Debris Disks: Challenge and Opportunity for The Detection of ExoPlanets

C. Beichman

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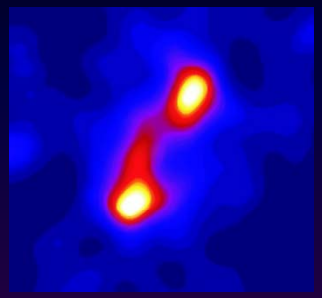
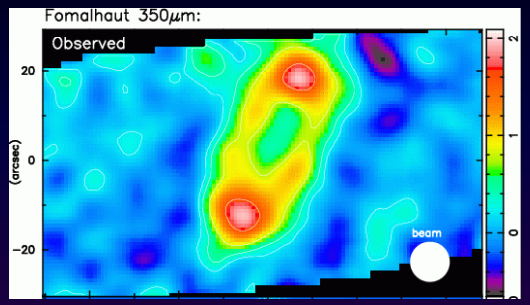
Disks And Planets

- Massive Disks around young A Stars may herald planets at large radii
- Disks around mature FGK Stars have little or no correlation with RV planets
- Disks in HZ may prevent detection of planets
- Programs underway approach necessary levels of sensitivity to survey target stars

Fomalhaut's Resolved Disk Hints at Planets

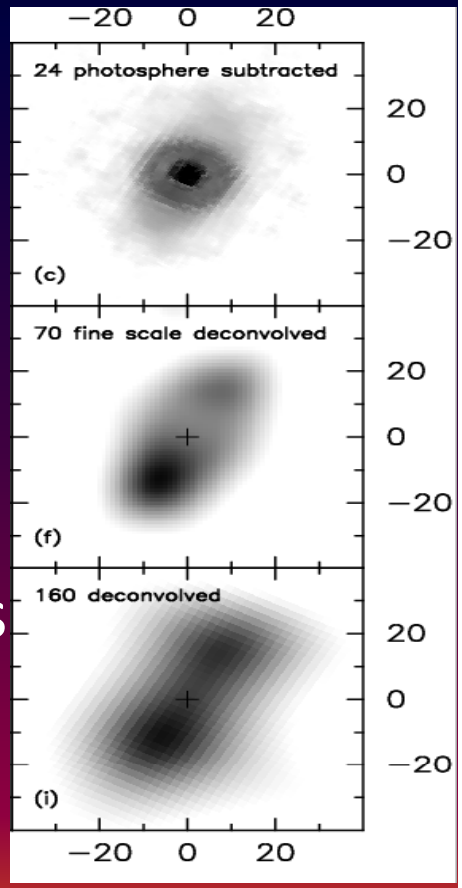


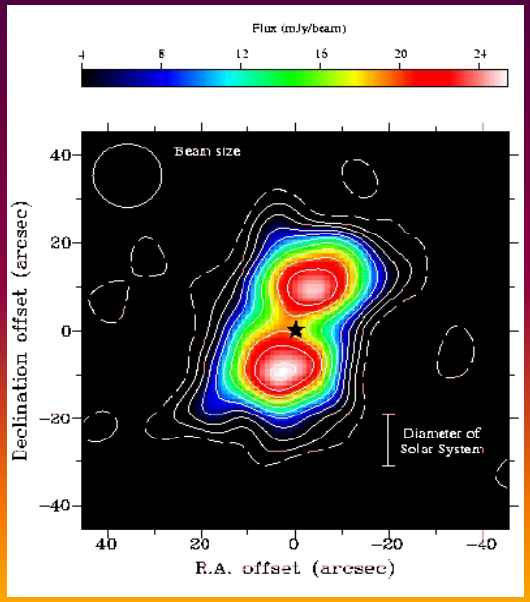
JCMT 450 µm
(Holland 1998, 2003
Wyatt 1999)
JCMT 850 µm



CSO 350 µm
(Marsh 2005)

