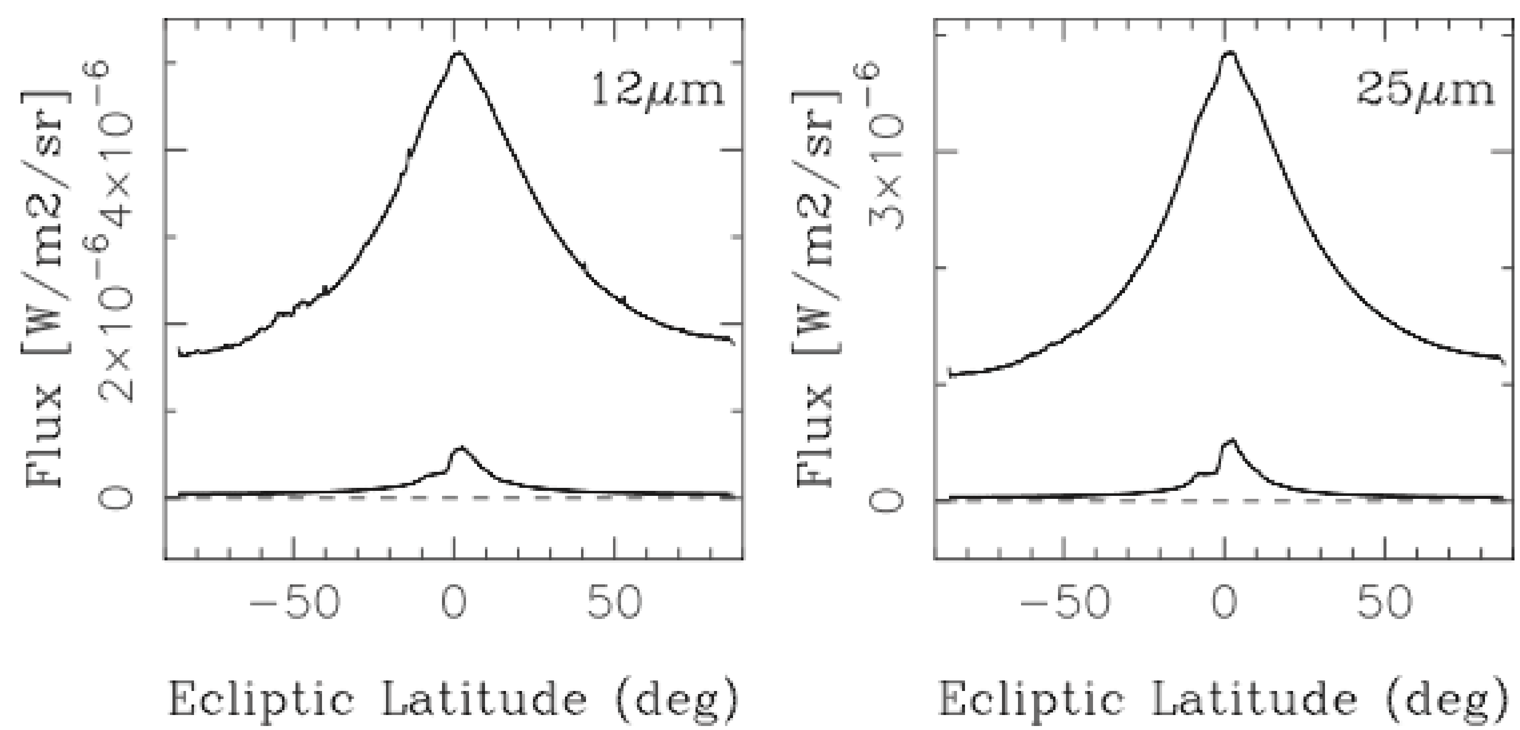


Image credit: M. Rizzo / A. Roberge

Zodiacal Dust







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

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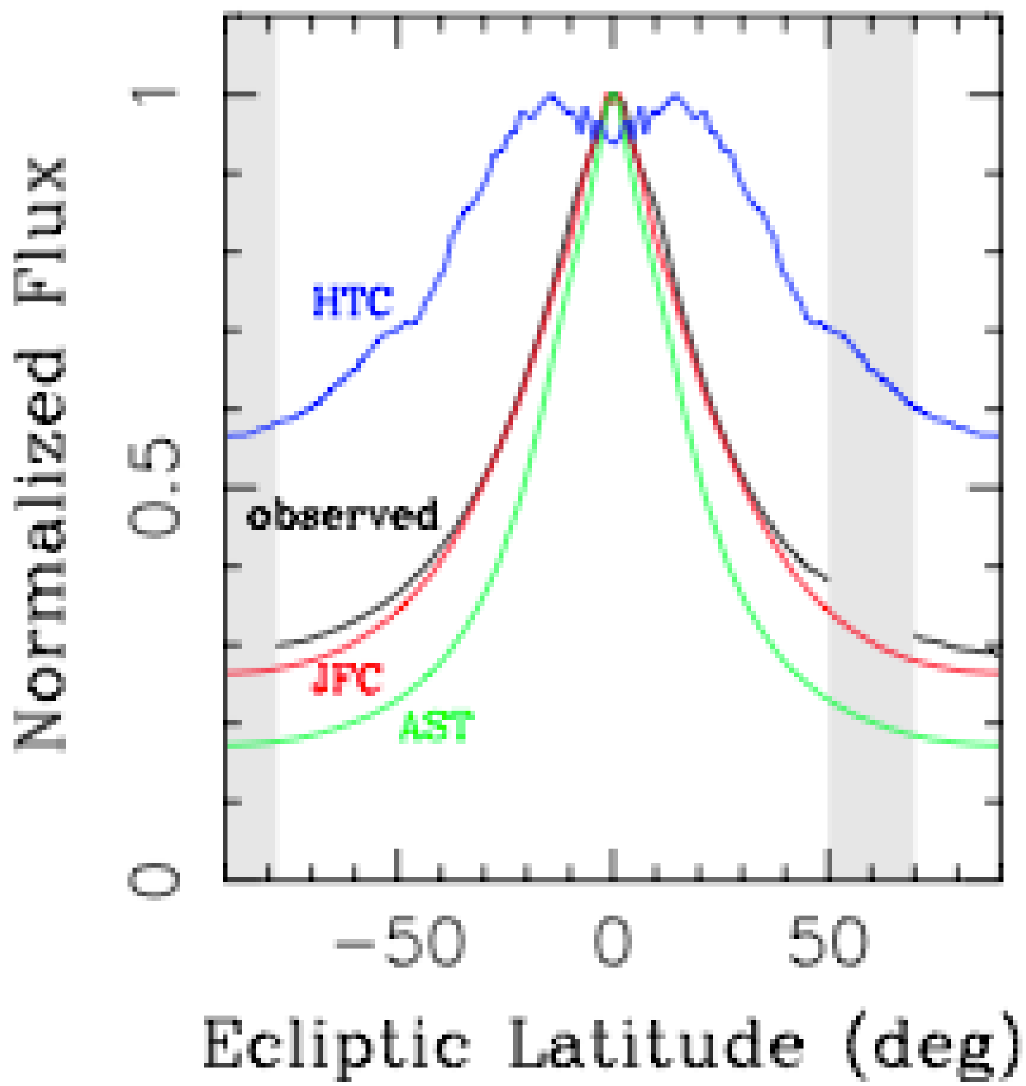
from Nesvorney et al. 2010

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.

