Progress and first statistics from LBTI/HOSTS

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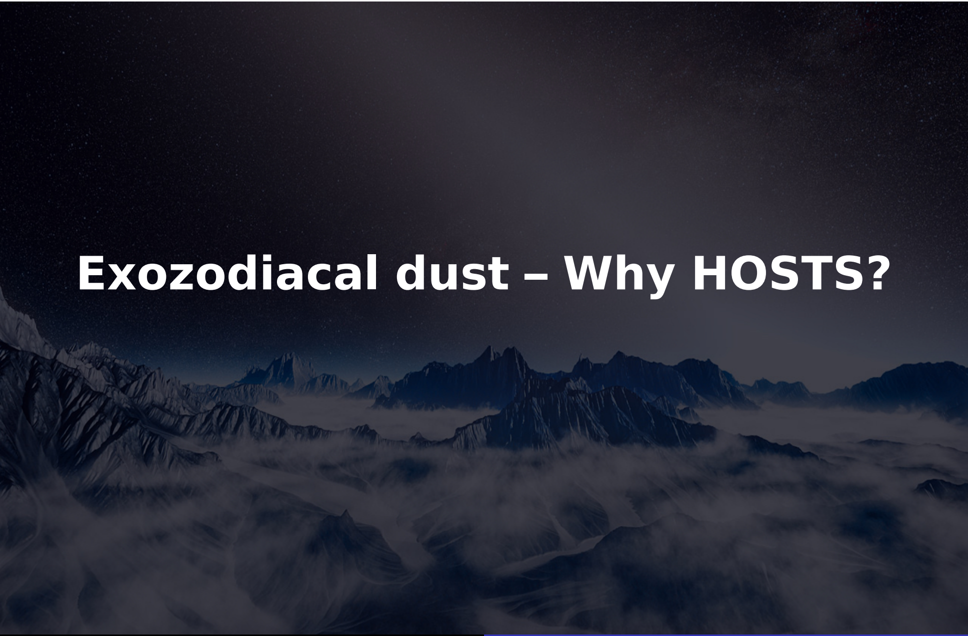
Outline

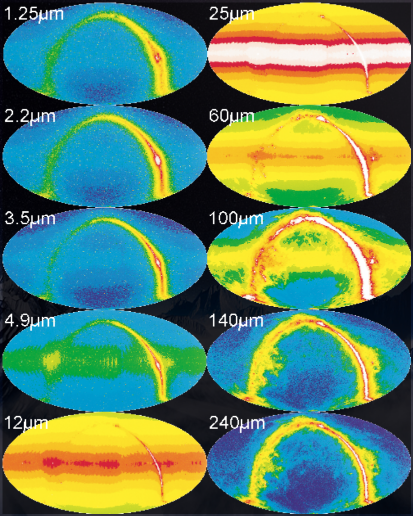
- Exozodiacal dust – Why HOSTS?
- Measurement technique – Nulling interferometry
- The HOSTS survey – Status update & early results
- Beyond the survey
- LBTI Programmatics (Phil Willems)



Exozodiacal dust – Why HOSTS?

Why HOSTS?

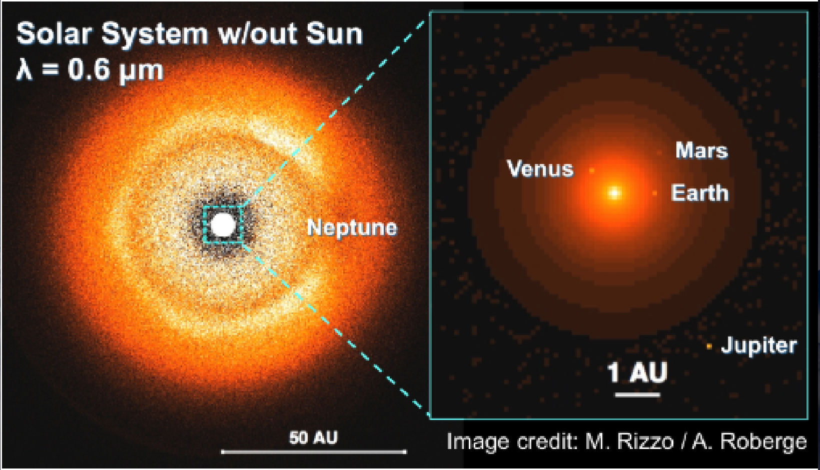
The zodiacal dust



COBE/DIRBE (Kelsall et al. 1998)

