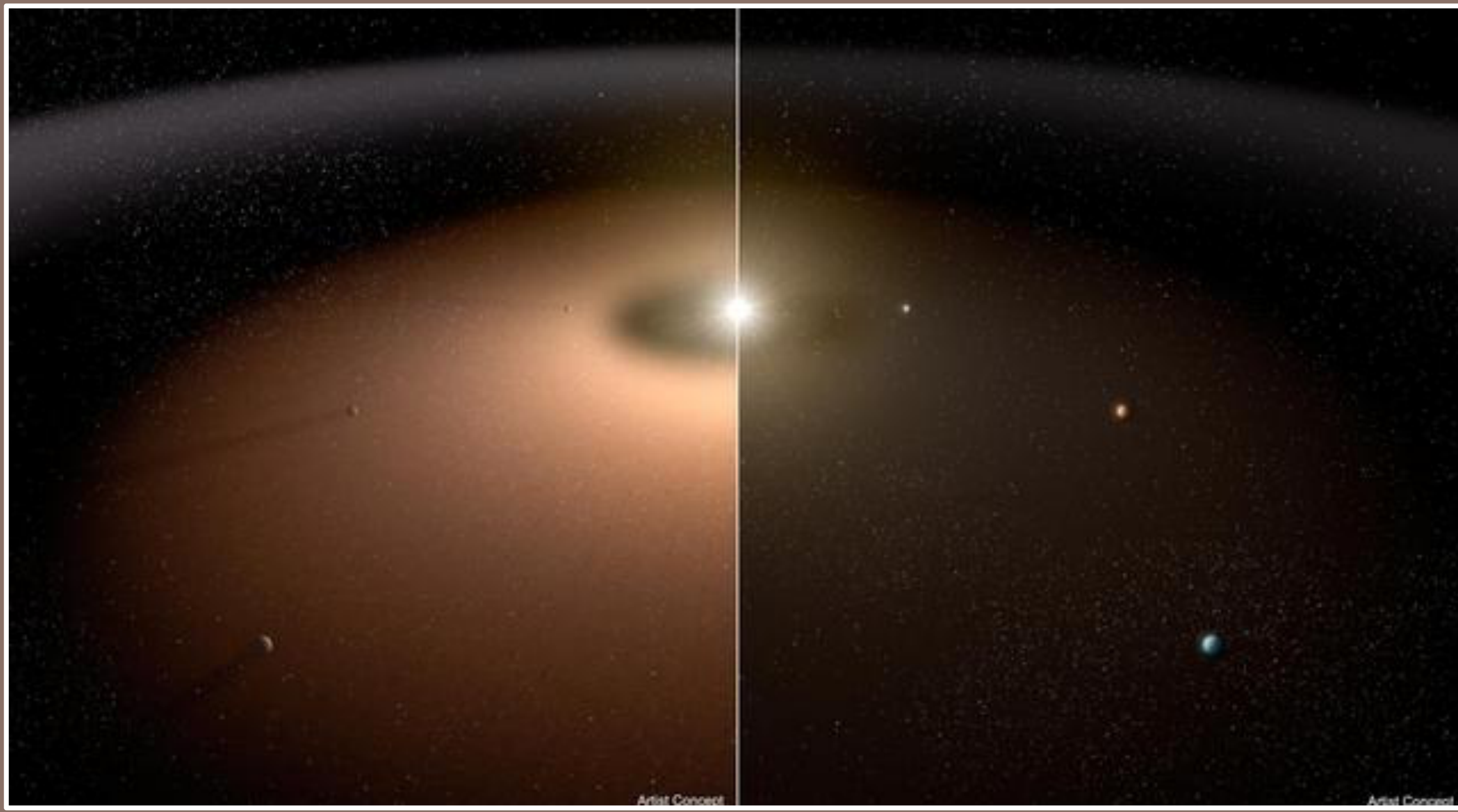
PREVALENCE OF EXOZODIACAL DUST

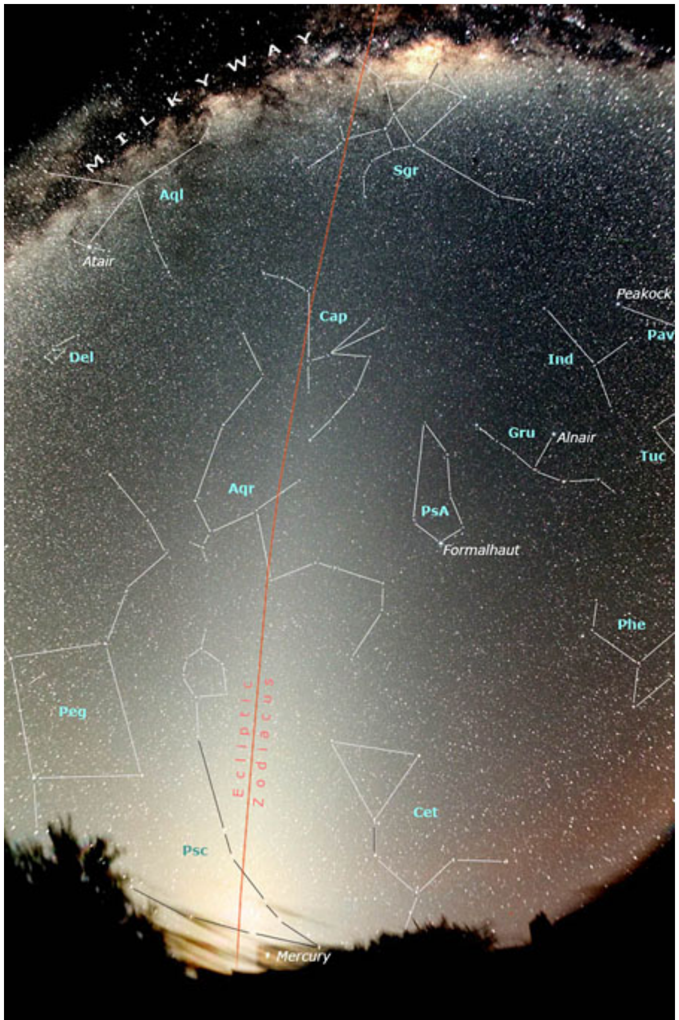


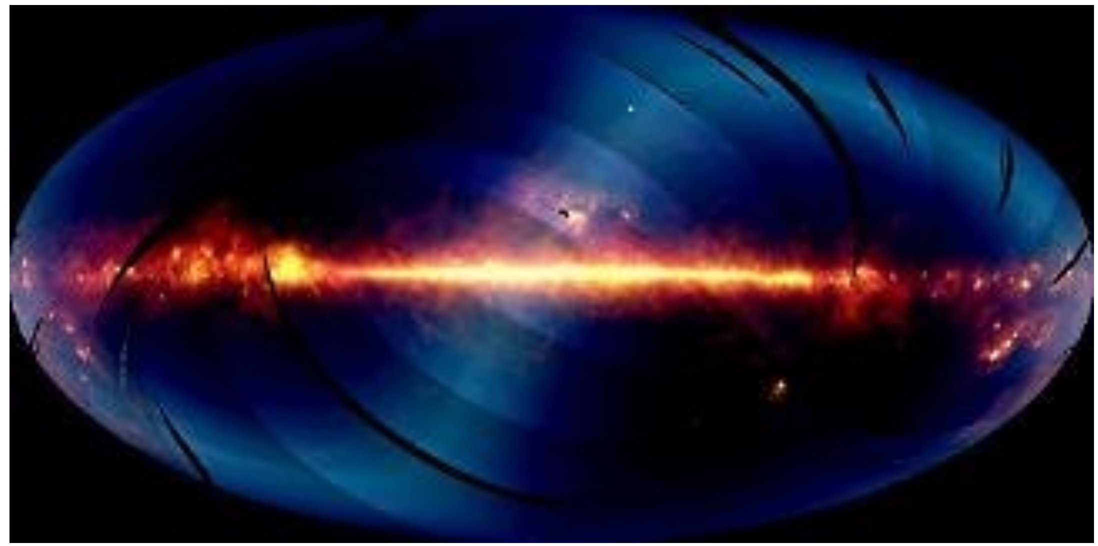
with contributions from
B. Danchi, S. Ertel, P. Hinz, G. Kennedy, A. Roberge, K. Stapelfeldt, and J. Trauger