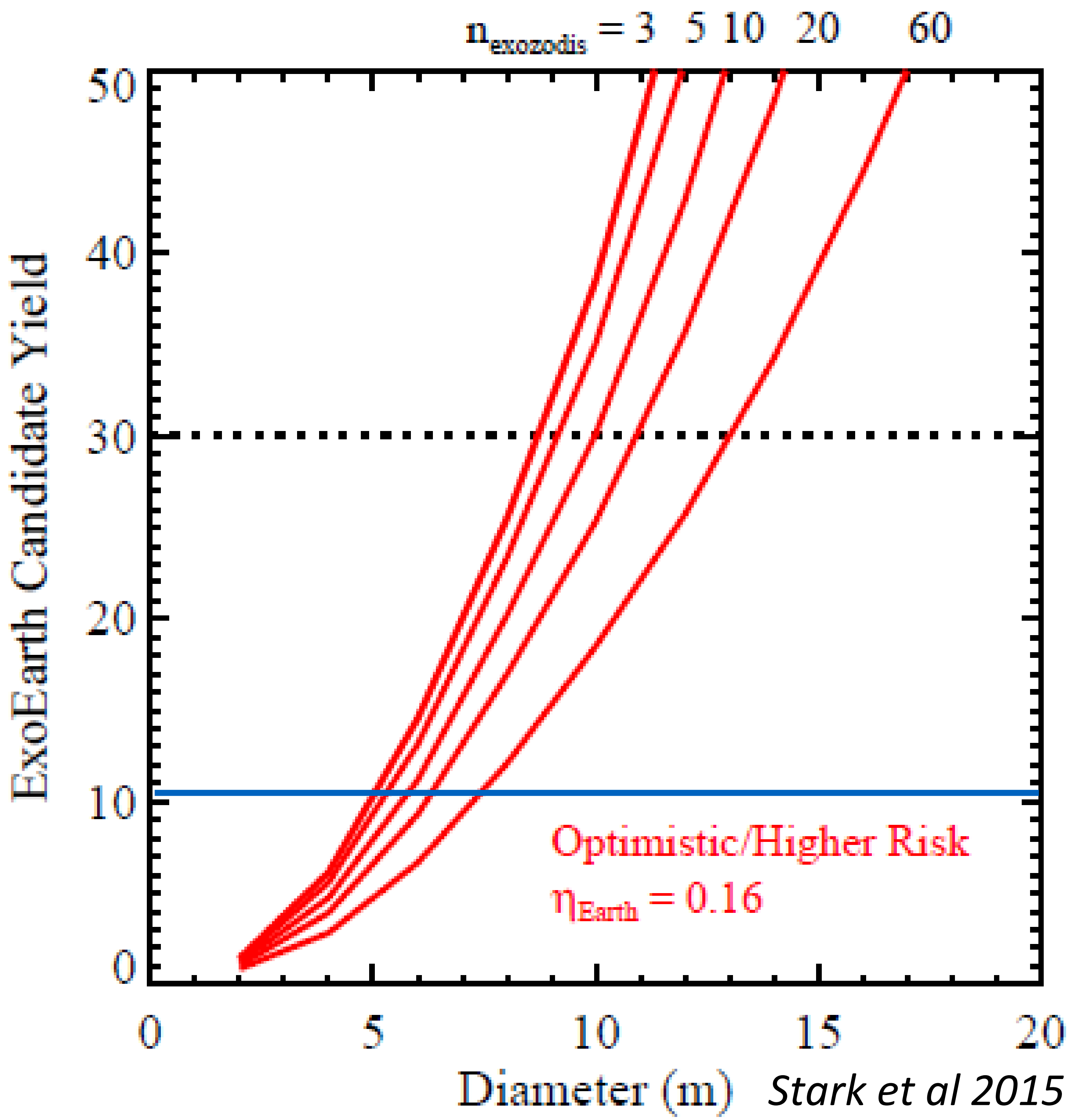


from Nesvorney et al. 2010

Exozodi Affects Exoplanet Yield

- Telescope aperture and exozodi level affect exoplanet yield.
- Exozodi is particularly important for small telescopes, especially when confusion taken into account.

Telescope Size (m) for Given Yield and ExoZodi		
Exoplanet Yield	EZ=5	EZ=60
10 Earths	5 m	8 m
30 Earths	9 m	13 m



