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

- 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: \( M \leq 3 \) MJup to avoid disrupting/spreading disk
Another Planet Disk Interaction?

Lagrange et al 2009

- 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.
The Problem for Earth-Detection

- Total ExoZodi (EZ) $\sim 300 \times$ planet signal for Solar System Zodiacal cloud
- Photon noise from (EZ) can overwhelm planet
- Signal within single pixel ($\sim \lambda/D$) significant for $>10$ zodi for either visible or IR
Spitzer Limits to Debris Disks

• \( L_d/L_\star \approx 10^{-5} \sim 10^{-6} \) for cold dust (30-60 K, >10 AU; 70 \( \mu \)m) 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
Spitzer Limits In the HZ

- \( \frac{L_d}{L^*} < 10^{-4} \) (1,000 zodi; 3 \( \sigma \)) for hot dust in Habitable Zone (10 \( \mu \)m) 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 (UoF), Kuchner (GSFC), Serabyn (JPL)
- Known disk systems & nearby main sequence stars
  - 44 targets
  - No large excess for 40 targets
- Factor of 3-5 deeper than Spitzer in HZ
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
The Next\(^\infty\) Step: Imaging And Characterizing Earths

TPF-Coronagraph

Darwin/
TPF-Interferometer

External Occultor (TPF-O)