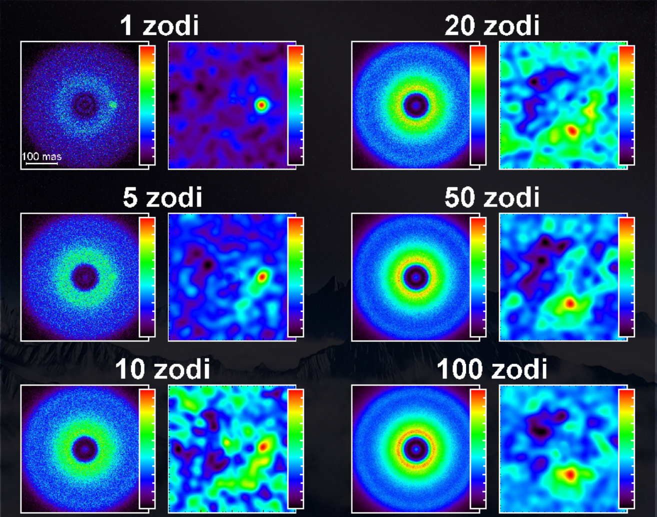
- Dust inside a few AU
- Power law surface density ($\alpha \sim -0.5$)
  (Kelsall et al. 1998, Hahn et al. 2002)
- Continuous transition to F-corona at few $R_\odot$, T: few 100K to ~2000K
  (Kimura & Mann 1998, Hahn et al. 2002)
- Comet evaporation
  (Dermott et al. 2002),
  asteroid collision
  & P-R drag
  (Nesvorney et al. 2010)
- Complex local structure (planetary interaction, local dust creation)

Our Solar system from outside



Why HOSTS?

Dust adds photon noise, structures add confusion



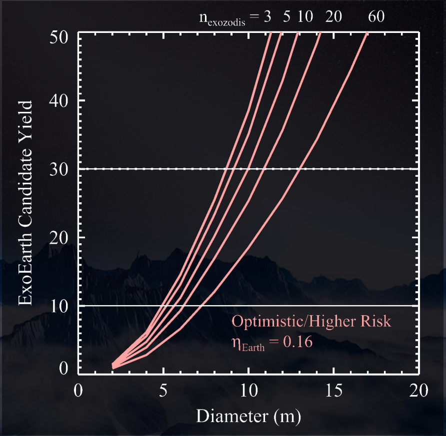
Defrère et al. (2012)

Why HOSTS?

Impact on exo-Earth imaging

- Aperture size and exozodi level affect exo-Earth yield.
- Exozodi level particularly critical for smaller apertures.

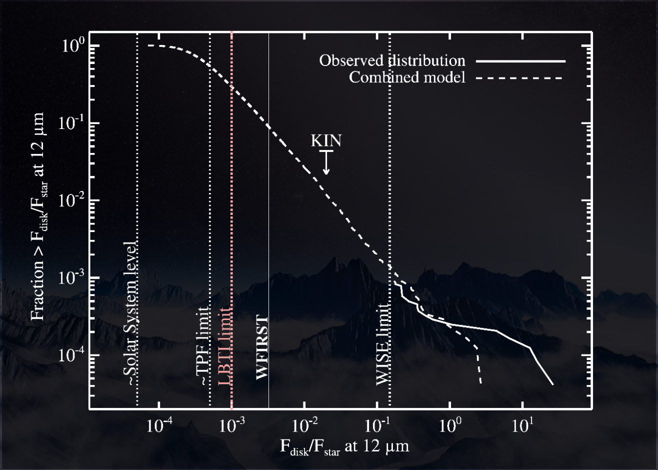
Telescope Size (m) for Given Yield and ExoZodi		
Exoplanet Yield	EZ=5	EZ=60
10 Earths	5 m	8 m
30 Earths	9 m	13 m



Stark et al. (2015)

Why HOSTS?