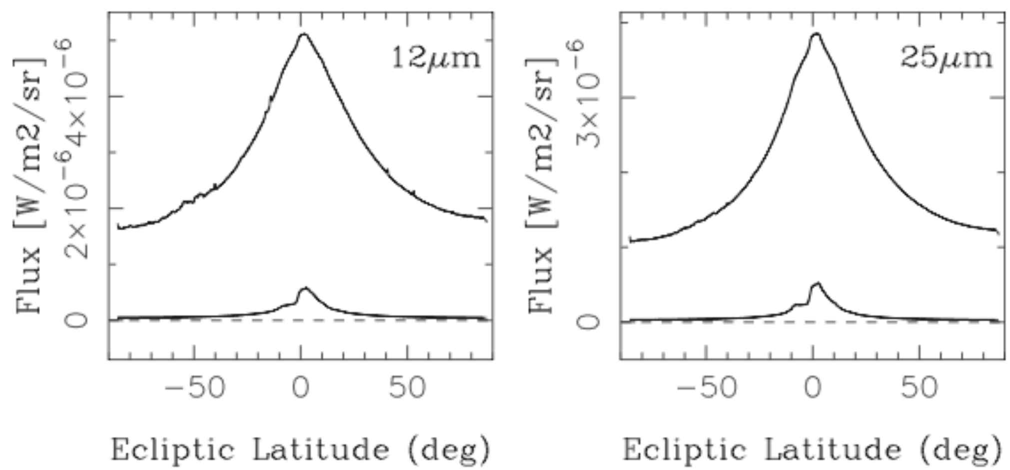
Bern – July 2015

Denis Defrère – University of Arizona

Zodiacal dust

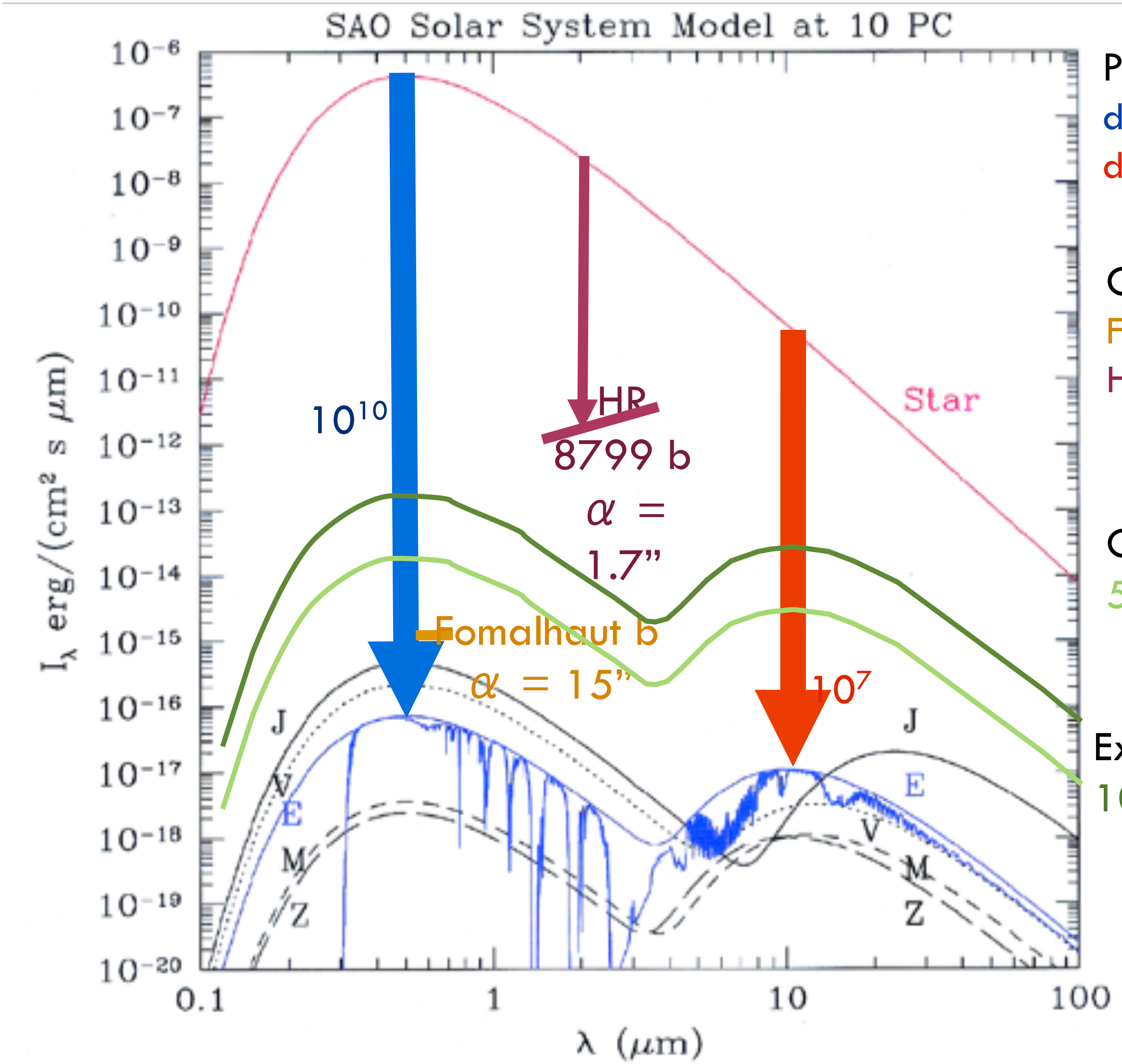






from Nesvorney et al. 2010

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.