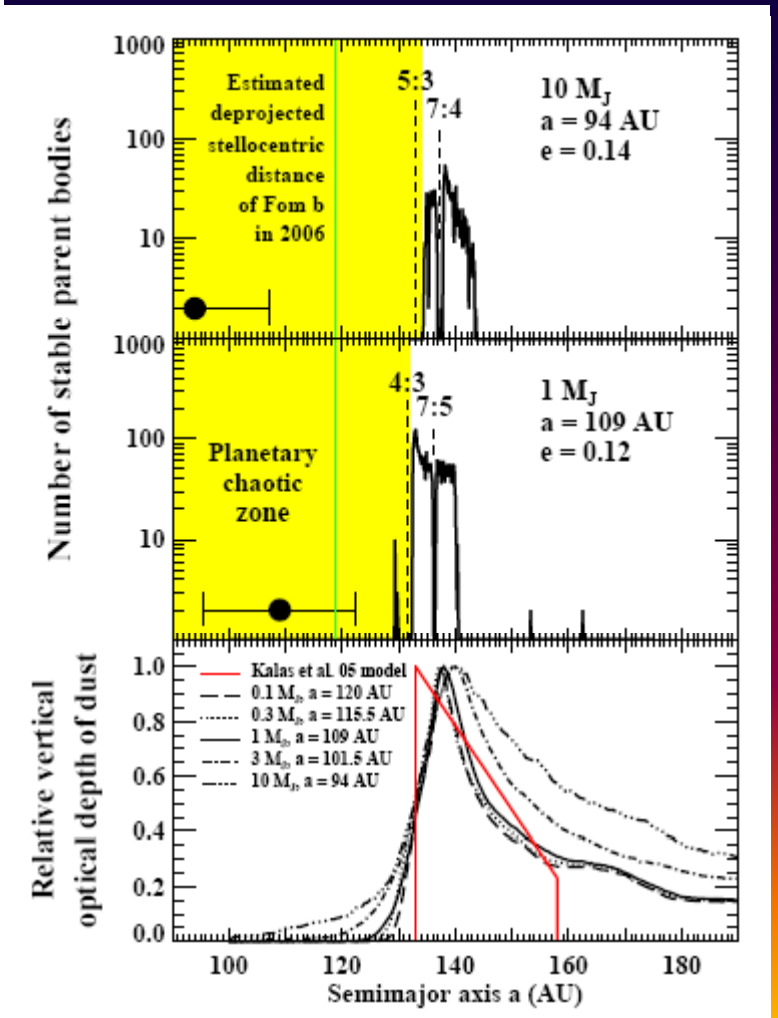
(Stapelfeldt 2004)