So far, constraints are very poor!



Kennedy & Wyatt (2012)

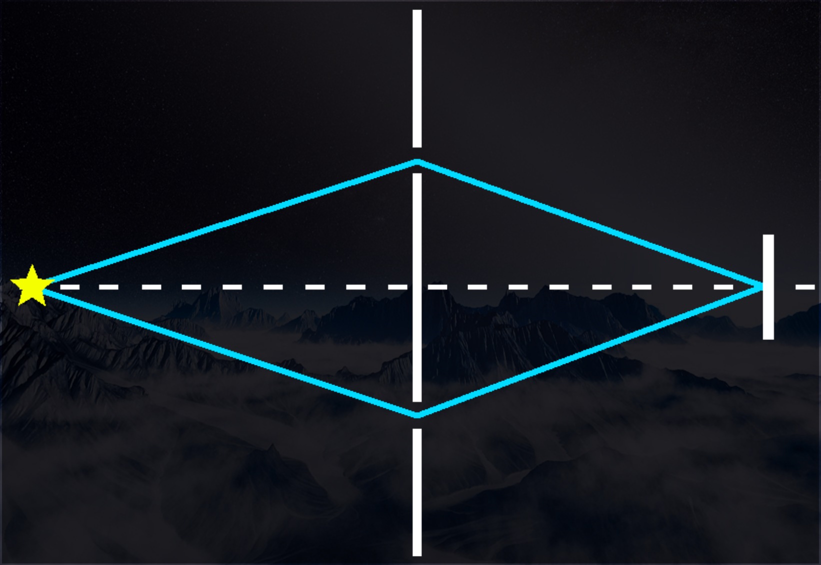
Measurement technique – Nulling interferometry

Nulling interferometry

Large Binocular Telescope Interferometer (LBTI)

- Located on Mt. Graham, AZ
- Telescope operated by The University of Arizona
- LBTI is a PI instrument funded by NASA

Nulling interferometry:



Nulling interferometry

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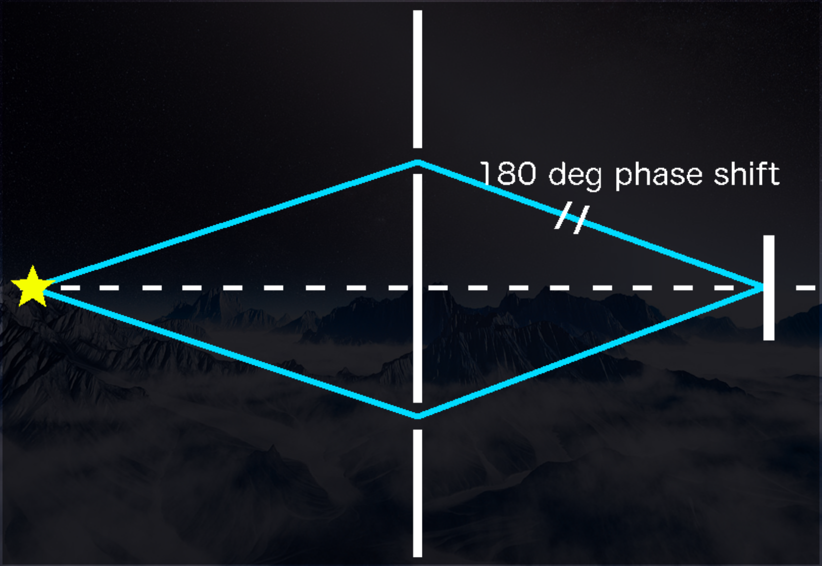