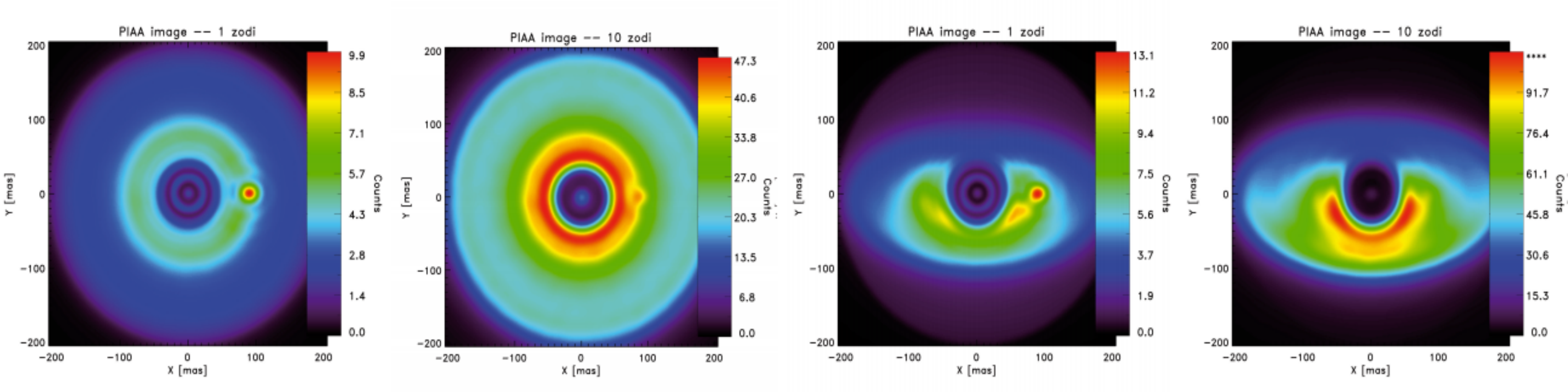
Our own Zodiacal dust:

$5x\ 10^{-5}$ at 10 μm =1 zodi.

Exozodiacal dust becomes a problem:

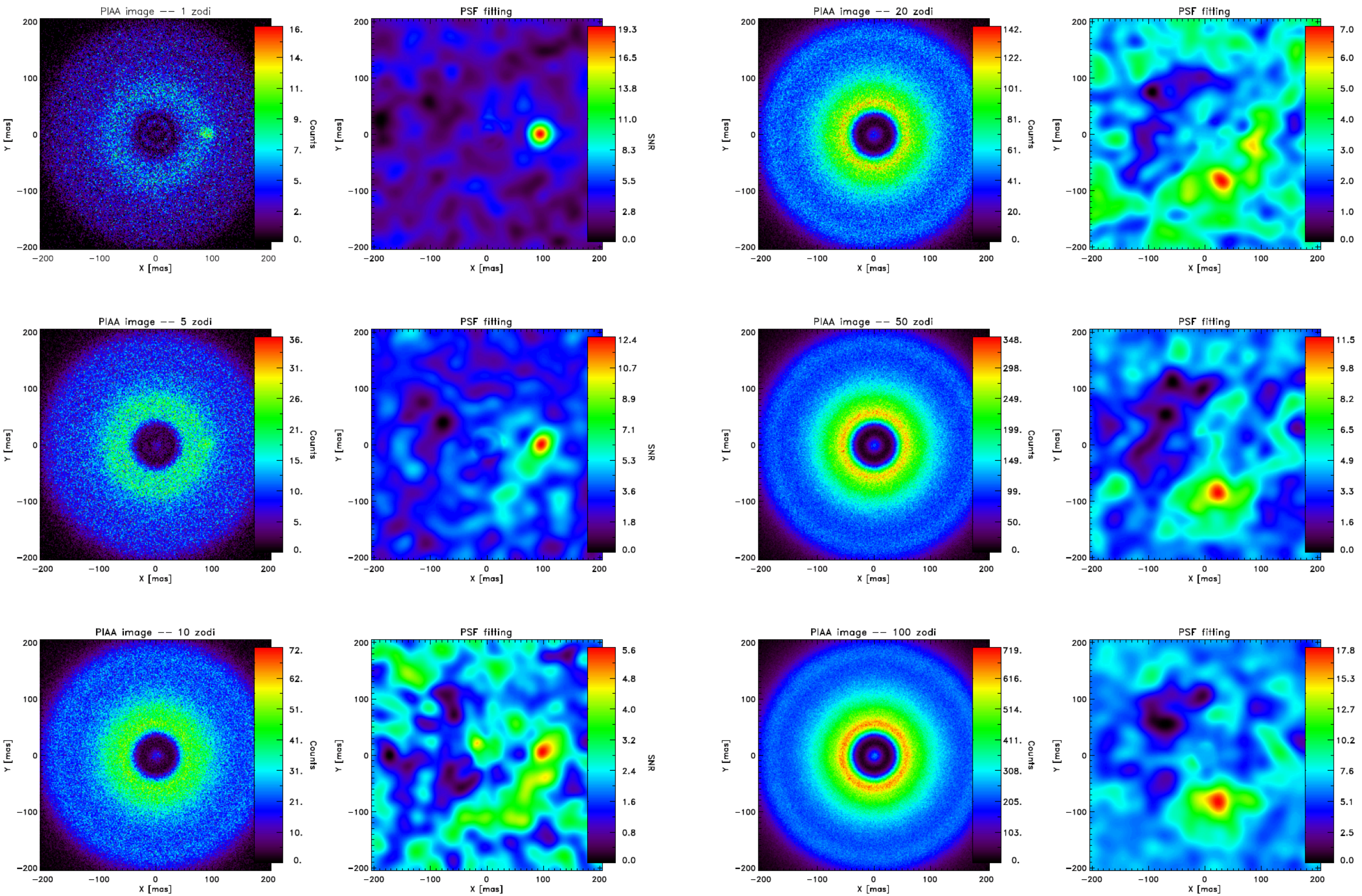
10 zodi or above.

Source of noise



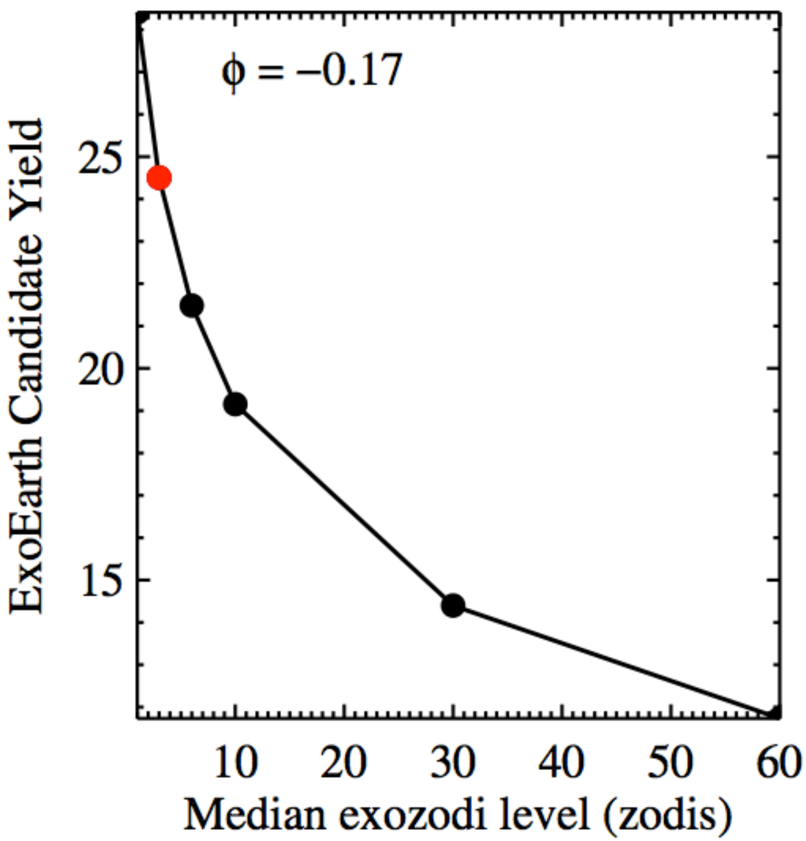
Sun-Earth system at 10 pc surrounded by a 1 and a 10-zodi exozodiacal disk (Defrère et al. 2012)