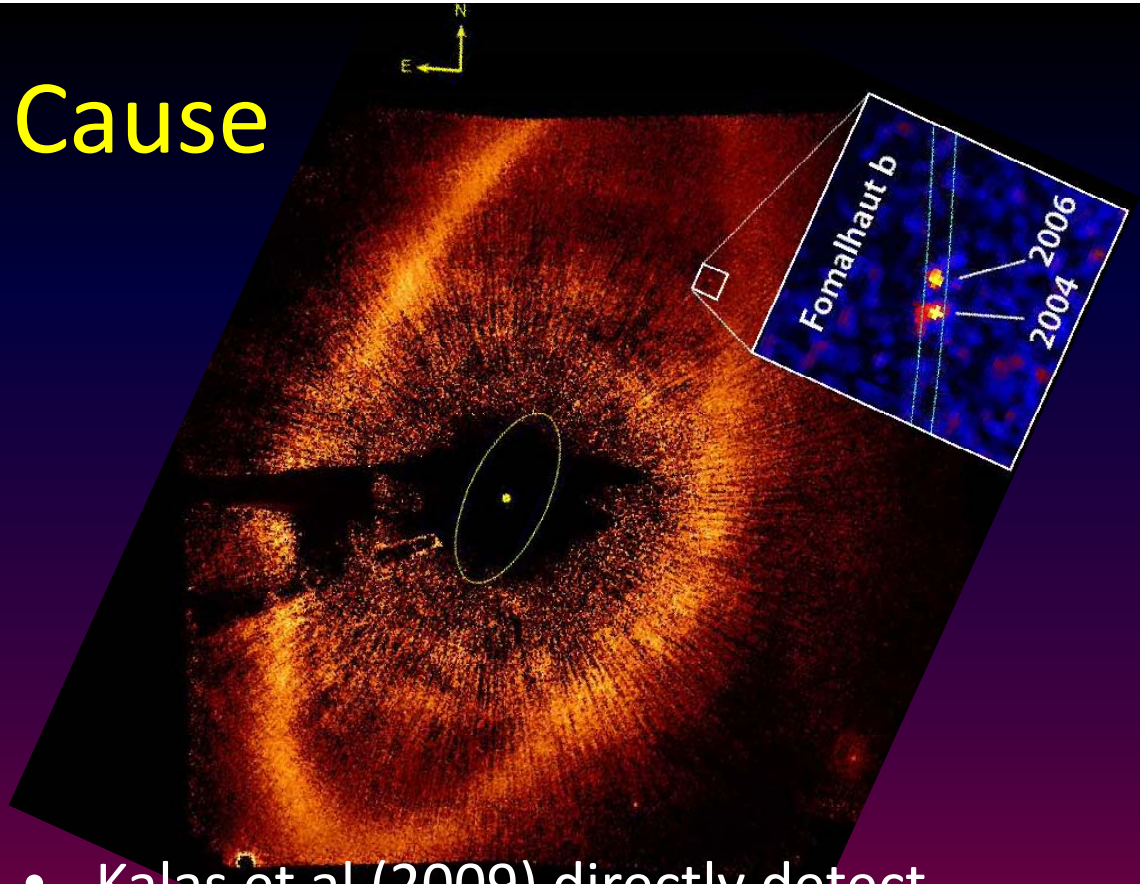




- A3V star at 7.7 pc; 200 Myr
- Submm suggests disk perturbed by planet (e=0.07)
- MIPS resolves SE ansa into ring with azimuthal variations from warmer dust at periastron
  - 350 µm ring displaced 8 AU
    - – Excess material at apocenter due to slow orbital motion
    - –Perturber: 86 AU orbit and e=0.07, M>> MEarth