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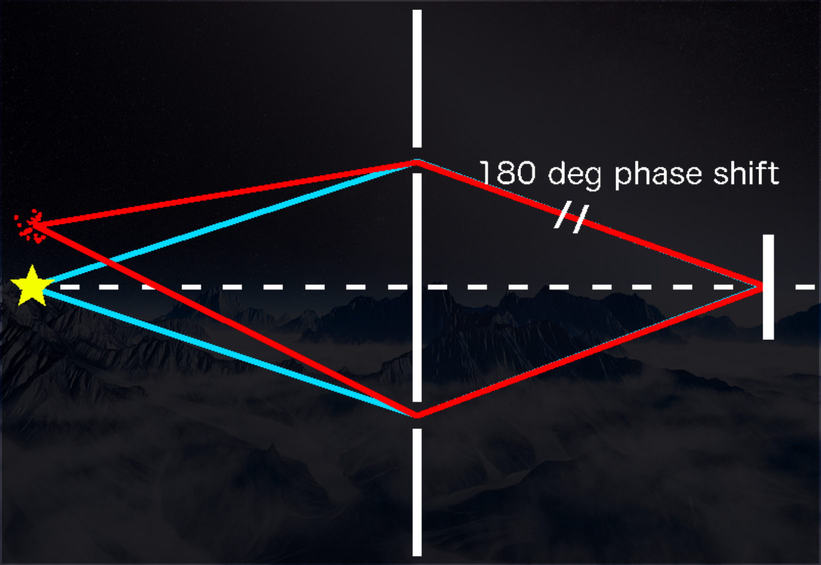
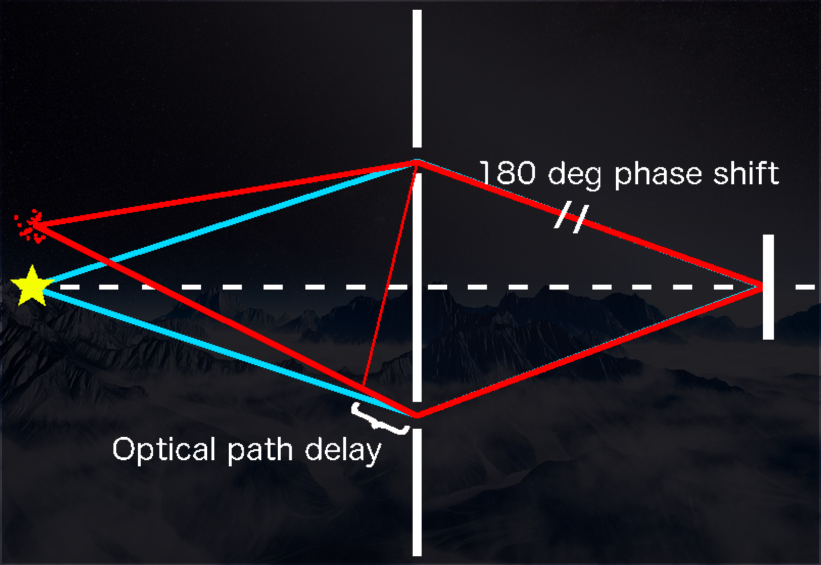
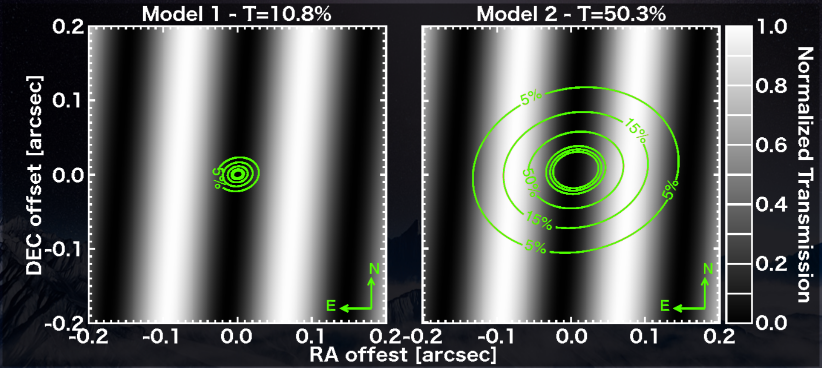


Nulling interferometry:



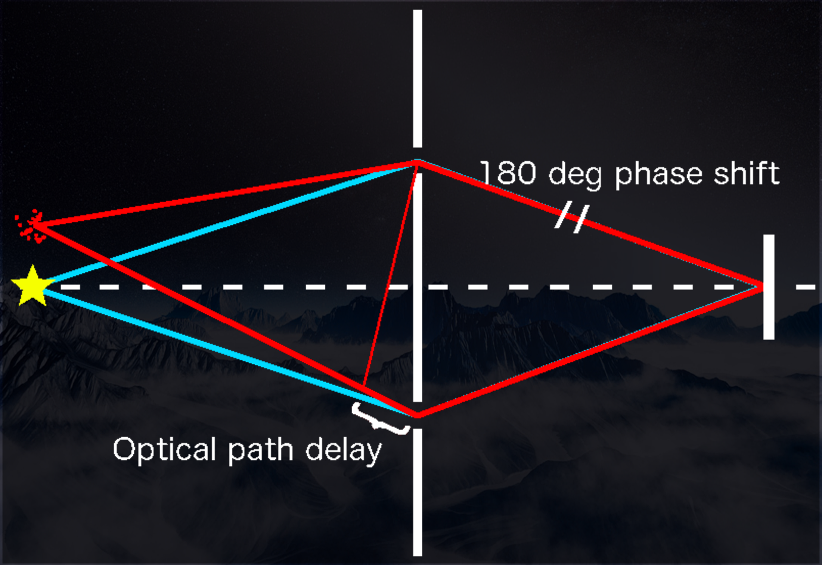
Nulling interferometry:



Defrère+ (2015)

Nulling interferometry

Not THAT simple ...



Nulling interferometry

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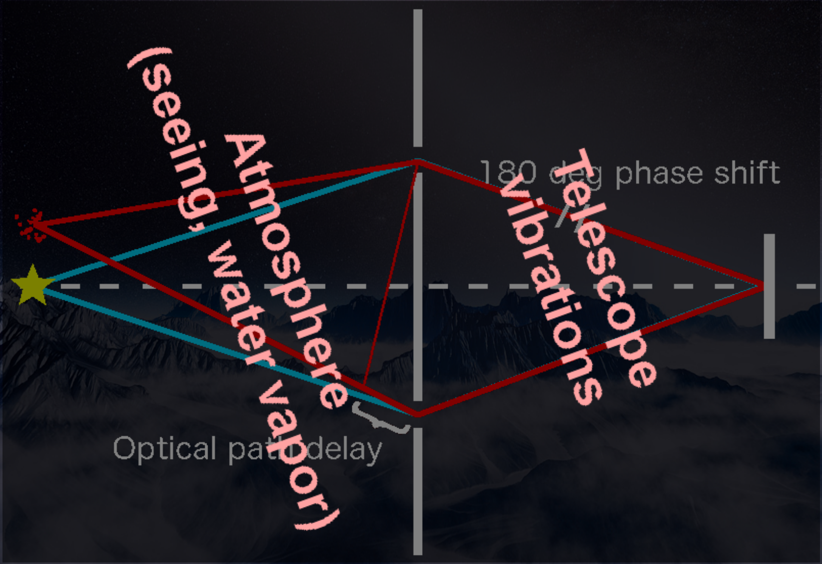

Nulling interferometry

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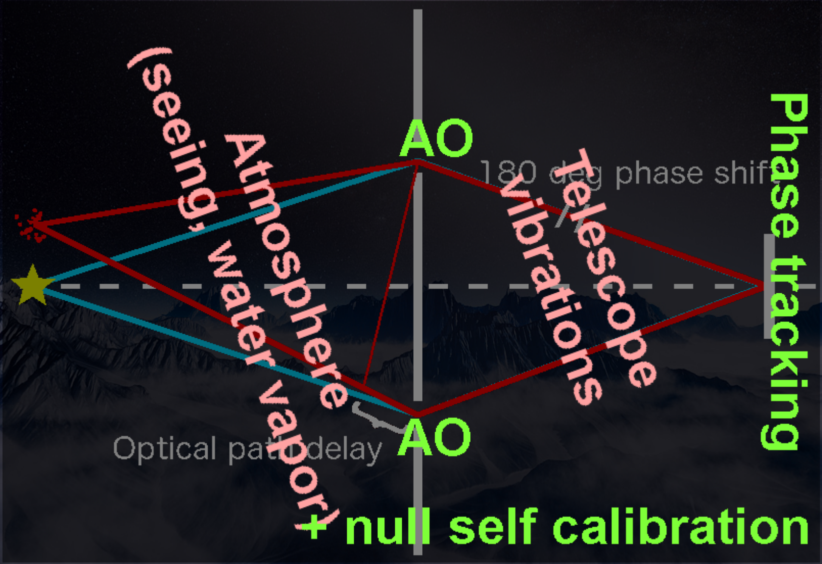

