exo-Zodi & exo-Earths

(The bright end of the exo-Zodi luminosity function and implications for disk evolution and exo-Earth detectability)

Grant Kennedy & Mark Wyatt, IoA, Cambridge
block starlight

brighter Zodi
= greater noise
= longer integration
= fewer detections

figure of merit:
>10 “zodi”=bad

find planet here
Questions:

✦ what is the origin of the dust?
✦ when/where is the dust brightest?
✦ what is the typical dust level?
✦ which stars should we observe?
✦ dust non-detections (i.e. KIN, LBTI)
✦ “best” (i.e. understanding exozodi)
HD 69830: an example exo-Zodi

*~3 Ga old, 3 planets, bright dust at 1 AU*

HD 69830: Not an old Asteroid belt that was bright when the star formed

Asteroid belts decay collisionally, so are not bright at late times

Wyatt et al 2007
Origins of detectable exo-Zodi

- Old stars
  - PR drag? (Wyatt05/van Lieshout14)
  - Comet delivery (not considered here, but definitely plausible)
  - Recent single collision
  - Dynamical instability

- Young stars
  - All old star scenarios
  - Initially massive asteroid belt
  - Terrestrial planet formation

\{ \text{start at time } \sim 0 \} \quad \sim \text{random in time}
Previous warm dust work

- Many surveys used for large-scale warm dust searches:
  - 10-20µm ideally suited for terrestrial zone dust
  - i.e. IRAS, MSX, AKARI, Spitzer, WISE...
- Relatively small number of warm dust systems found:
  - e.g. Song et al 2005, Fujiwara et al 2010, Melis et al 2012
- Candidates reported, non-detections generally not
  - Occurrence rates unknown - quantify!
Goal: derive 12µm luminosity function

\[ \text{Fraction} > \frac{F_{\text{disk}}}{F_*} \left( = \frac{F_{\text{obs}}}{F_*} - 1 \right) \text{ at 12µm} \]
Goal: derive 12µm luminosity function

\[ \text{Fraction} > \frac{F_{\text{disk}}}{F_*} \left( = \frac{F_{\text{obs}}}{F_*} - 1 \right) \text{ at } 12\mu m \]

Photometric surveys (rare bright disks)

Kepler FOV limit

WISE detections here

Fraction $> F_{\text{disk}} / F_*$ at 12µm

approximate Solar System level

TPF limit

KIN

PTI unique

prediction here

\[ F_{\text{disk}} / F_* \] at 12µm
Sample: Hipparcos x WISE

Select 24,174 MS FGK-type stars from Hipparcos

❖ Select candidates using W1-W3 (3-12µm) colour
❖ Check images and SEDs by hand, resulted in 25 excess systems

see also poster #69: Stan Metchev
## 22 warm dust candidates
(from 24,174 targets)

<table>
<thead>
<tr>
<th>HIP</th>
<th>Name</th>
<th>$R_{12}$</th>
<th>$T_{BB}$</th>
<th>Spty</th>
<th>Age</th>
<th>Group</th>
<th>Comments</th>
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<td>8920</td>
<td>BD+20 307</td>
<td></td>
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<td></td>
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<td>Close binary, no cold dust (1,2)</td>
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<td>LCC?</td>
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<td>TWA Close binary in quadruple system. Possible transition disk. (11,12)</td>
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<td>260</td>
<td>F3</td>
<td>17Myr</td>
<td>LCC</td>
<td>Excess around primary in 160AU binary (8,14)</td>
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</table>

Well known warm dust systems recovered

Many are young

Several protoplanetary disks (discarded)
12µm disk/star flux distribution

Bright warm dust is a 1:1,000-10,000 occurrence

Fraction > F_{disk}/F_{star} at 12µm

WISE detection limit
Young disks common, old disks rare

Assume ages distributed evenly across MS lifetime for each spectral type

\[ \sim 600 < 120 \text{ Myr}, \sim 20,000 > 1 \text{ Gyr} \]
Two component model

1) All stars born with an initially massive asteroid belt needed for young warm dust systems
2) Dust also produced randomly once along the MS needed for rare old warm dust systems

Neither scenario works individually, but combined model reasonable

Initially massive and random collision

Monte Carlo realisations of model

Both decay as $1/t$

Neither scenario works individually, but combined model reasonable
Combined model for sample

Prediction:
Good for LBTI
Bad for TPF
Current/future tests

- Mennesson et al Keck Nuller paper (submitted)
- Consistent with model overall
- Warm/cold dust correlation - PR-drag/comets?
- SpiKes - IRAC survey of Kepler field
- LBTI
- Detection of eta Corvi (in prep)
- HOSTS survey ~50 stars
- Strong test, model updates, etc...
Summary

- Bright warm dust 1:10,000 occurrence for old MS stars
- Simple collisional prediction yields high typical dust levels
- BUT this prediction is model dependent

- Keck Nuller, LBTI - inform future models & predictions
Observing old stars may not help

Rare bright warm dust systems spend most of their time decaying through fainter levels later on
Detecatable zodi limit

Solar System level

Sensitivity

Sun-like

M0V  K0V  G0V  F0V  A0V
HD 166191 interpretations

Two-component debris disk

OR

Transition disk

near optically thick
very high mass
very short lifetime

consistent with ~4Myr age
“primordial” silicate feature

Schneider et al 2014

Kennedy et al 2014
The exo-zodi “problem”

where is the planet?

here!

Chris Stark/Roberge et al 2012