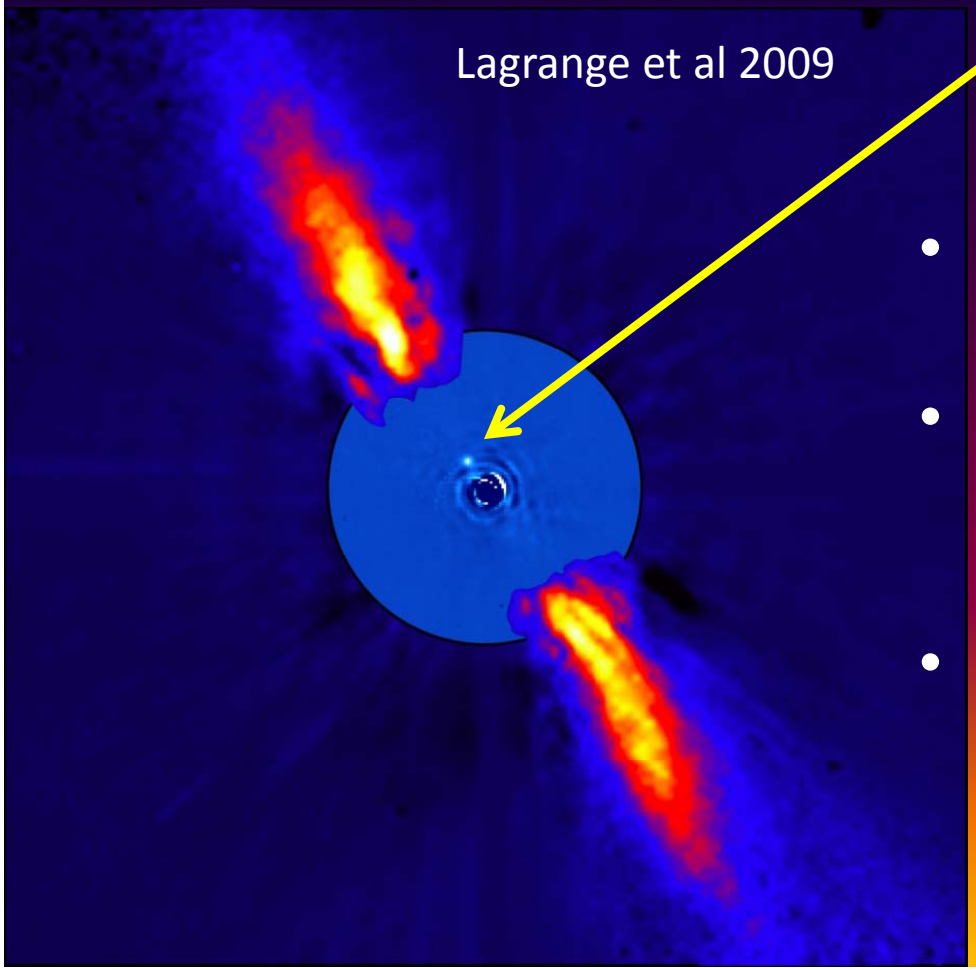
HST/Keck Finds Cause of Disk Offset

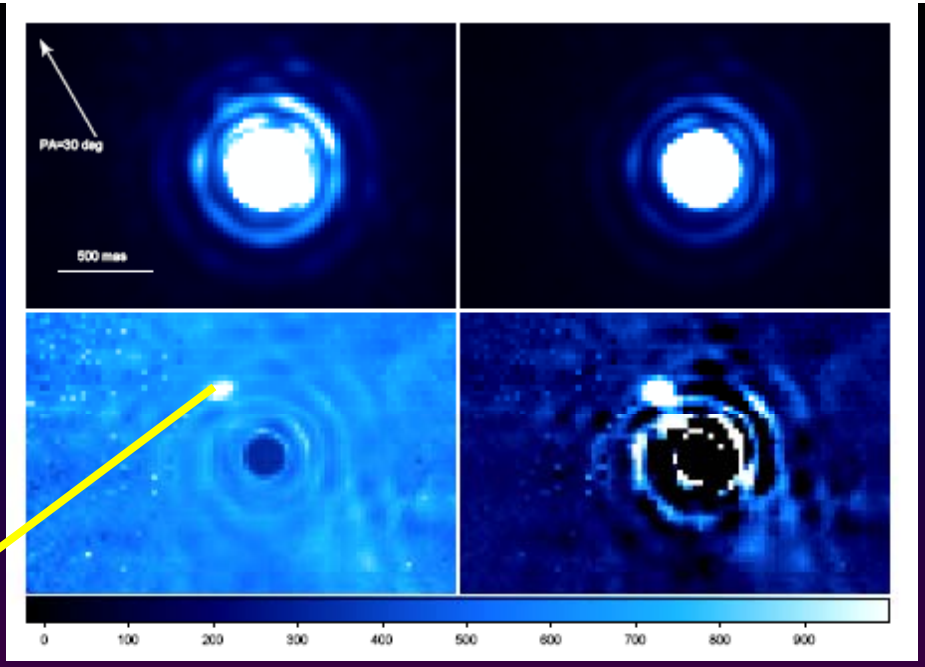




- Kalas et al (2009) directly detect Fomalhaut-b at 115 AU, e~0.13
- Common Proper Motion and evidence of orbital motion (1.4 AU in 1.7 yr)➔P=872 yr
- Quasi-dynamical mass: M≤ 3 MJup to avoid disrupting/spreading disk

Another Planet Disk Interaction?

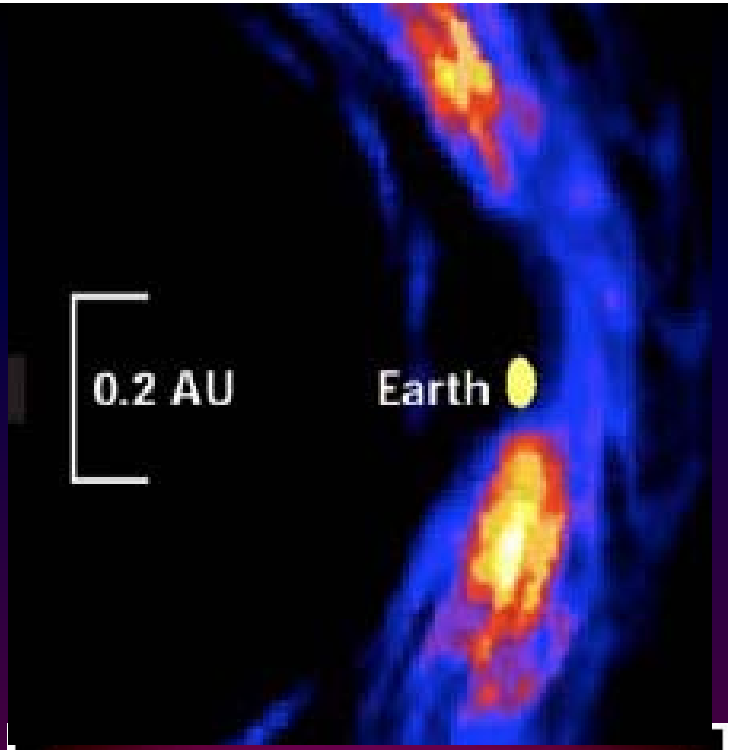


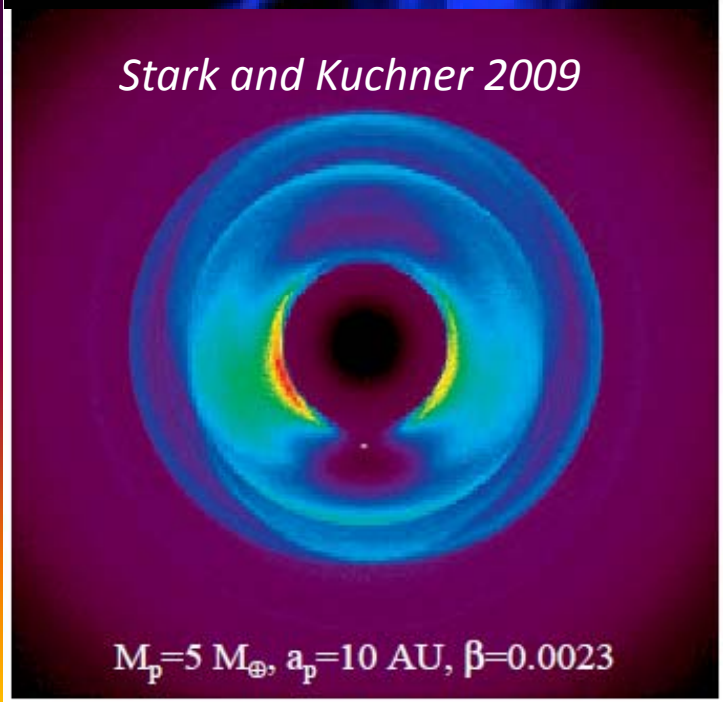


- Canonical IRAS disk with warp and multiple substructures
- Models predict planet 6-13 MJ at 10-8 AU (Mouillet 1997; Heap 2000)
- Deep L-band imaging reveals object 8 AU from β Pic, possibly 8 MJ planet (awaits RV, proper motion confirmation)