Source of confusion



Sensitivity of yield to exozodi

- 1 zodi: different things to different people (Roberge et al. 2012)
- Here, 1 zodi = 22 mag/arcsec^2 at V band

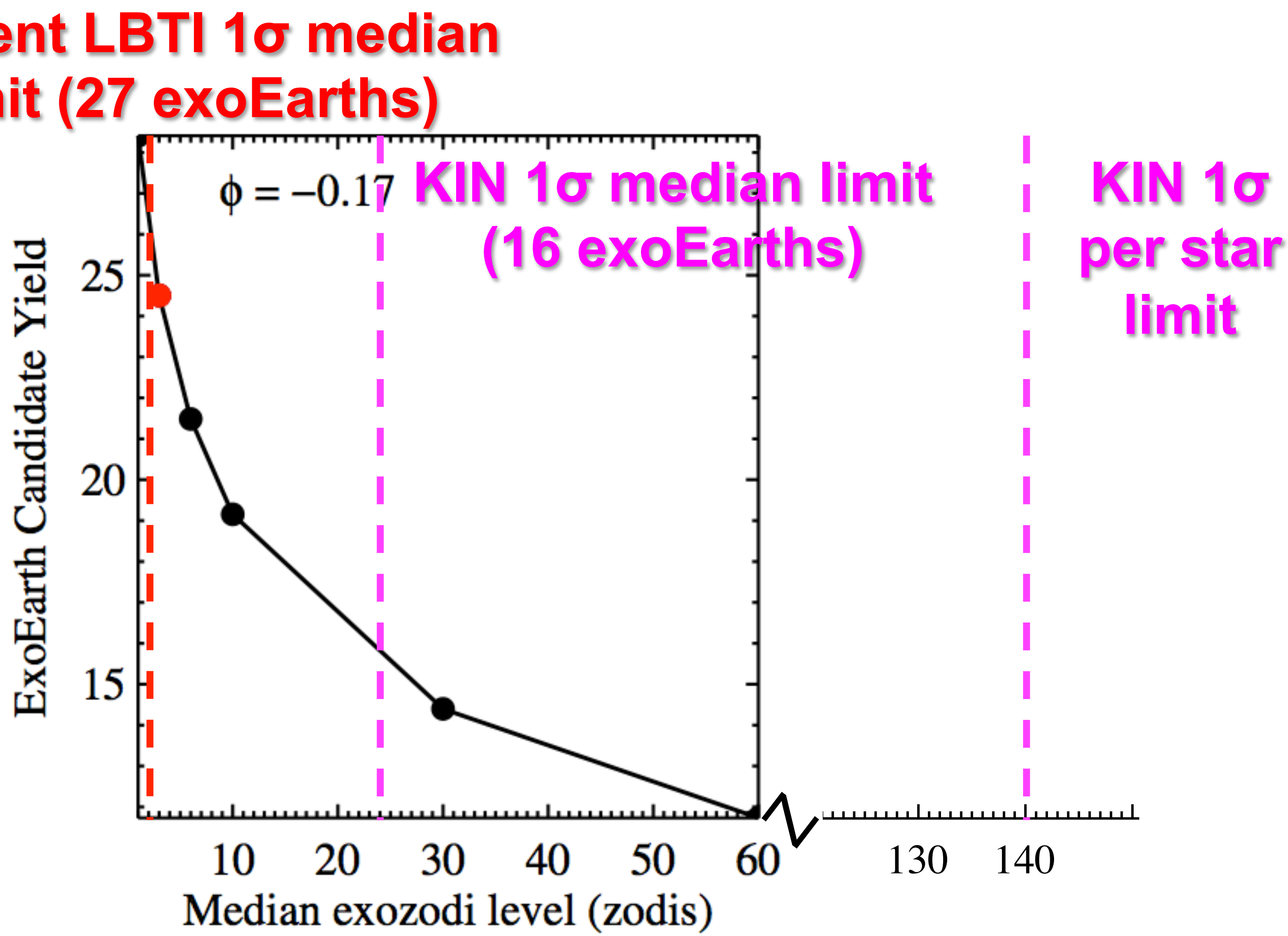


ϕ_x = % change in yield / % change in parameter x

Weak function of exozodi (reduce exozodi by 10x, increase yield by ~ 2x)

Stark et al., 2014, 2015

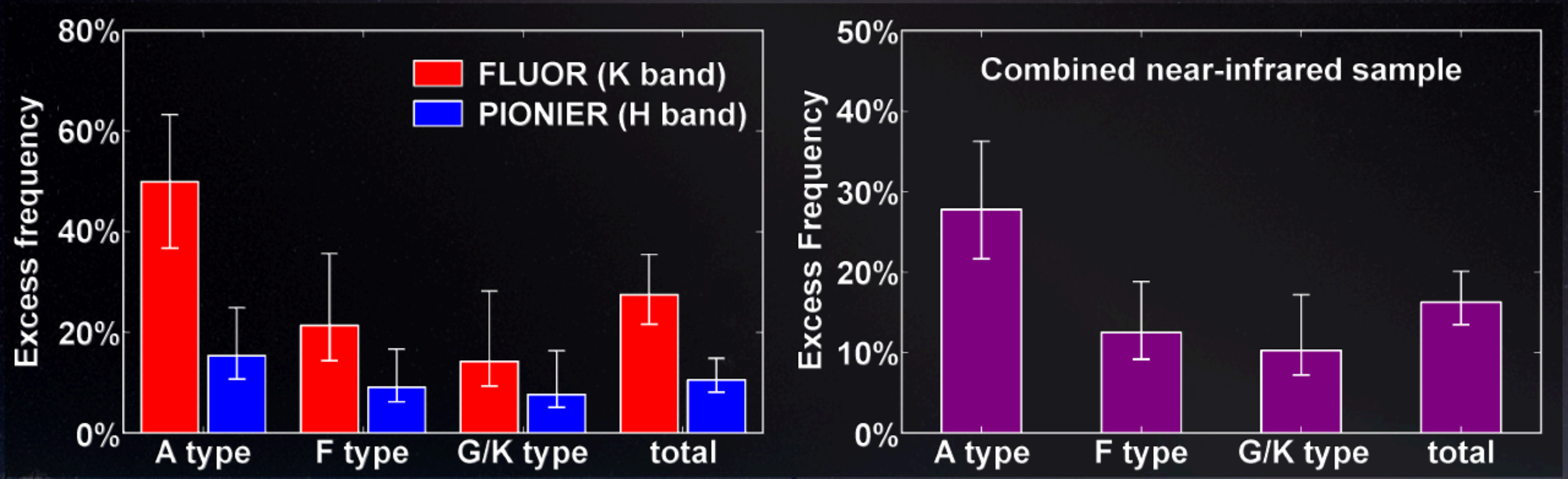
Big room for improvement in knowledge



From S. Ertel's talk

Results of near-IR surveys

Statistics based on 123 stars observed:

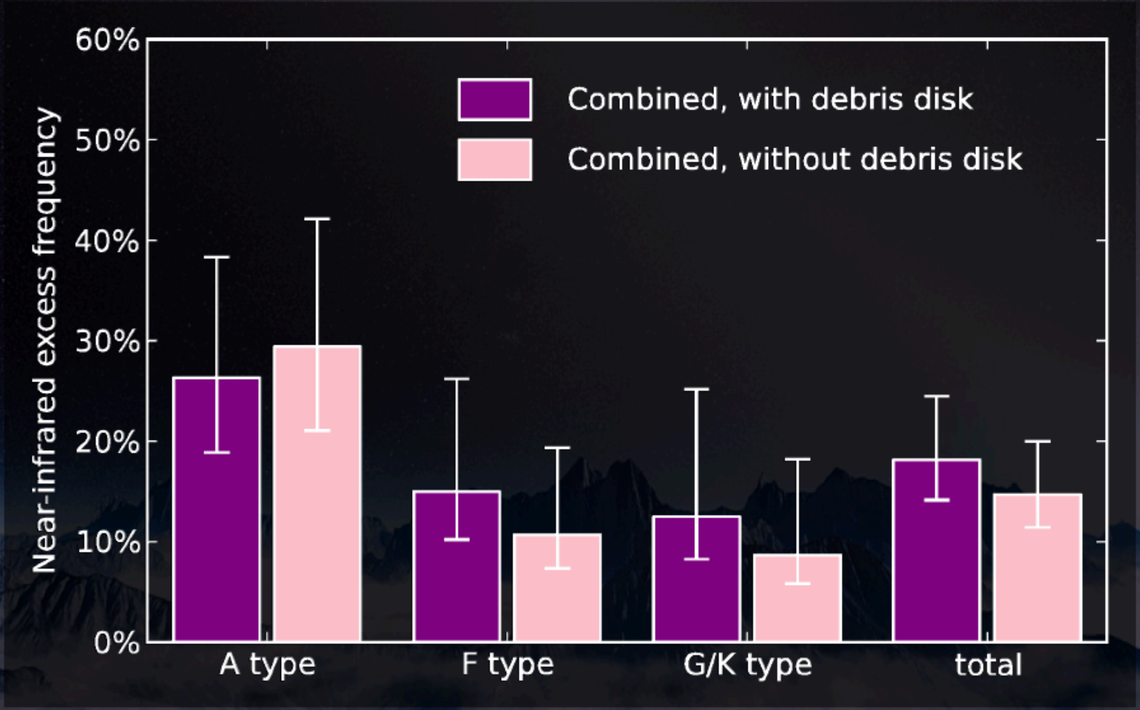


- Detection rate with FLUOR (*K* band) by factor of ~2.5 higher than with PIONIER (*H* band)
- Correcting for this factor all statistics consistent between the two samples
- Detection rate decreasing with later spectral type
  ⇒ ***Like a normal debris disk?***

From S. Ertel's talk

Results of near-IR surveys

Statistics based on 123 stars observed:

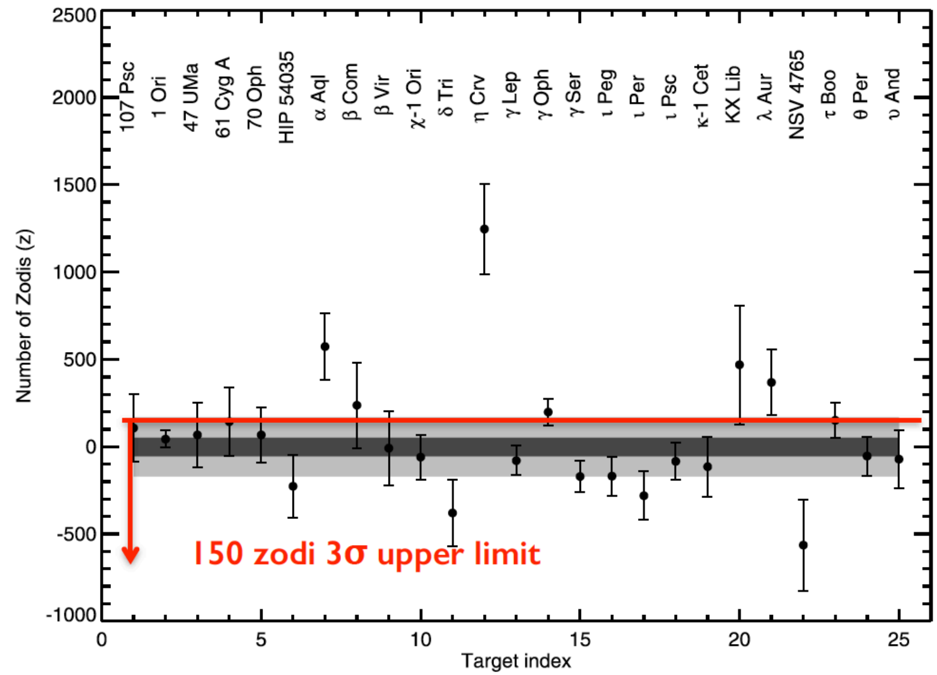


- No correlation with presence of cold dust
  ⇒ ***Not (simply) the hot inner rims of debris disks!***

From P. Hinz's talk

Results of mid-IR surveys

- **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.

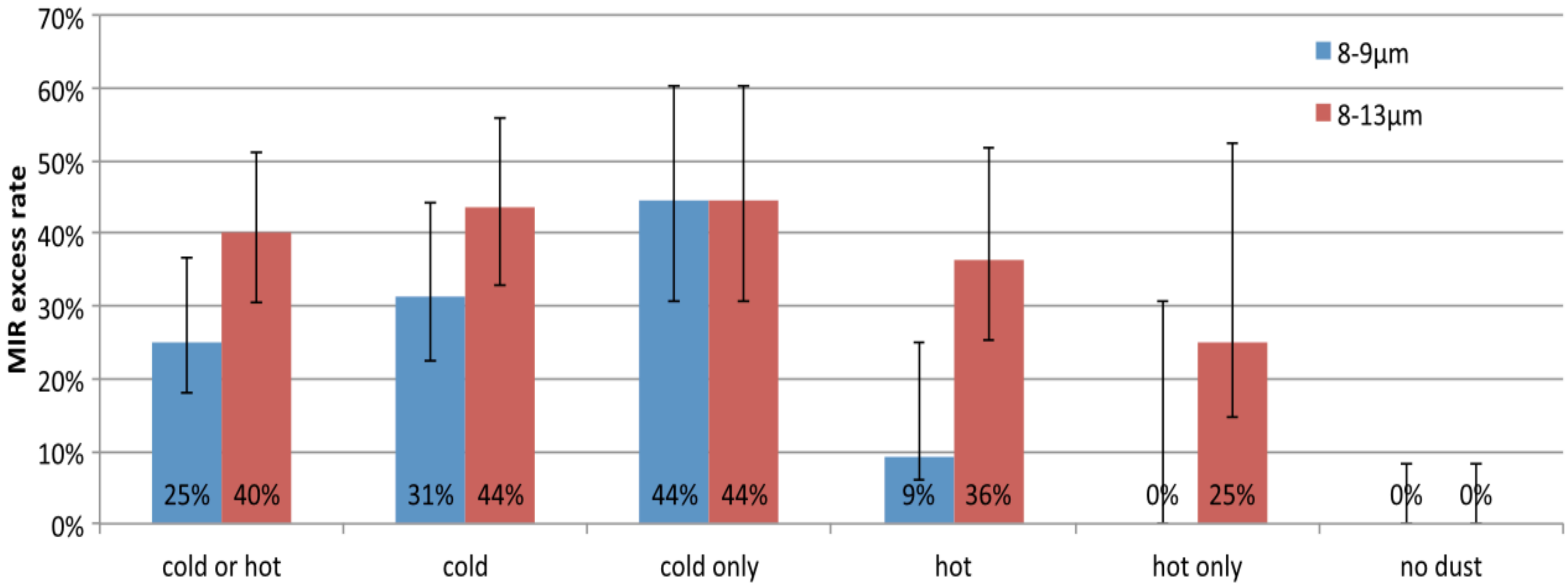


Need improve the sensitivity down by > 1 order of magnitude.