Nulling interferometry

And there we go!

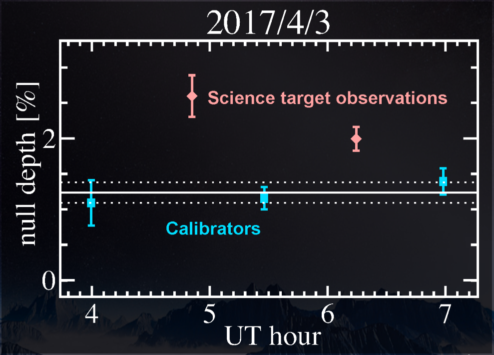

Figure courtesy of D. Defrère

- *β* UMa, complete observation of this target
- 142 ± 15 zodis (preliminary!)
- Variation with hour angle due to edge-on disk?
  Booth et al. (2014)

The HOSTS survey –
Status update & early results

Status update & early results

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	Sample:														
decision pending	Sun like														
to be repeated	sensitivity														

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Status update & early results

Progress in numbers:

- 29 stars observed (at least part of the data taken)
- 17 stars have completed observations
- 11 (equivalent) stars in 2016B, 13 in 2017A, 2 before
- 2 more semesters to go, observations 75% complete
- 1 full semester margin completely preserved

Some mile stones:

- Cadence of > one CAL-SCI pair per hour is routine
- Stars of ~1.5 Jy observed routinely, good data quality
- Still problems with low elevation (AO), but not critical for 35 stars goal

Status update & early results

So, what did the trick?

- Huge problems till 2016A, well on schedule since 2016B
- Improved instrument reliability, redundant systems
- Improved communication with LBTO
  - ⟶ Better awareness of LBTI needs and impacts of telescope work/changes
- More formal risk management
- Implementation of LBTI queue mode to make efficient use of open dome time
  - ⟶ Ensures HOSTS is getting suitable observing conditions
- Development of efficient and robust observing scripts
  - ⟶ Minimizes overheads and error recovery time

Good (and still improving!) data quality

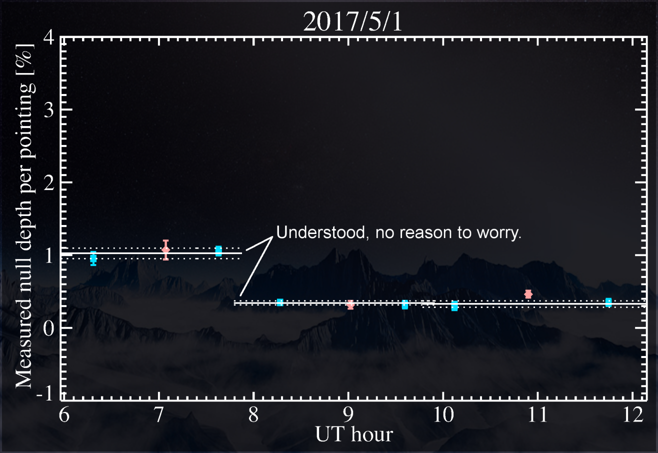
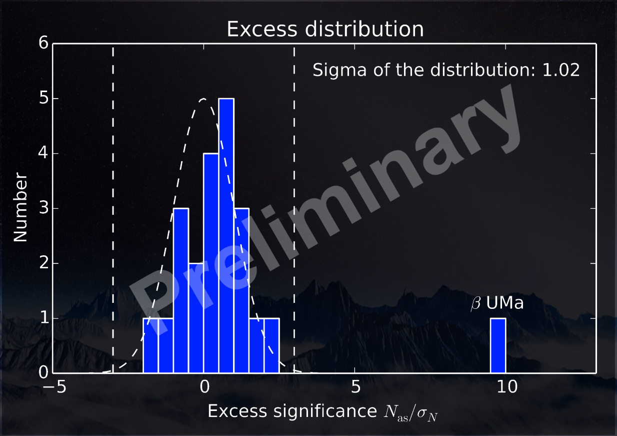