Planets Affect Their Disks

- Planets as small as Earth create resonant structures in EZ clouds (wakes and rings)
- Structures can masquerade as planets for imaging systems with low resolution (coronagraphs) or low information density (interferometers)



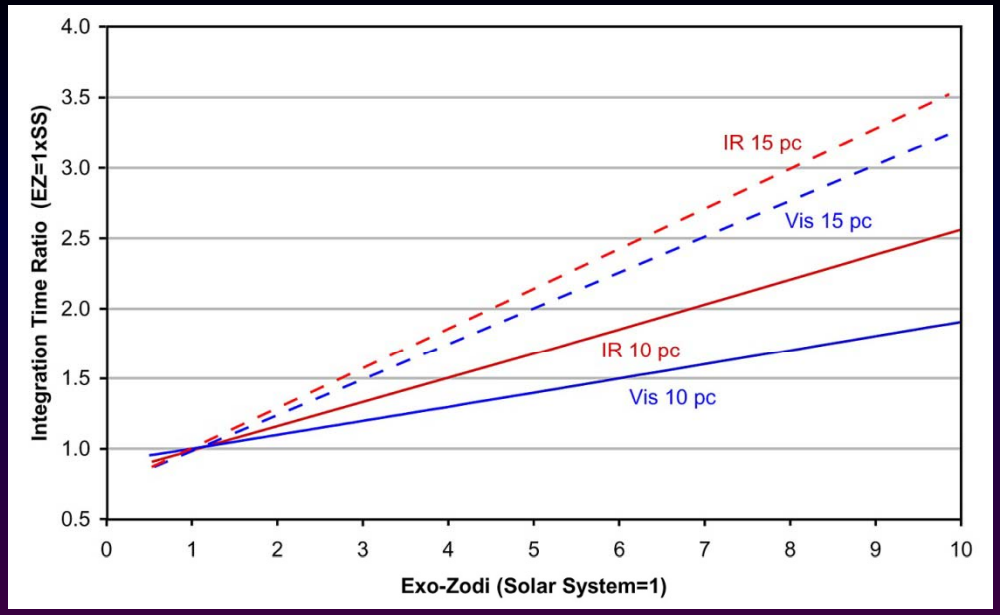



Stars are a billion times brighter…

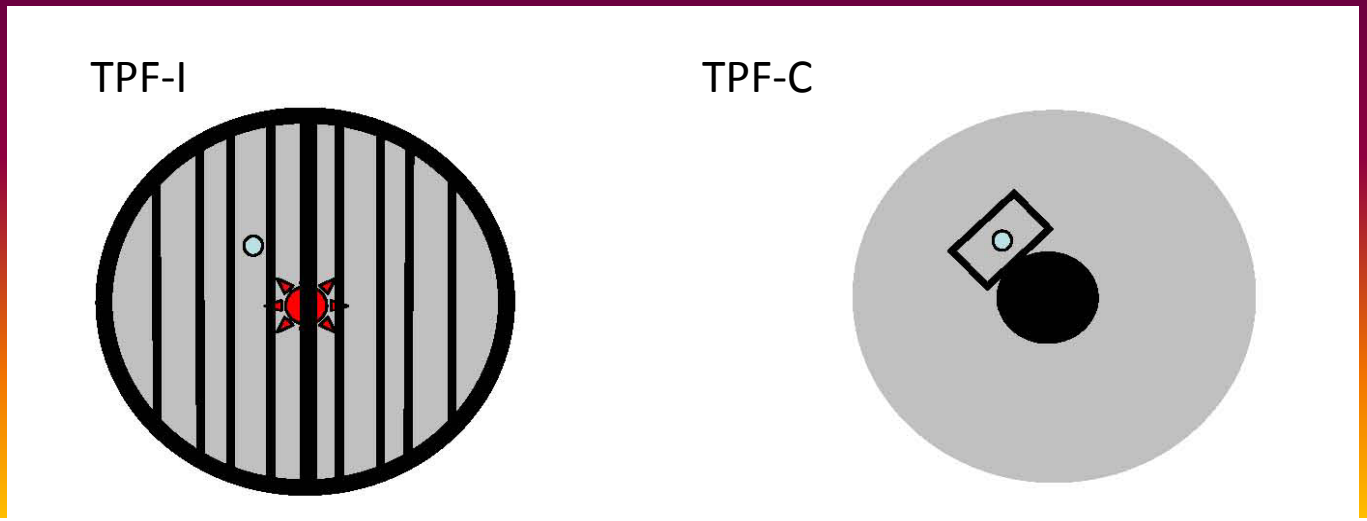

…than the planet
…hidden
in the glare.