From B. Danchi's talk

Results of mid-IR surveys

- Stars with known far-infrared (> 70 μm) excesses have higher exozodiacal emission levels than stars with no previous indication of a cold outer disk.

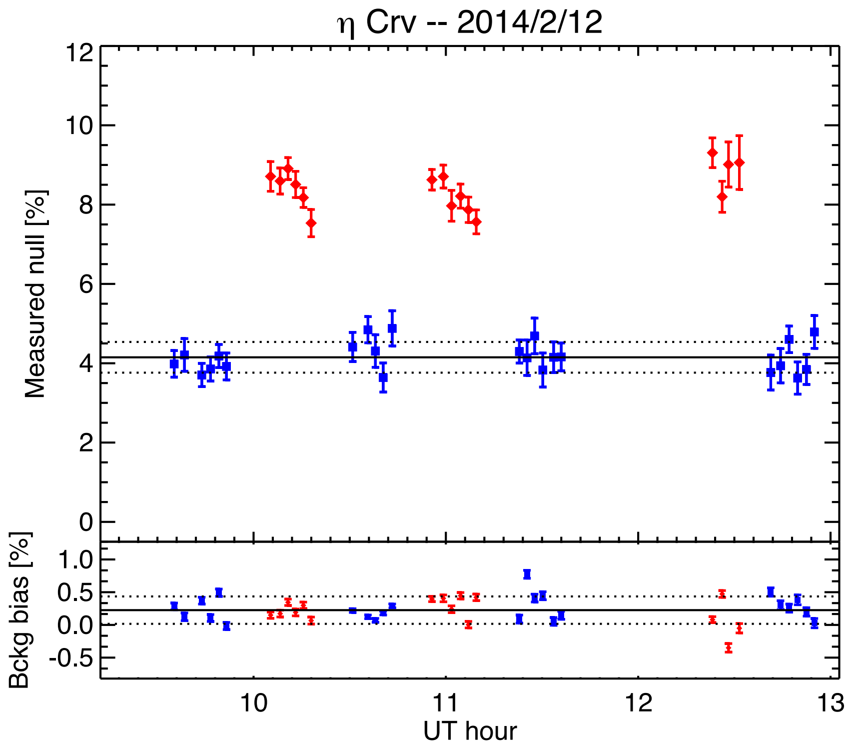


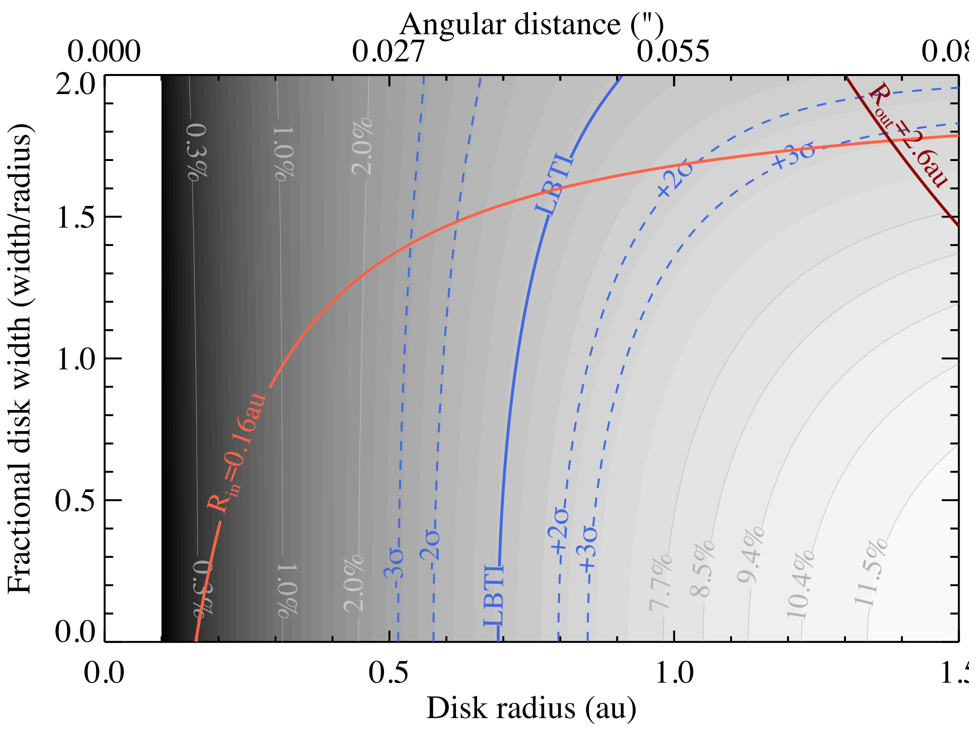
Mennesson et al. 2014

From B. Danchi's talk

LBTI survey: HOSTS

- 32 stars FY 2016-2017
- First-light null detection around η Crv: 4.40% +/- 0.35% (Defrère et al. 2015):