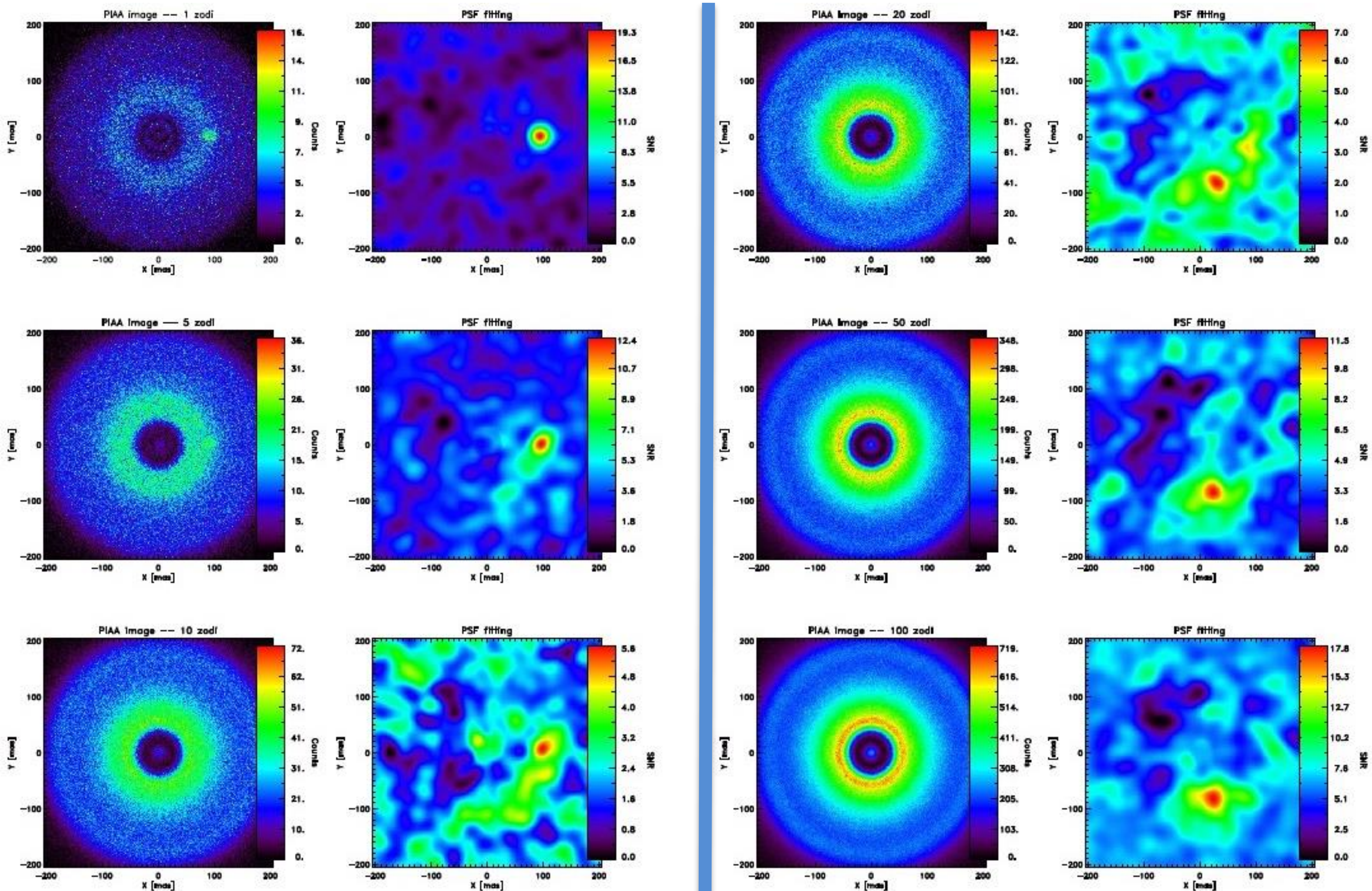
Stark et al 2015

Exozodi Clumps Can Create False Positives

1 zodi

5 zodi

10 zodi



20 zodi

50 zodi

100 zodi

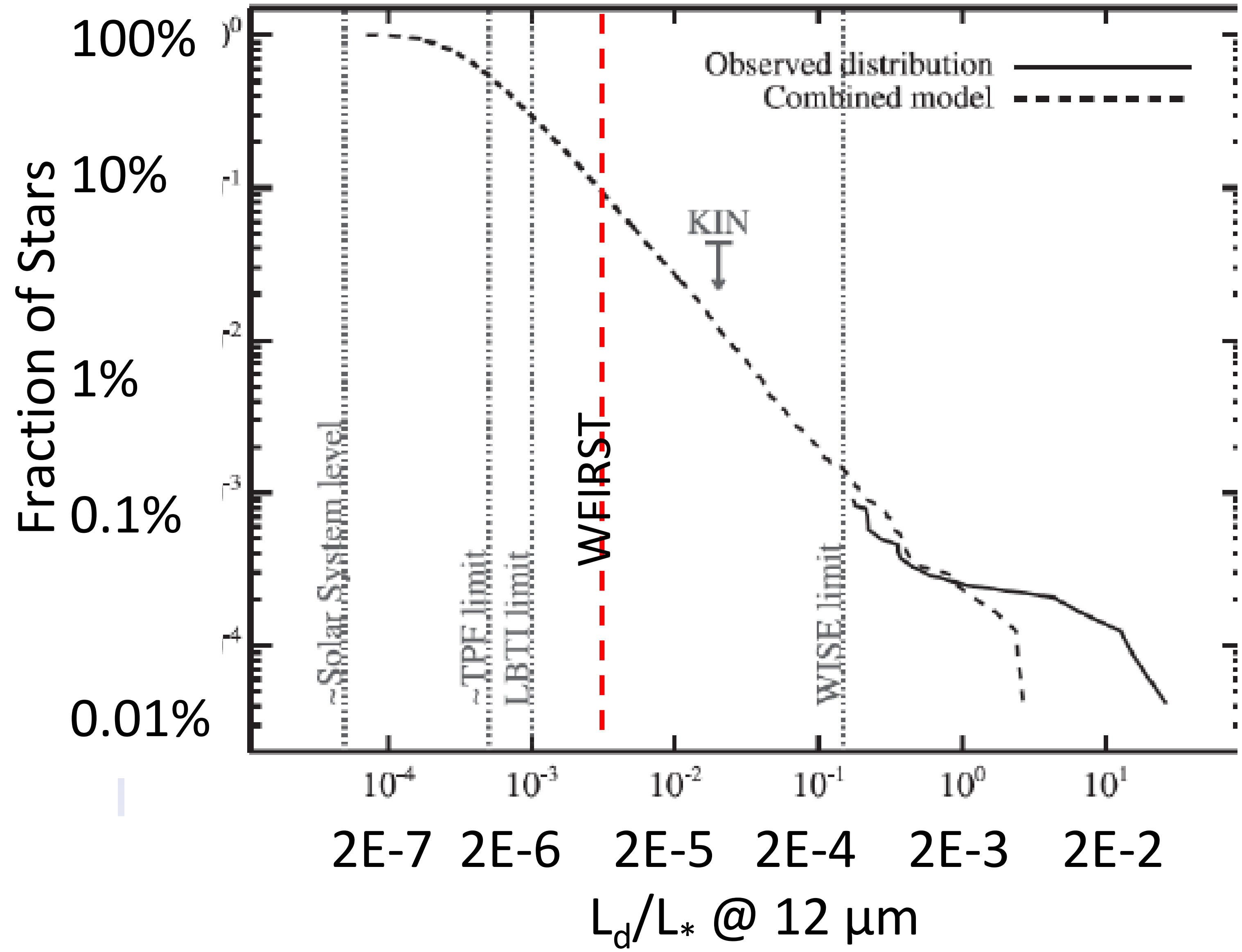
Figure 3. Images produced by the PIAA coronagraph and corresponding result of the PSF fitting for a Sun-Earth system located at 10 pc and surrounded by an exozodiacal cloud of various densities (left column: 1, 5, and 10 zodis; right column: 20, 50, and 10(

If exozodi >20x Solar System level, resonant dust ring structures could be confused for an exo-Earth at 1 AU (Defrere *et al.* 2012)

LBTI Must Determine Exozodi Luminosity Function

Wyatt 2014, Wyatt and Kennedy 2013

- To demonstrate that EZ is manageable part of noise budget, LBTI must observe enough stars to determine exozodi luminosity function to ~10 Zodi level

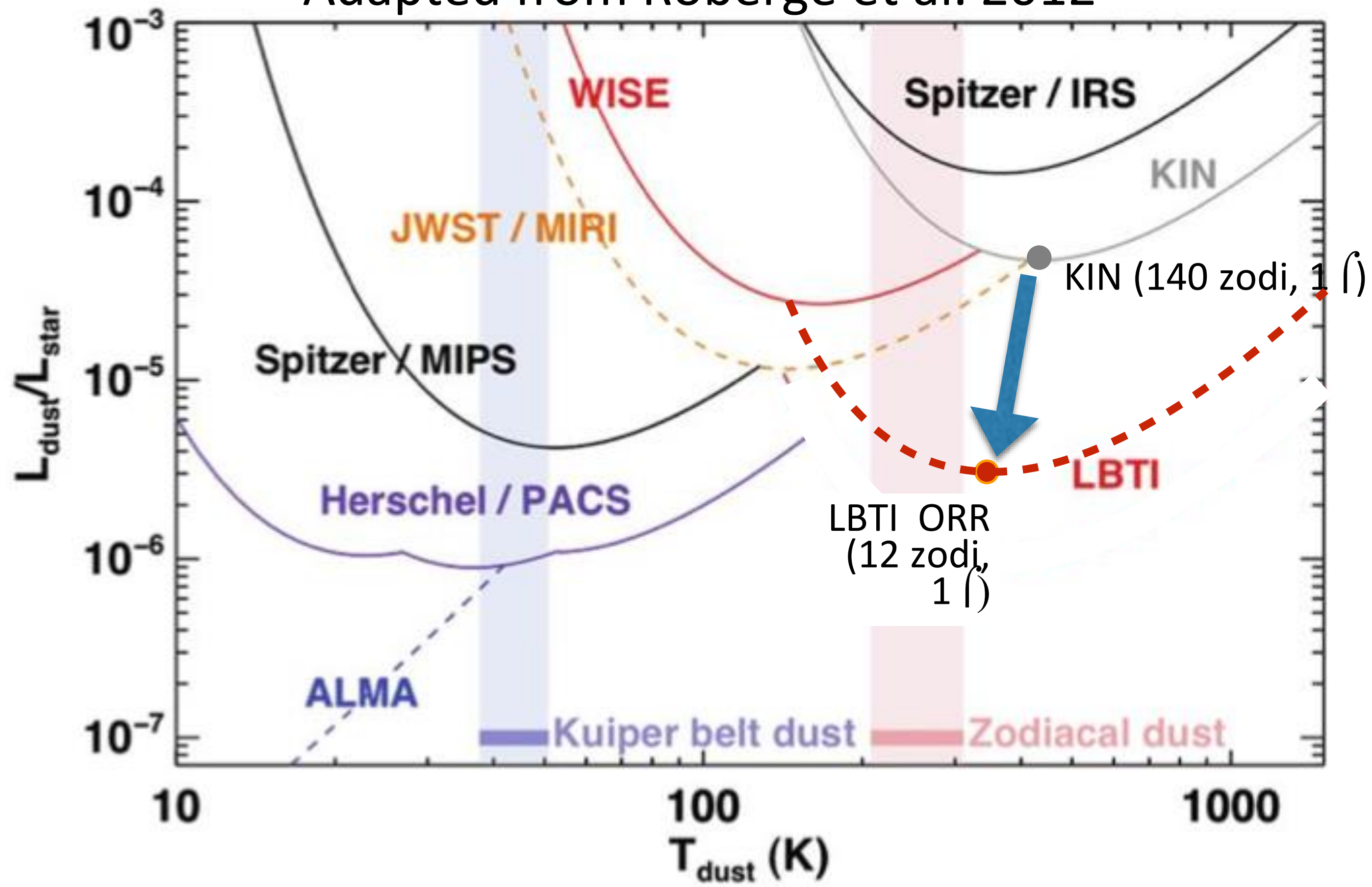


- A NASA review concluded that a 35 star survey is the minimum needed to provide the necessary data

State of the Art – Keck Nuller

- Surveyed 20 stars and demonstrated 24 zodi, 1 σ uncertainty on median exo-zodi level
  - *Mennesson et al. 2014, ApJ, 797, 119*