Like this firefly.
Exozoo!

The Problem for Earth-Detection

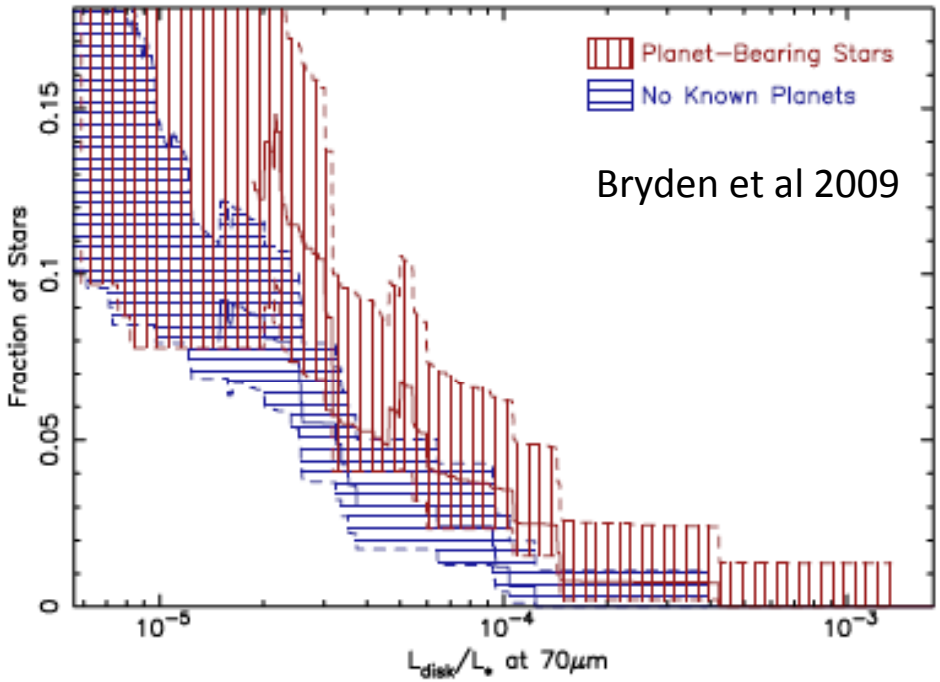


- Total ExoZodi (EZ) ~300 x planet signal for Solar System Zodiacal cloud
- Photon noise from (EZ) can overwhelm planet
- Signal within single pixel (~λ/D) significant for >10 zodi for either visible or IR



Spitzer Limits to Debris Disks

- L_d/L_*~10^{-5} ~10^{-6} for cold dust (30-60 K, >10 AU; 70 μm) for roughly 14% of stars.
- No statistical difference between debris disk incidence for stars with or w/o planets
- Stars with planets may have brighter disks