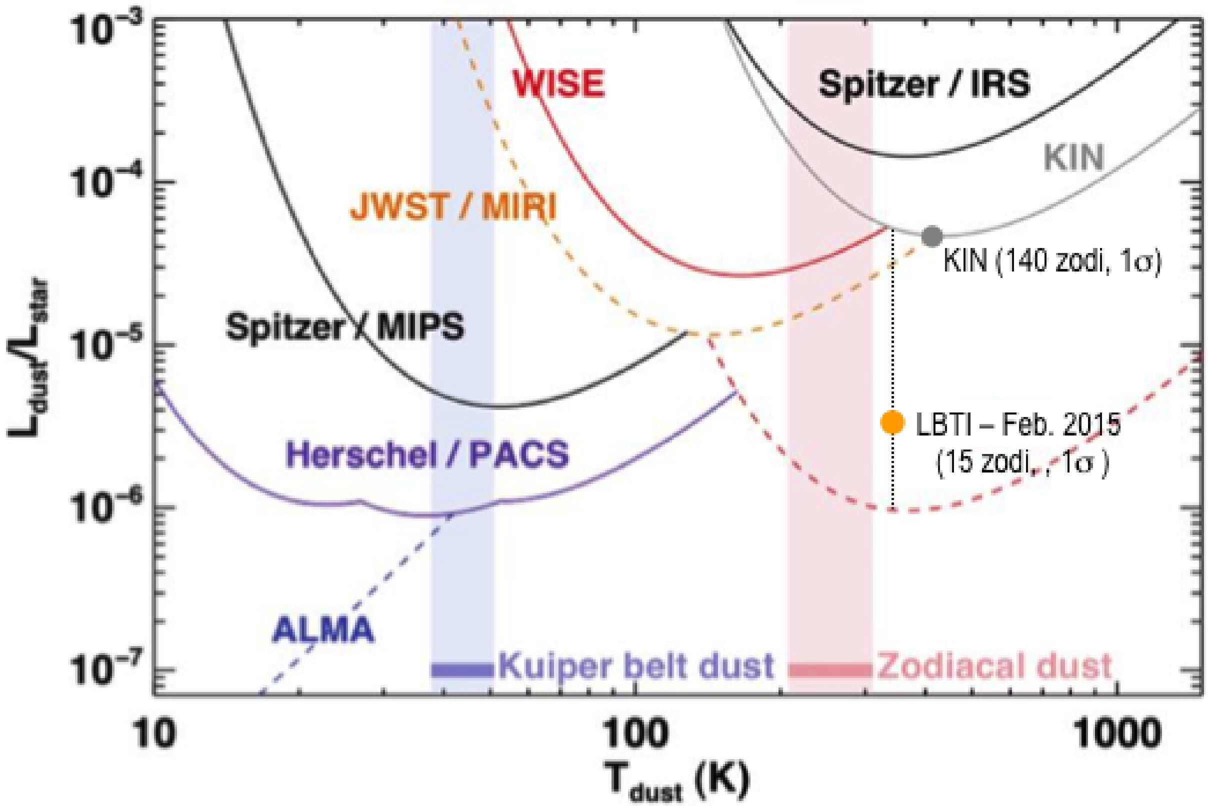




From B. Danchi's talk

Results of mid-IR surveys

- Latest LBTI performance measured on β Leo in Feb. 2015: 0.64% +/- 0.052%:



From J. Trauger's talk

Prospects with space-based coronagraphs

- Local zodi dust model: Radial location of the HZ dust is scaled for stellar luminosity, surface brightness is scaled with HZ radius as $r^{-2.3}$
- Exozodi surface brightness scaled from V=22 mag/arcsec^2 at 1 AU
- Table gives number of observable HZs overall, and the subset of these that are around solar-type stars

HZ R & exozodi	AFTA CGI	Exo-C
1 AU, 1 zodi	12, 10	11, 4
1 AU, 5 zodi	35, 16	28, 6
1.5 AU, 1 zodi	16, 16	20, 12
1.5 AU, 5 zodi	50, 40	52, 21

- Required observing times for the above results are 1000-2000 hours for both platforms. AFTA achieves better spatial resolution

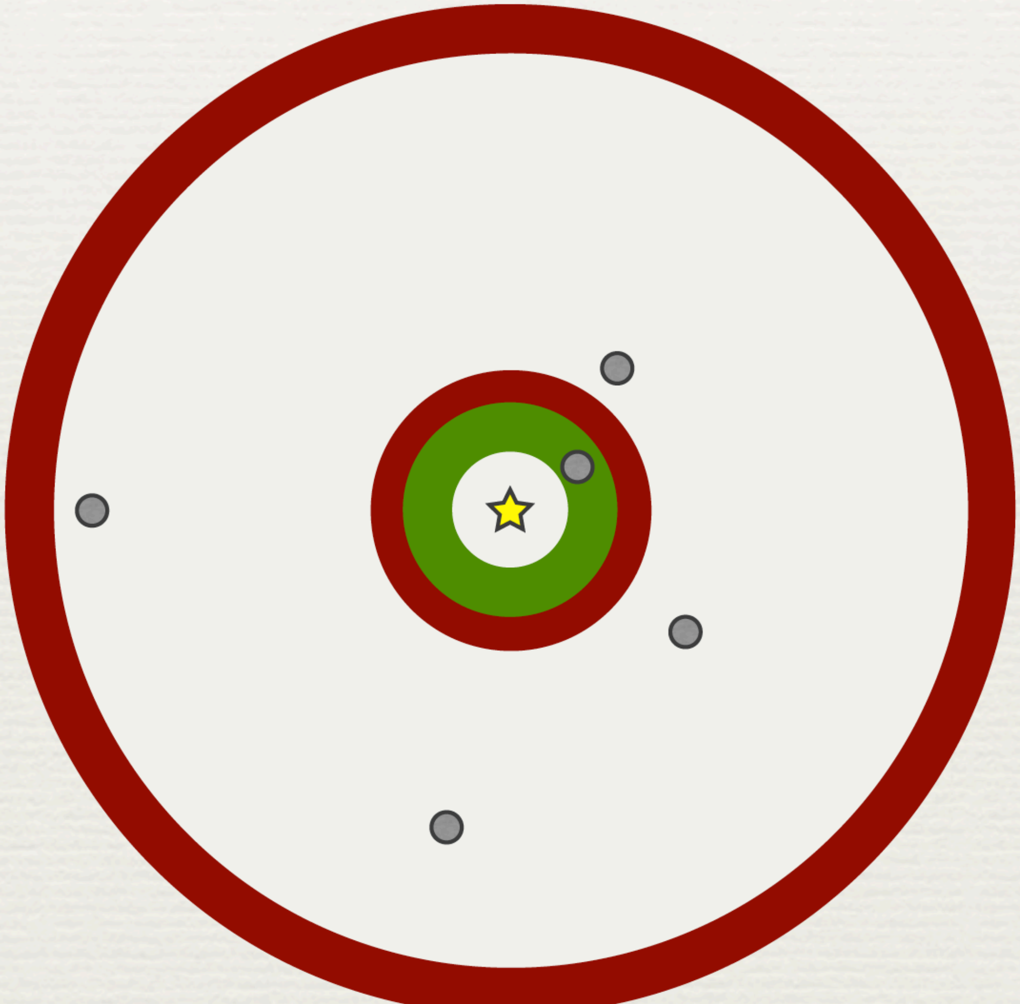
Prospects with space-based coronagraphs

- Constant HZ surface brightness: Radial location of the HZ dust is scaled for luminosity, surface brightness is fixed at V=22 mag/arcsec^2 regardless of radial location - a proxy for younger stars being dustier
- Table gives number of observable HZs overall, and the subset of these that are around solar-type stars

HZ R & exozodi	AFTA CGI	Exo-C
1 AU, 1 zodi	80, 41	80, 11
1 AU, 5 zodi	190, 66	80, 11
1.5 AU, 1 zodi	88, 34	203, 65
1.5 AU, 5 zodi	320, 129	203, 65

- Exo-C sample strongly weighted toward brighter early-type stars, results in 5-15x faster observing times per row above