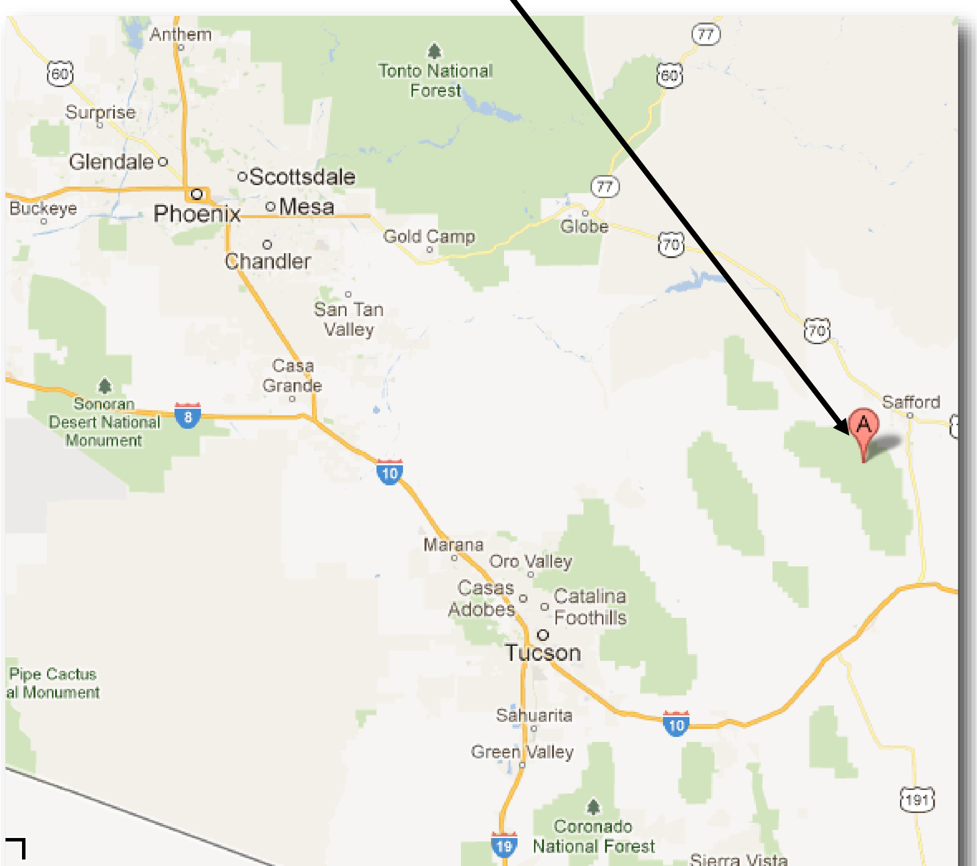
Adapted from Roberge et al. 2012



Performance is currently improved 12X over KIN.

Measurement Technique

LBTI and the HOSTS Survey



The Large Binocular Telescope Observatory

(**W**109°53′20.63″ **N**32°42′04.71″ 3221m MST=UT-7)

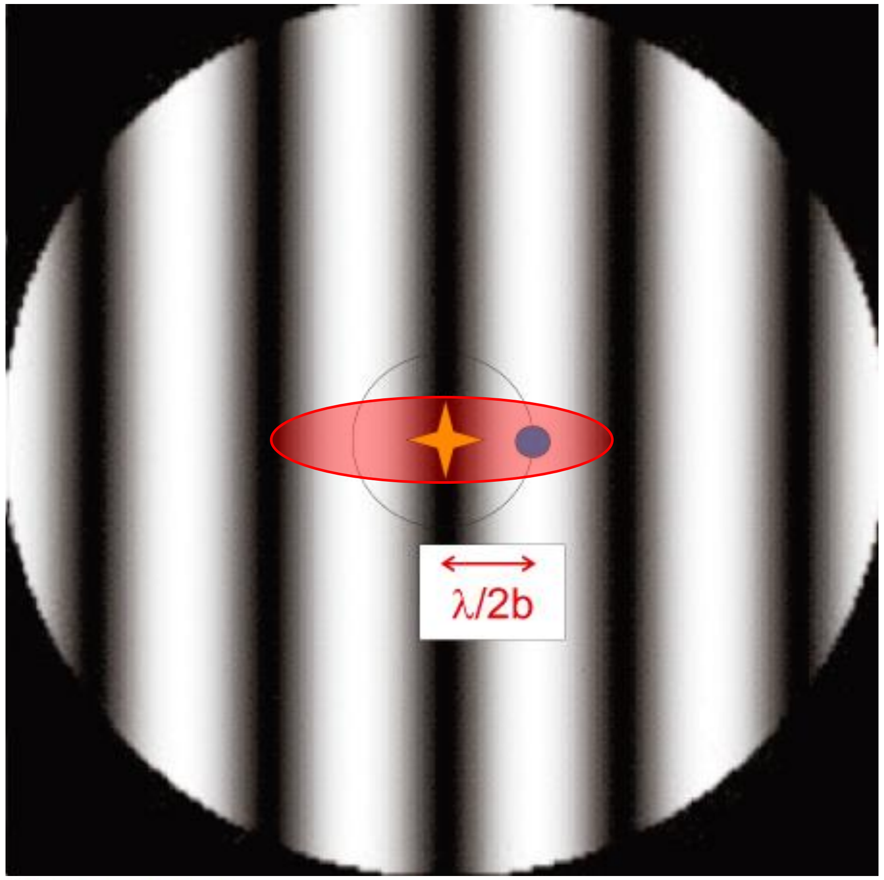
Mt. Graham International Observatory, Arizona

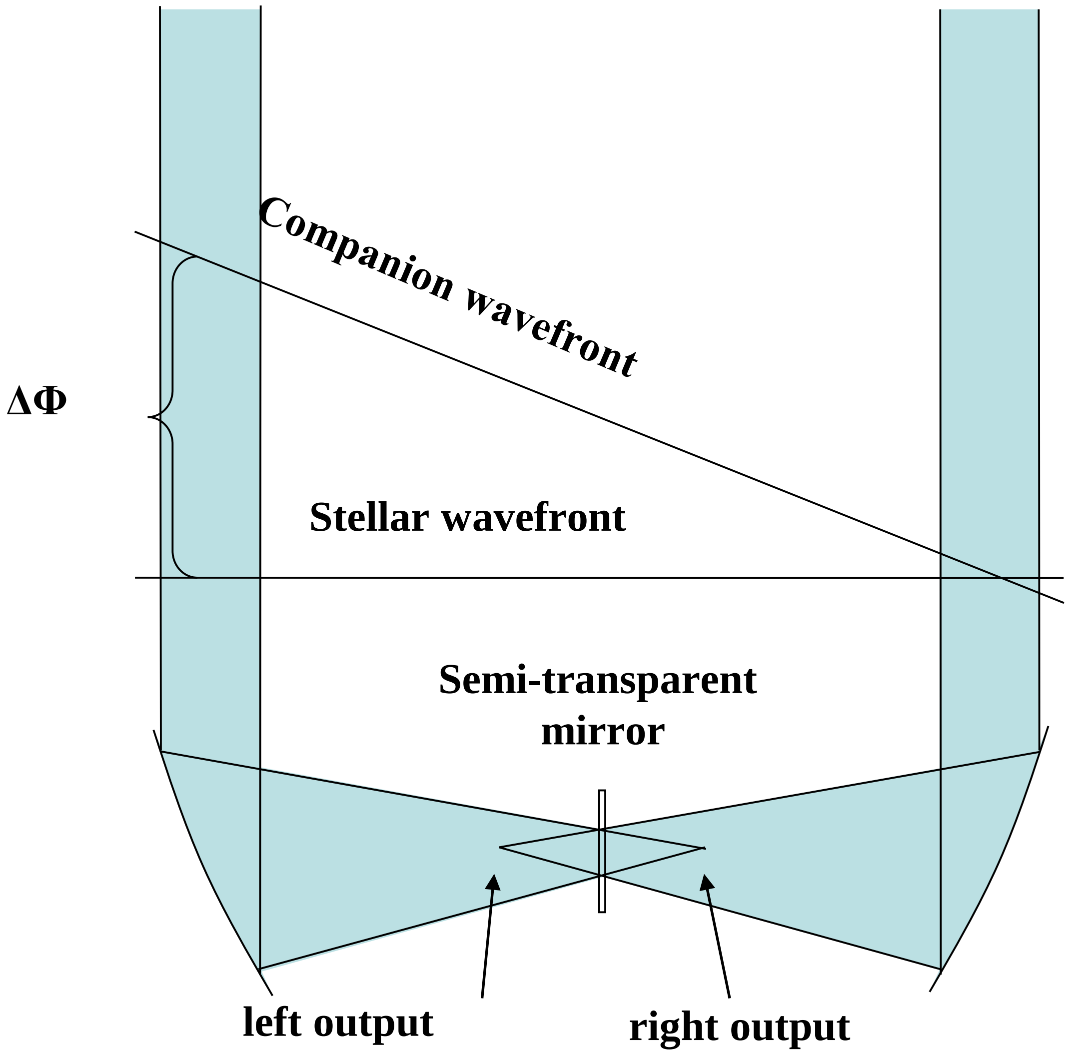
- LBTO is located on Mt. Graham in Arizona
- LBTI is a mid-infrared nulling interferometer
- Designed to carry out the Hunt for Observable Signatures of Terrestrial planetary Systems (HOSTS)

- Managed by Exoplanet Exploration Office at JPL
- Operated by University of Arizona
- Data archiving at NExScI