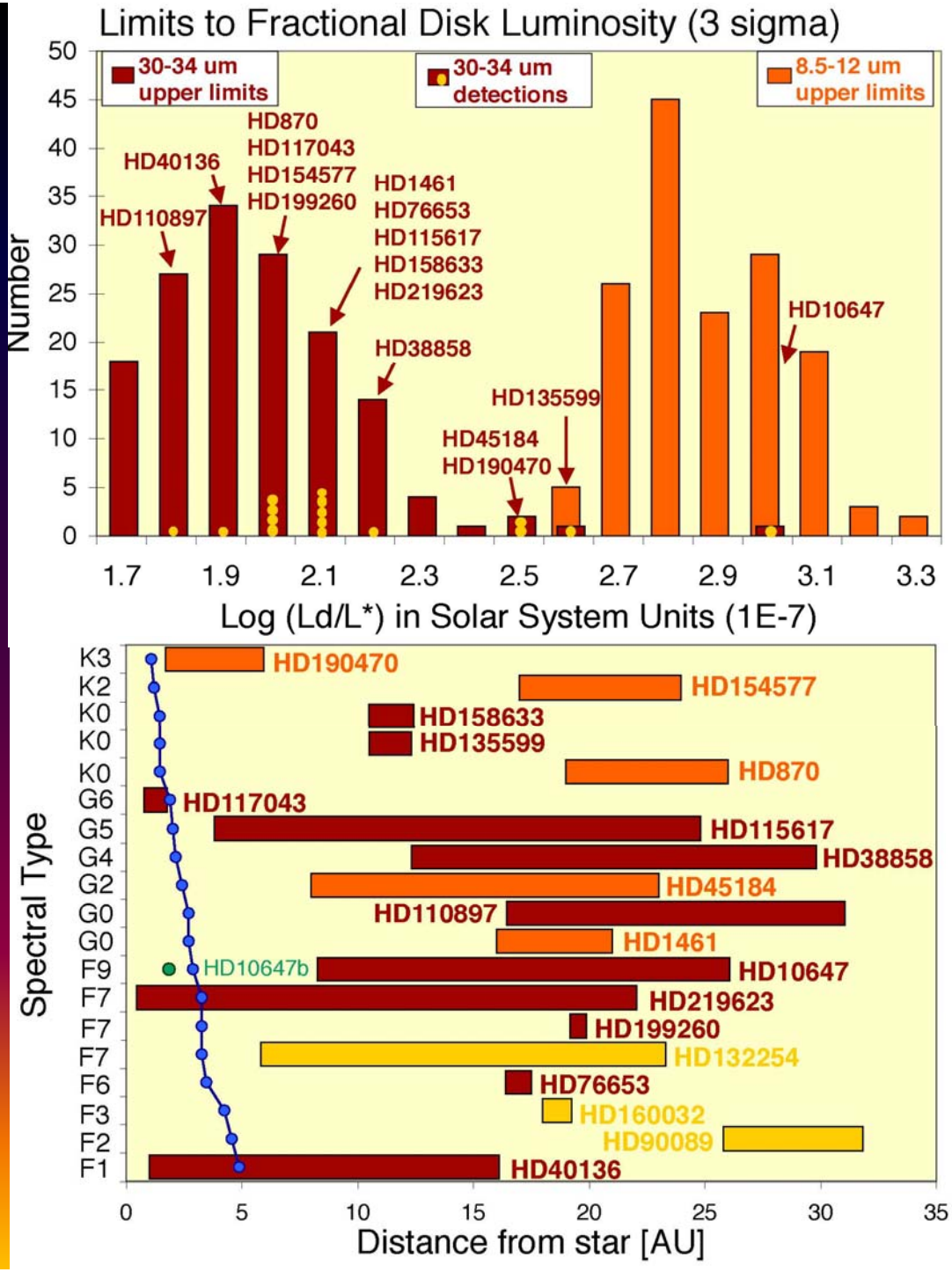
Bryden et al 2009

Table 2
Summary of Detection Statistics at 70 μm

Metric	Stars Without Known Planets	Stars With Known Planets[a]
Detection of significant IR excess	23/165 (14% ± 3%)	13/139 (9% ± 3%)
Detection of strong excess ($L_{dust}/L_* > 10^{-4}$)	2/165 (1.2% ± 0.9%)	4/113[b] (3.5% ± 1.7%