Exozodi origin

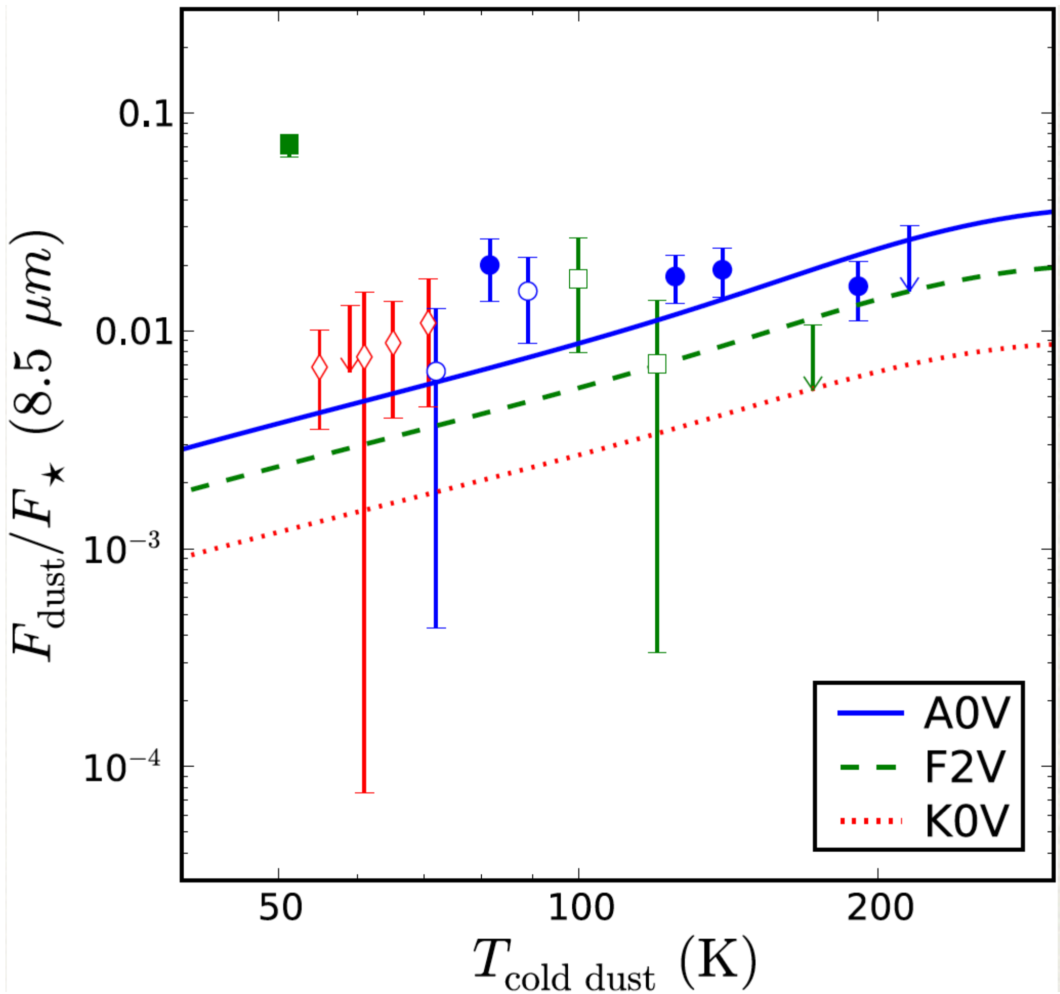


- Local
  - planet formation
  - late collisions
  - Asteroid belt
- External
  - comet delivery
  - instabilities (LHBs)
  - **P-R drag**

Evidence for P-R drag?

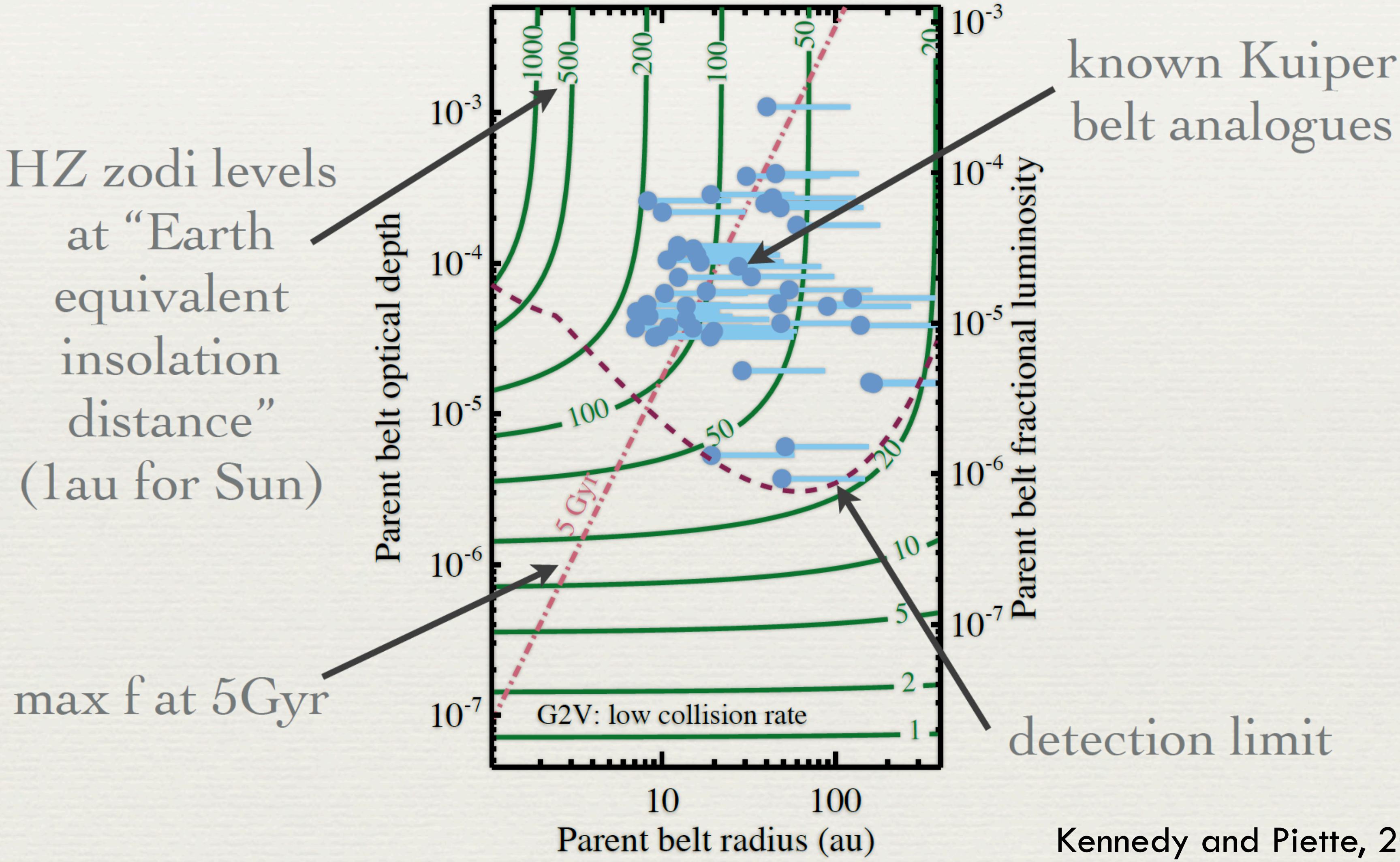
- Keck Nuller detections of ~300 zodi levels, only around A-stars with known cool outer parent belts

- Predictions from Wyatt PR drag model:



Exozodi level from P-R drag?

predictions at EEID using Wyatt 05 model



Kennedy and Piette, 2015

Summary

- Exozodi is a source of noise and confusion: reduce exozodi by 10x, increase yield by ~ 2x (for coronagraphs);
- Current knowledge from the Keck nuller survey: median zodi level < 25 zodis for sun-like stars;
- Upcoming LBTI survey => median zodi level of ~1 zodi
- First indications that we can predict the exozodi level from the cold outer belt (early-type stars)
- Puzzling near-infrared detections: need to be considered for exoEarth imaging

Recommendations from panel

- Investigate the impact of hot dust on exoEarth imaging;

- Investigate extrapolation from mid-infrared zodi level (KIN,LBTI) to visible brightness.