How Nulling Interferometry Works

- First proposed by Bracewell (1978) to directly detect “non-Solar” planets;
- Subtracts starlight by destructive interference;





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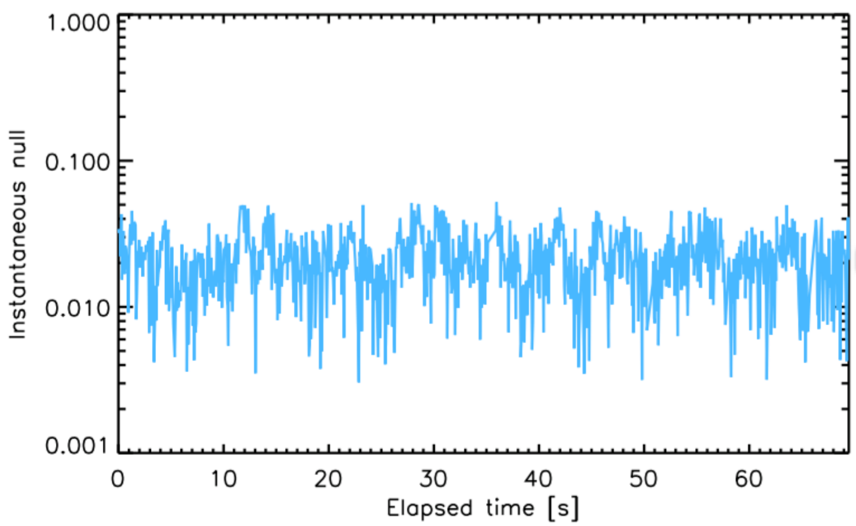
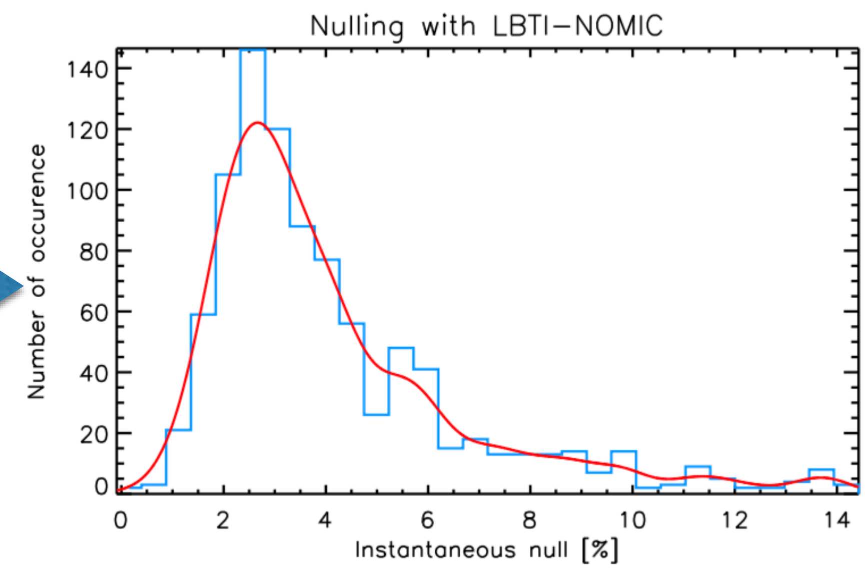
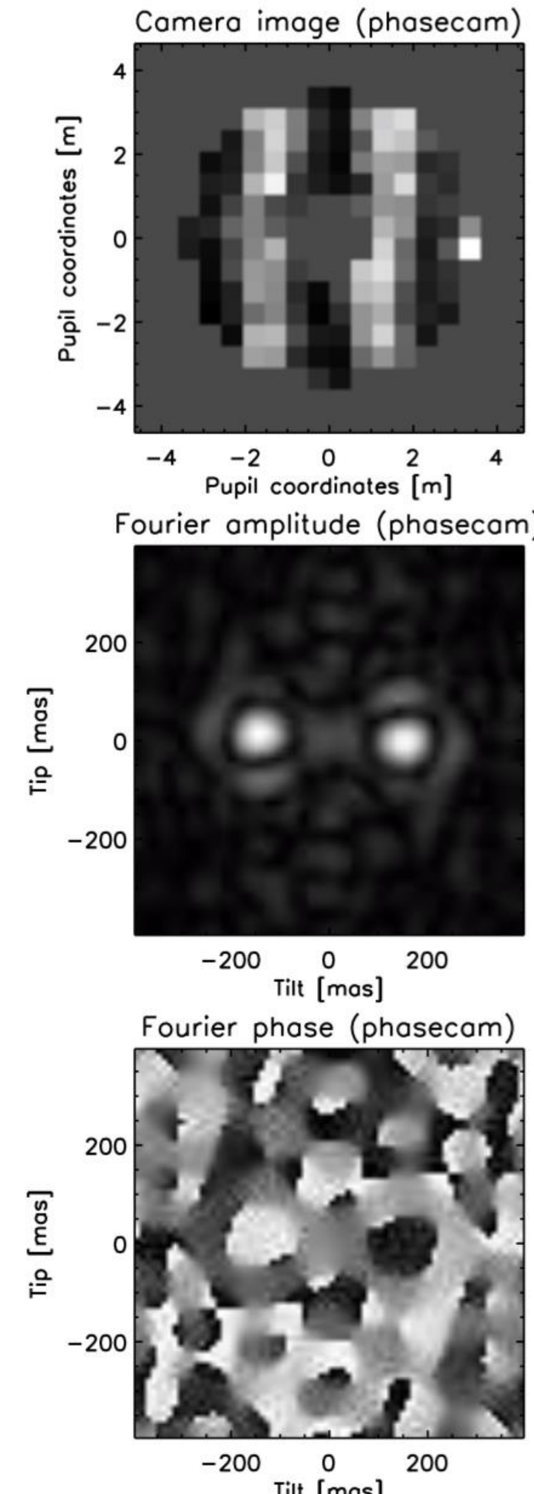
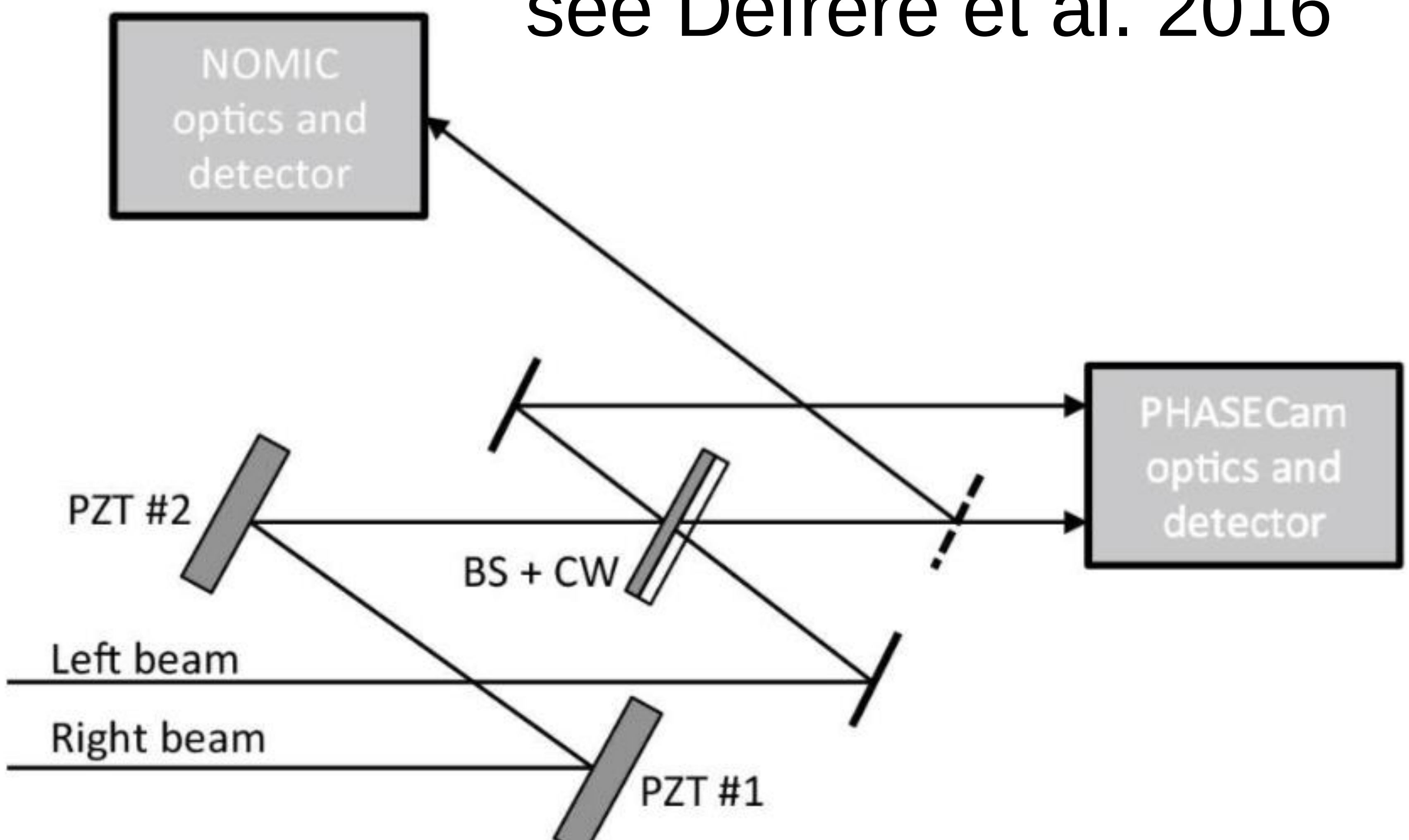
Nulling Implementation