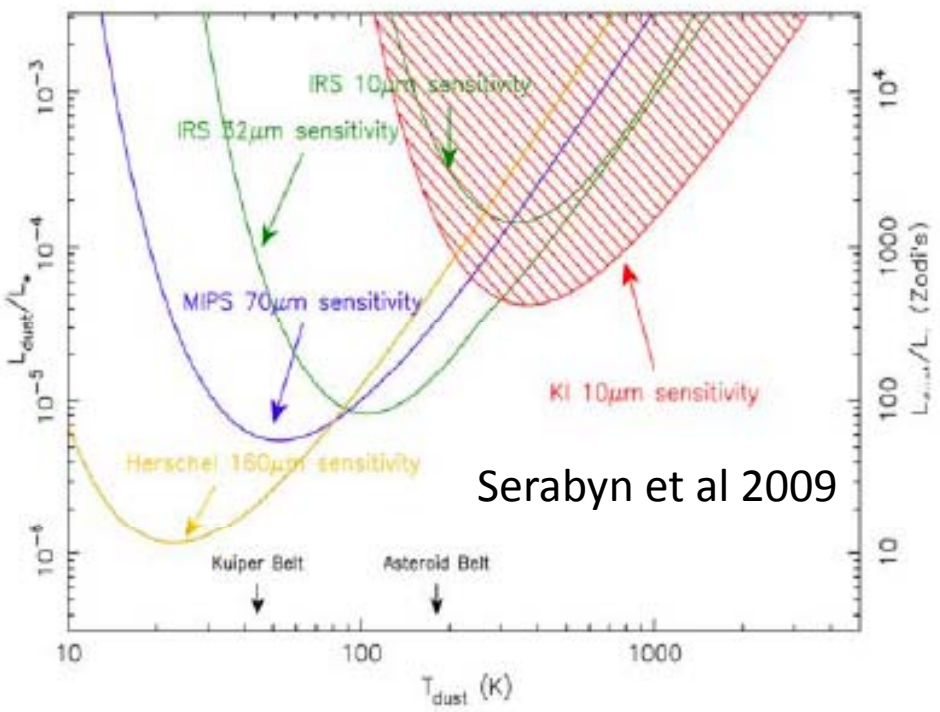
Spitzer Limits In the HZ

- $L_d/L_* < 10^{-4}$ (1,000 zodi; 3 σ) for hot dust in Habitable Zone (10 μm) for 1-2 % of mature stars
- Only 1 system with strong HZ disk. Also 3 planets within 1 AU (HD 69830)
- Limits of few 100 zodi outside of ice-line (5-10 AU)



Keck Interferometer: The Next Step

- Keck survey of nearby stars for EZ dust
  - –Hinz (UofA), Kuchner (GSFC), Serabyn (JPL)
- Known disk systems & nearby main sequence stars
- 32 interferometer nights (2008 –2009)
  - – 44 targets
  - – No large excess for 40 targets
- Factor of 3-5 deeper than Spitzer in HZ



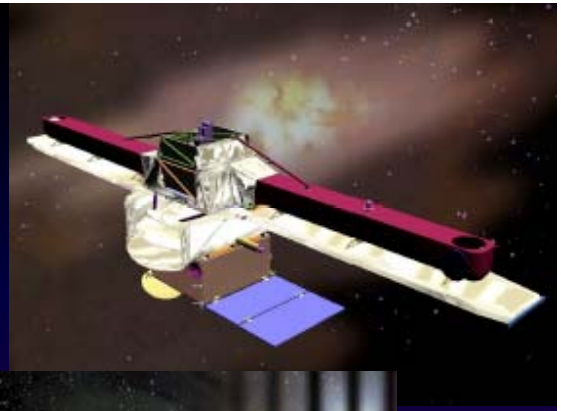
Serabyn et al 2009

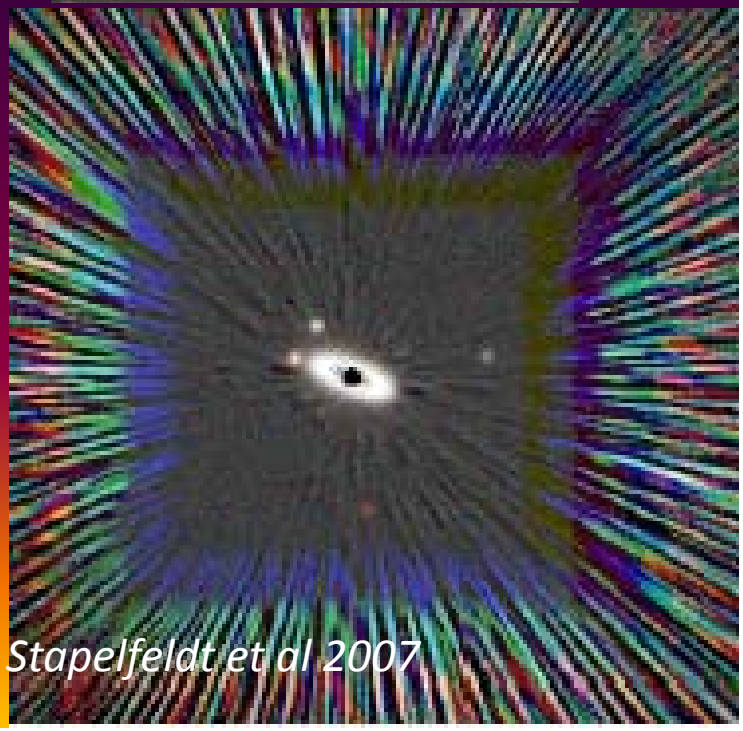
LBTI: Next^2 Step

- Lower background of LBTI (wrt KI) should enable LBTI to push down to 10 zodi (5-10x better than KI)
- Starting in 2012, LBTI will undertake a survey of 60 nearby stars for zodiacal dust to 3-10 times our own planetary system

The Next^3 Step: A Dedicated Space Mission

- 10 μm Interferometry from space can reach 1 zodi
  - Pegase, (separated s/c interferometer) being investigated by CNES
  - FKSI, interferometer on a stick being investigated by GSFC-led team (Danchi et al)
- Visible coronagraphy (Trauger, Stapelfeldt)
  - High contrast imaging with ~2 m telescope at 1-5 zodi as well as imaging nearby Jupiters





Stapelfeldt et al 2007

The Next$^{\infty}$ Step: Imaging And Characterizing Earths

TPF-Coronagraph

Darwin/
TPF-Interferometer