Figure courtesy of D. Defrère

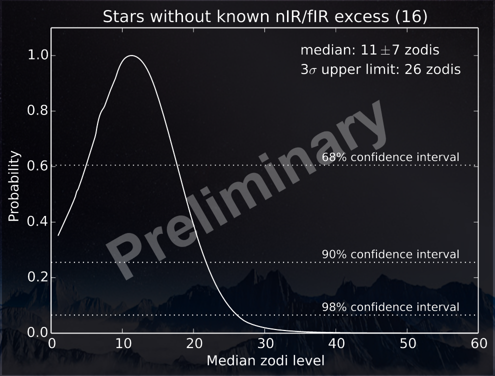
Status update & early results

First statistics based on incomplete survey:



- Most data consistent with no dust detection
- Three detections: β UMa, β Leo Hinz et al., in prep., and η Crv Defrère et al. (2015)

Median zodi level (assuming lognormal distribution):



- First time getting close to actually MEASURING median zodi level
- Already a factor 3 stronger constraints than Keck (26 vs. 90 zodis at $3\,\sigma$)

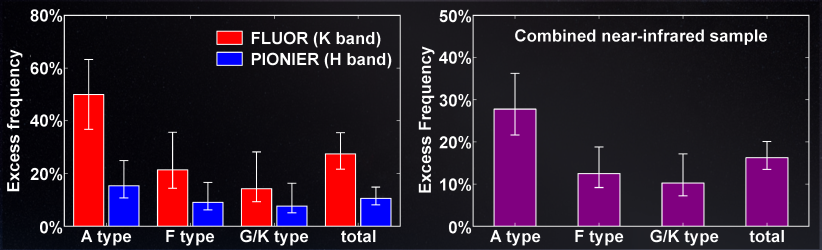
Beyond the survey

Beyond the survey

LBTI work to be done:

- Better statistics from more stars, improving accuracy
- AO upgrade: reach further South for some particularly sensitive stars
- Multi-wavelength observations of detections to characterize architecture and dust composition
- Deep observations of specific exo-Earth imaging targets
- More general: Synergies with JWST

Don't forget the near-infrared:



Ertel et al. (2014)

- Complementary information on dust architecture & grain size, ~200 stars observed, ~40 detections!

  Absil et al. (2013), Ertel et al. (2014), Nuñez et al. (subm.), Marion et al. (subm.)

- Multi-wavelength modeling for better constraints Lebreton et al. (2014), Kirchschlager et al. (2017)

- Extended emission, might cause coronagraph leakage???

Conclusions

Conclusions:

- HOSTS survey 75% complete
- Preliminary results suggest that exozodis are no obvious hindrance to future exo-Earth imaging missions
- Significant potential for more input to mission planning from LBTI possible beyond the main survey
- Significant improvements of our knowledge expected from detailed modeling of all available data

LBTI Programmatics

Since ExoPAG 15 in Grapevine ...

- LBTO has repaired its left secondary mirror by installing a new distributor
- LBTI held a Program Assessment Review at JPL on February 21 – revised scheduling and mission assurance judged to be working and worth continuing
- HOSTS survey brought to 75% of completion

Upcoming milestones ...

- DPMP review scheduled for July 28 at NASA HQ
- HOSTS survey expected to be completed in 2017B observing semester
- HOSTS survey funded through 2018A observing semester (schedule margin or survey extension)

Beyond the survey

Thank you very much!