see Defrere et al. 2016



Survey Status

How routine are the observations?

- A queue observing strategy was implemented starting in fall 2016.
  - Improved ability to obtain useful conditions.
  - Helped minimize impact of technical downtime in Winter 2016.
- Observing now routinely can obtain 3 stars per night.
- We can obtain good data on stars as faint as 1 Jy
  - This was the orignal survey brightness limit.
- Observations of stars at southerly declinations is a problem.

HOSTS Tally

- 13 stars observed in 2017 A
- 11 stars observed in 2016 B
- 2.3 stars previously observed

- Total HOSTS survey = 26.3 stars (75% complete)

A star is considered observed
after three calibrated data sets on it.

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HOSTS Progress

Target	UT Date	SpT					<==	before trans	after trans	==>				
1 Ori	2017-02-09	F6V					HD31421	SCI	SCI	HD31767				
107 Psc	2016-11-14	K1V						HD7087	SCI					
	2016-11-16						HD7318	SCI	SCI	HD6953				
23 UMa	2016-11-15	F0IV					HD86378	SCI						
	2017-02-11			HD73108	SCI	SCI	HD92424							
40 Leo	2017-02-09	F6IV			HD89024	SCI	SCI	HD93257						
alf Cep	2016-10-16	A7IV								HD198149	SCI	???	Unclear log, one more SCI-CAL	
bet Eri	2017-02-10	A3III						HD36780	SCI	SCI	HD31767	Just one nod pair on second CAL, was setting rapidly		
bet Uma	2017-04-03	A0			HD86378	SCI	SCI	HD94247	SCI	SCI	HD95212			
del Crv	2017-02-10	A0IV			HD114113	SCI	SCI	HD111500						
del Leo	2017-02-10	A4V		HD94336	SCI	SCI	HD99902							
	2017-05-12								HD99196	SCI	SCI	HD98262		
del UMa	2017-02-09	A3V					HD107465	SCI	SCI	HD102328				
	2017-05-21								HD101673	SCI	SCI	HD113092		
gam Ser	2017-04-06	F6IV				HD149009	SCI	SCI	HD142574					
	2017-05-21						HD141992	SCI	SCI	HD145892				
gam UMa	2017-04-06	A0V					HD94247	SCI	SCI	HD95212				
	2017-05-01									HD102224	SCI	SCI	HD107274	
GJ 380	2017-04-06	K8V				HD86378	SCI	SCI	HD95212					
GJ 105A	2016-11-15	K3V					HD21051	SCI	HD13596					
ksi Gem	2016-11-14	F5IV					HD49968	SCI	SCI	HD48433	HD 52960			
	2016-11-15				HD52960	SCI								
ksi Peg A	2016-11-14	F7V						HD218792	SCI					
	2016-11-16						HD209167	SCI	SCI	HD220009				
lam Aur	2017-01-29	G1V								HD38656	SCI	SCI	HD40441	
mu Vir	2017-02-10	F2V		HD131477	SCI	SCI	HD133165	SCI	HD130952					
sig Boo	2017-04-03	F2V					HD133392	SCI						
	2017-04-06				HD126597	SCI	SCI	HD129972						
tet Boo	2017-02-09	F7V					HD128902	SCI	SCI	HD128000	data quality to be checked for last CAL			
	2017-04-11						HD128902	SCI	SCI	HD138265				
Vega	2016-04-18	A0V						HD163770	SCI	only one SCI nod pair taken				
	2017-04-06				HD164646	SCI	SCI	HD163770	only two nod pairs on the last cal					
110 Her	2017-04-08	F6V			HD170951	SCI	SCI	HD176527						
chi Her	2017-04-11	F8V							HD137704	SCI	SCI	HD144204	SCI	HD137704
lam Ser	2017-05-01	G0IV-V						HD145892	SCI	SCI	HD145085			
sig Dra	2017-05-01	G9V			HD191277	SCI	SCI	HD170693						
tau Boo	2017-05-12	F6IV							HD114326	SCI	SCI	HD125560		
alf Aql	2017-05-12	A7V	HD184406	SCI	SCI	HD189695	HD192107	SCI						

finished
decision pending
to be repeated

Sample:
Sun like
sensitivity

- 29 total stars observed with some data
- 14 early type stars (<F5)
- 15 solar type stars (F6 – K8)

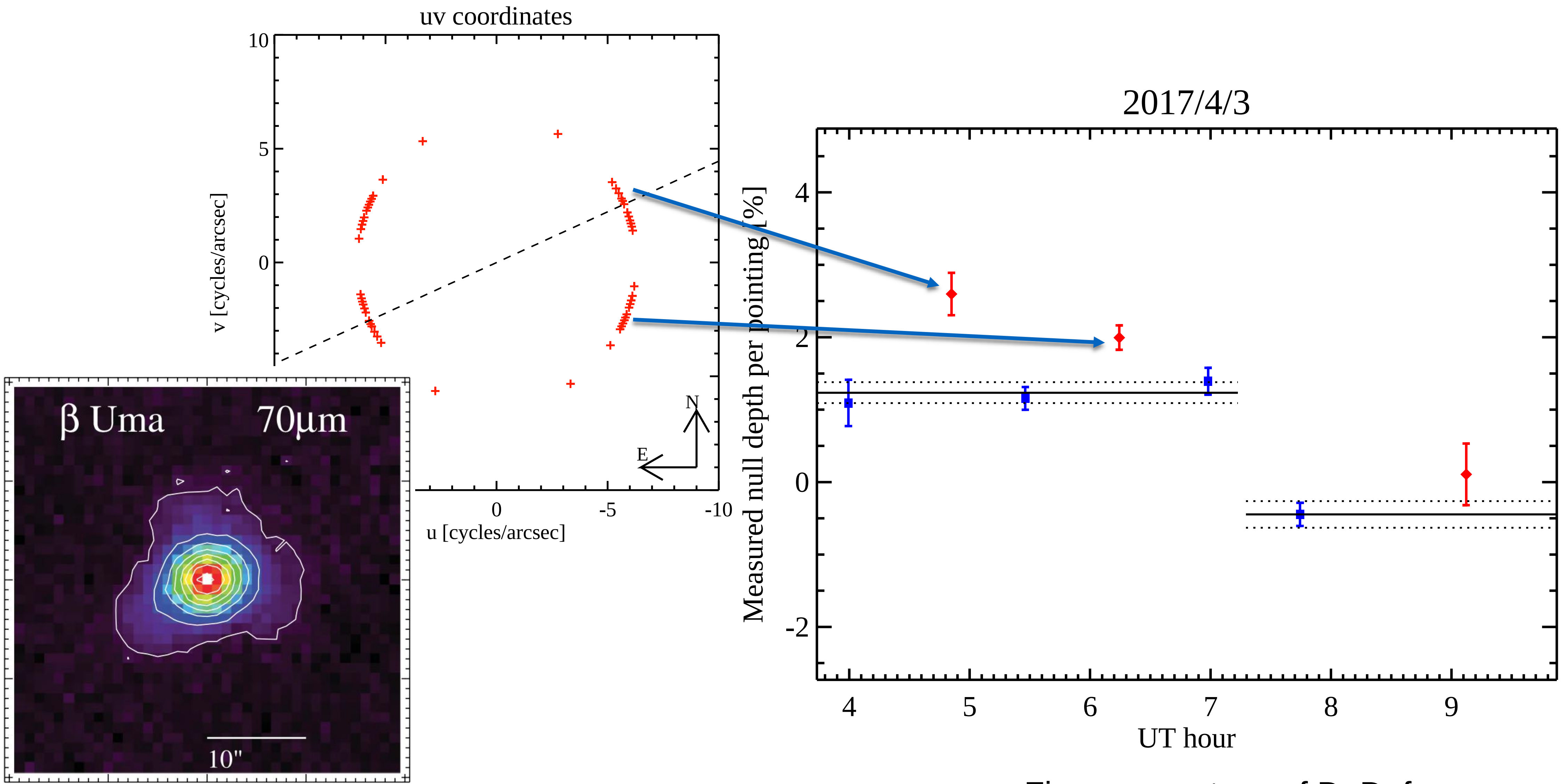
Preliminary Results

Caveats:
(Why I shouldn't be showing you these results)

- Only about ¾ of total data has been analyzed to-date.
  - Some requires additional pre-conditioning
  - Our last observing block ended May 22 – this set is not included.
- Conservatively large aperture was used to measure the null:
  - Increases noise but ensures all flux is measured.
  - More recent pipeline comparisons suggest a significant improvement can be achieved via smaller apertures without losing flux.

Example Results (1)

- Beta UMa warm dust detected.
  - Preliminary indication that more excess is detected along major axis of cold disk seen by Herschel.

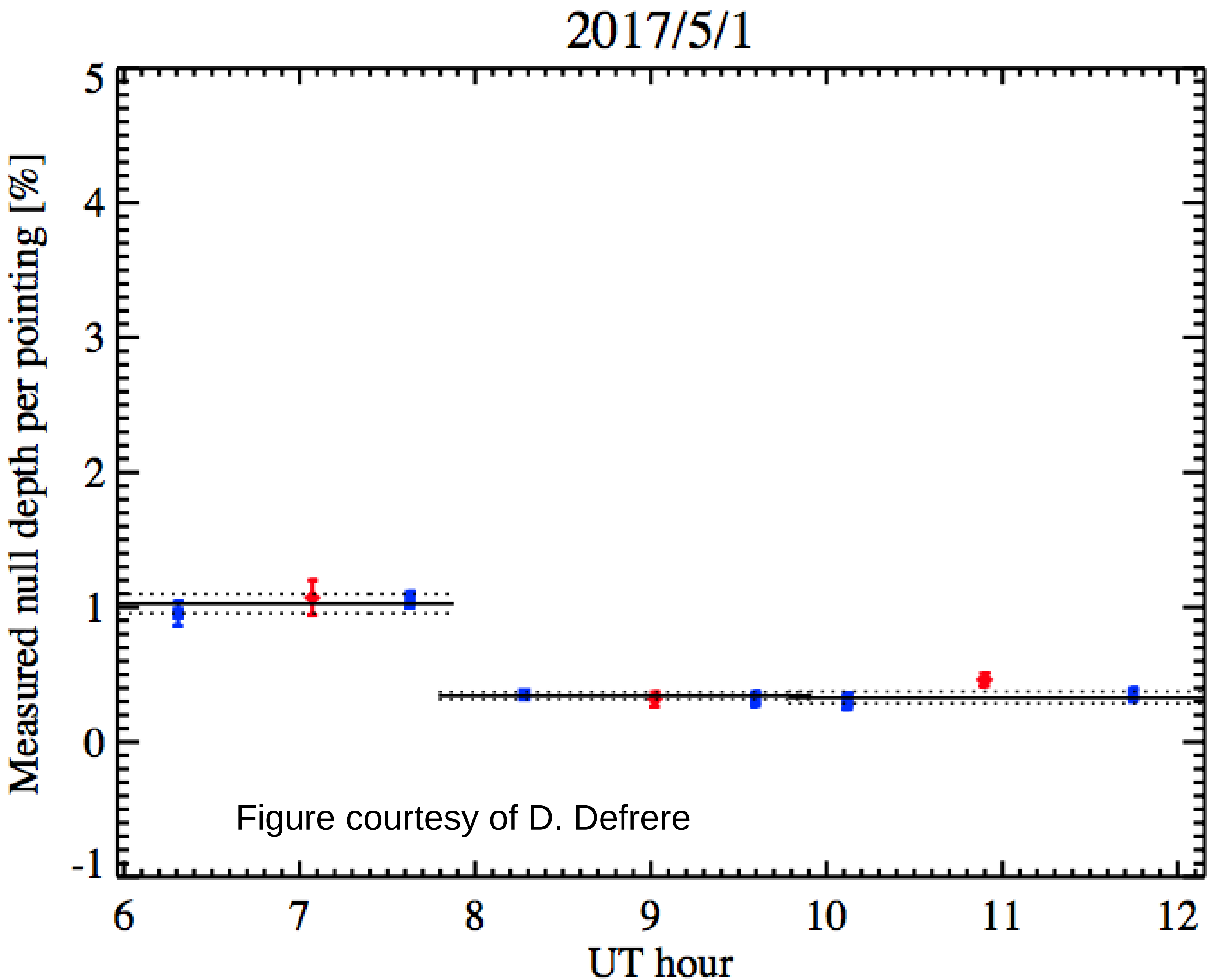


Figures courtesy of D. Defrere

From Booth et al. (2014).
Incl=84 deg, PA=114

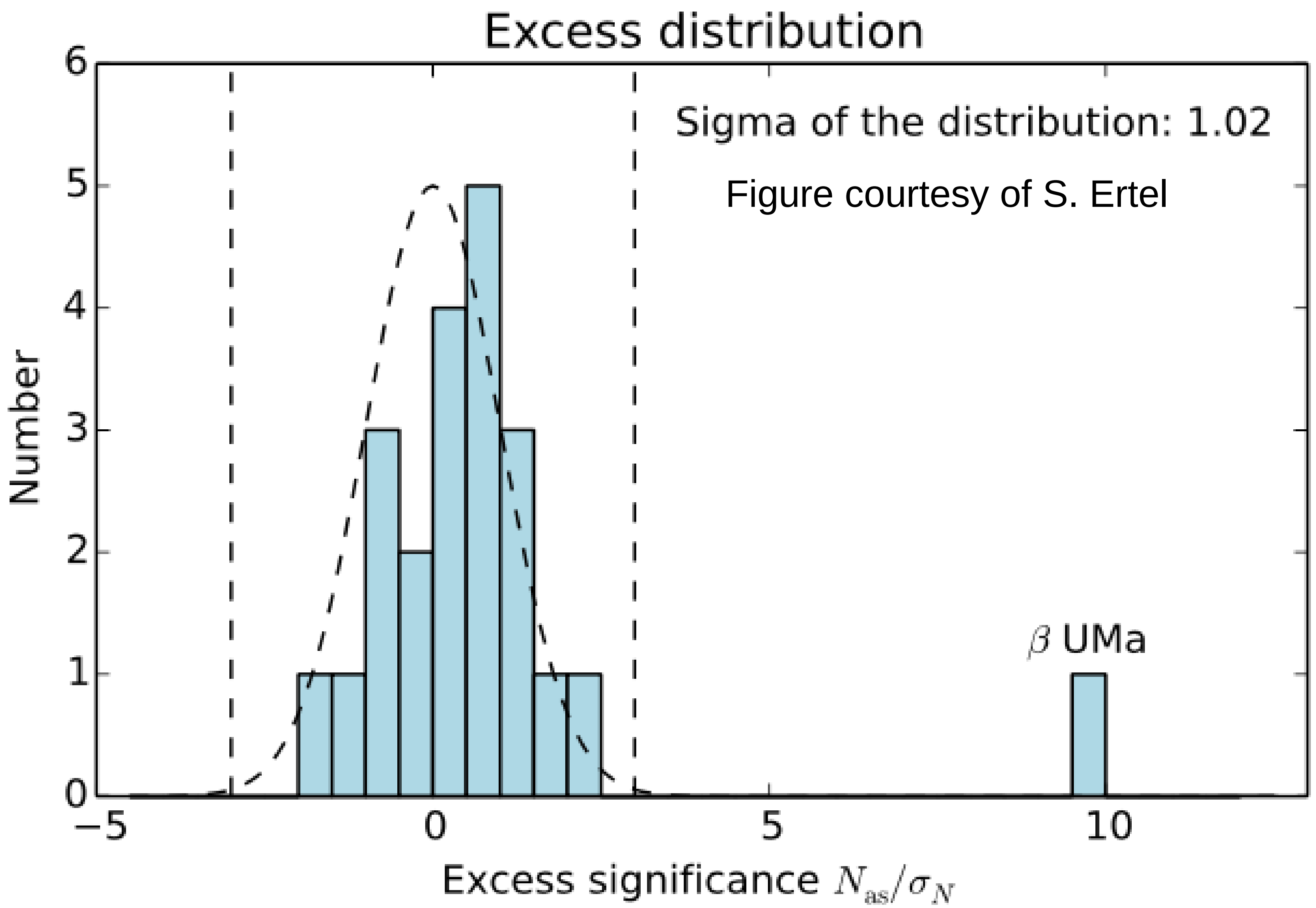
Example Results (2)

- Most measurements are consistent with a non-detection of dust.

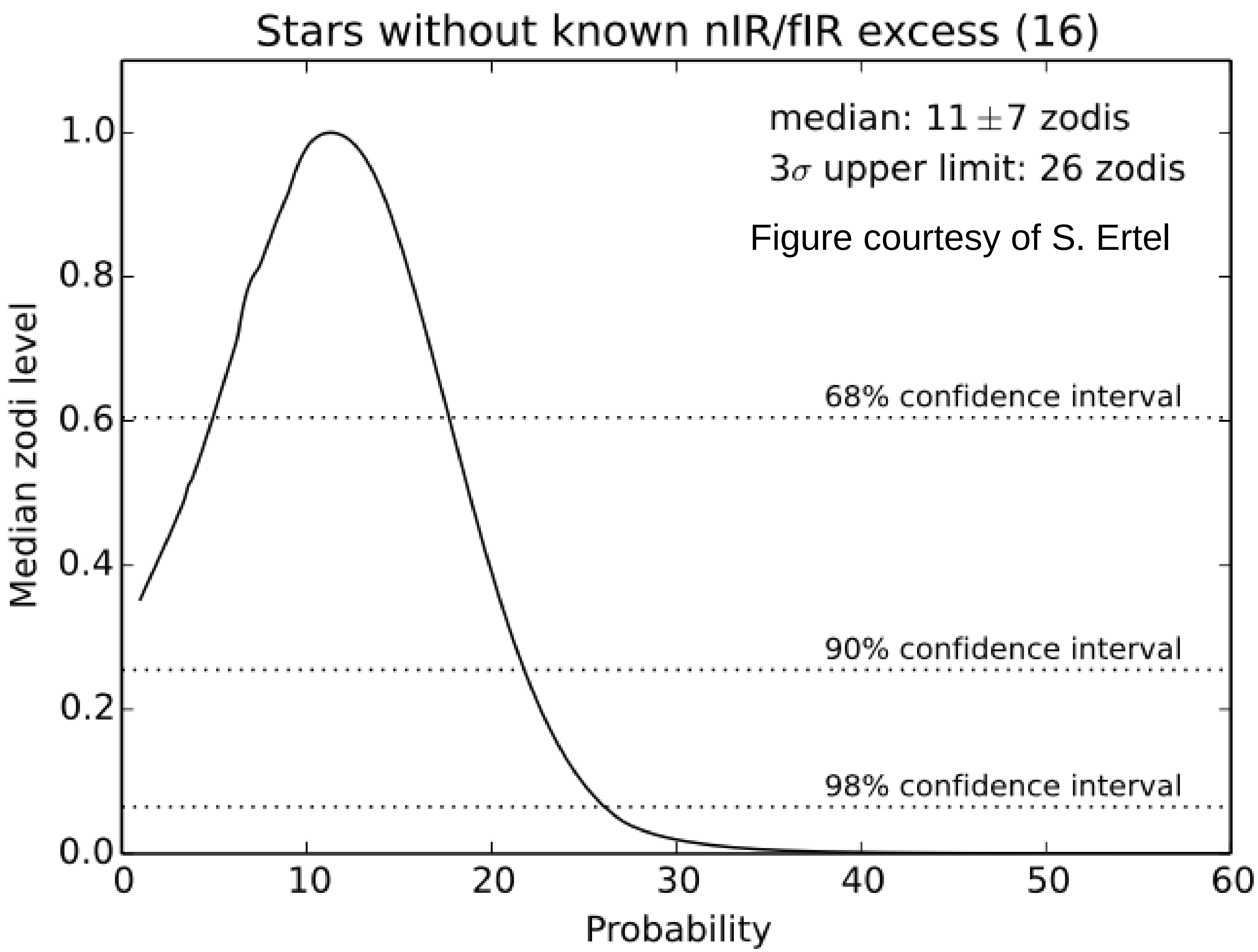


Distribution of Measurements

- Excess Flux Signal/Uncertainty level for
  - subset of 22 stars.
  - Preliminary analysis.



Constraint on Exozodi Luminosity Function



Assumed Distribution: Log-Normal

- Median dust level does not appear to be a show stopper for imaging missions.
- Is the median zodi level non-zero?

Summary

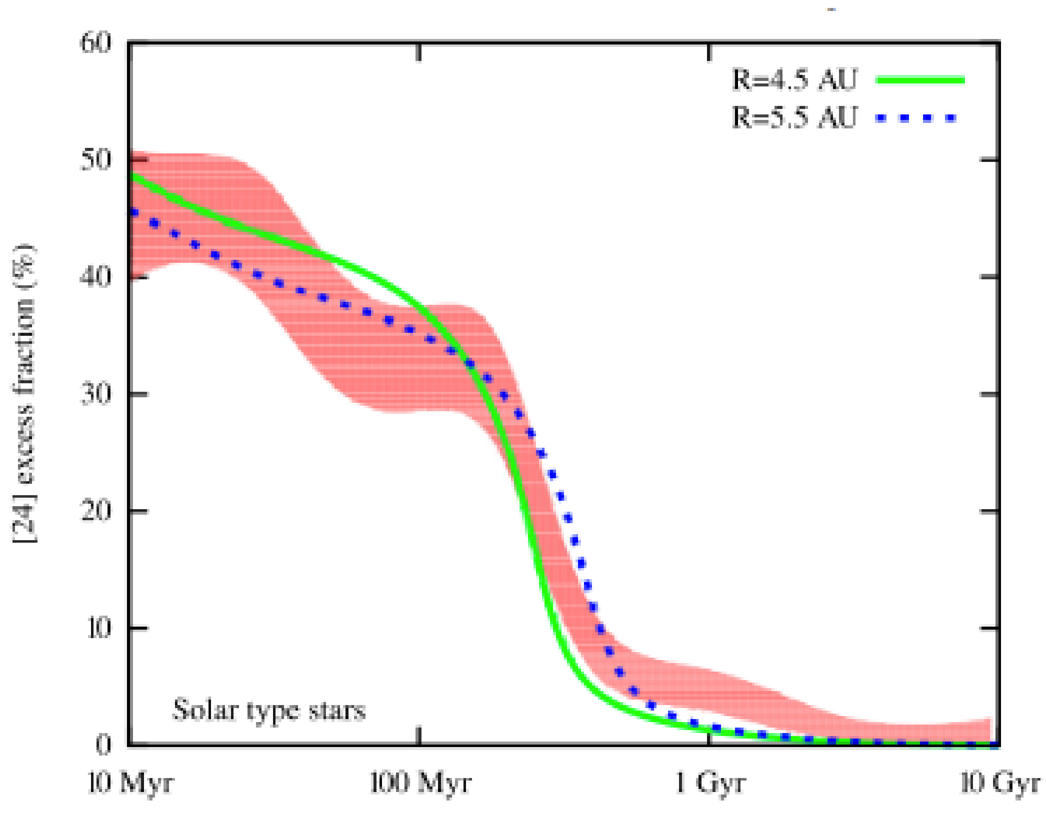
- The HOSTS survey made good progress in 2016-2017.
  - 26 stars have now been observed.
- The initial look at the data suggest an exozodi luminosity distribution that is not an obvious hindrance to future exo-imaging missions.
- Additional observations and improved data analysis can provide input to mission planning for future exo-Earth imaging missions.

Backup Slides

Modeling other Dust Disks

- Collisional model by A. Gaspar can predict evolution of dust from comets (3-D model in the works).
- Collisional in-situ model from Kennedy and Wyatt provides comparison.

Gaspar et al. (2012)



Kennedy and Wyatt (2013)