Kuiper Belt dust and extrasolar debris discs

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Kuiper Belt in the far-IR

• the cold emission is very hard to see from our position inside the zodiacal / asteroidal dust

Fig. 4.—The IRAS data shown in Fig. 3 minus the model fit, i.e., the “residuals.” The residuals are due to warm dust band, Galactic plane emission (estimated as the dash-dot line). The vertical bars at 180° inclination are the estimates of the peak flux a cold cloud surrounding the solar system could have and be consistent with the data.
...but the Sun's debris IS faint

- tau Ceti at 3.65 pc has a debris disc much brighter than the Sun
  - NB this flux is only ~6x the confusion limit of a 15m telescope in the long-submm!

Greaves et al. 2004
expected particles

• impacts on *Pioneer 10* showed Kuiper Belt dust does exist – particles of 10+ micron, to 18 AU (when instrument failed)

• there are models predicting the distributions of different particle sizes under Poynting-Robertson drag and radiation pressure

Landgraf 2005, 2002
particle detection now

- the Student Dust Collector on New Horizons is now working at 14 AU and sensitive to particles just under 1 micron - plenty seen so far

lasp.coloradu.edu/sdc/
inferences from Spitzer

• volume-limited surveys of Sun analogues show cool debris in ~20%, with little trend with any other system property

Greaves & Wyatt 2010, from MIPS/70 data of Trilling et al. 2008; Beichman et al. 2006.

Darker symbol = less luminous star; smaller symbol = younger star; circle = star with planet; square = multiple star system
Solar twins

- e.g. other G2 V stars within 20 pc of the Sun:

<table>
<thead>
<tr>
<th>Star</th>
<th>Age (Gyr)</th>
<th>$E_{70}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD 102365</td>
<td>9</td>
<td>$-0.2 \pm 0.2$</td>
</tr>
<tr>
<td>HD 146233</td>
<td>5</td>
<td>$0.1 \pm 0.4$</td>
</tr>
<tr>
<td>HD 136352</td>
<td>12</td>
<td>$-0.1 \pm 0.3$</td>
</tr>
<tr>
<td>HD 38858</td>
<td>5</td>
<td>$9.3 \pm 0.7$</td>
</tr>
<tr>
<td>HD 217014</td>
<td>7</td>
<td>$0.3 \pm 0.2$</td>
</tr>
<tr>
<td>HD 130948</td>
<td>1</td>
<td>$-0.3 \pm 0.2$</td>
</tr>
</tbody>
</table>

see N. M. Phillips et al. 2010: arXiv 0911.3426:
detailed tables for nearest ~100 each A, F, G, K & M dwarfs
mapping faint belts

- Herschel detection is favourable in the short submm, e.g. PACS/170 and SPIRE 250-500
  - (modulo final calibration) DEBRIS science demo data finds a 30 K, $L_d/L_* \sim 5 \times 10^{-7}$ belt!

DEBRIS Key Project: PI Brenda Matthews, European PI Jane Greaves
our far-IR dust disc

- The Kuiper Belt excess is *not more than 2%* at 70 microns, placing the Sun in probably the *least dusty 10% of similar stars*.

Greaves & Wyatt 2010:

- Black line = power-law fit;
- Grey line = model prediction (including P-R drag) if discs are one ensemble;
- Dashed line = 2.5 sigma upper limit of non-detections;
- Yellow dot = maximum 70 micron excess of the Sun.
basis of Sun numbers

• from IRAS
  – KB peaks at \( \sim 3 \times 10^{-8} \ \text{W m}^{-2} \ \text{sr}^{-1} \) at 60 microns
    • take bandpass of 40 micron; belt \( \sim 10 \ \text{deg} \) high
  – gives 1 MJy (\( \pm 0.5 \) MJy from different scans)
    • but, COBE upper limit is \( \sim 0.33 \) MJy for features a few degrees across in latitude
  – from exo-belts, similar flux at 60 & 70 microns
  – and Sun = 100 MJy at 70 microns
    • if seen at \( \sim 45 \) AU like Kuiper Belt; for MIPS/70 filter

• gives estimate for Sun of \( E_{70} \leq 0.02 \) (2 sigma) - !!!
why map the Kuiper Belt?

• is it really so 'clean'? why?
  – we think our disc was cleared by a rather rare gas-giant migration event
    • Herschel will find out the context, for the nearest Sun analogues, where faint discs are resolvable

• if there's little dust, what kinds are there?
  – size distribution of particles tells us uniquely how comets shatter and how dust evolves
    • is the low dustiness just a boring moment in time?

• how does sculpting by planets really work?
• what goes here?

Schlichting et al. 2009: occultation by an ~500 meter KBO see by HST FGS
mission parameters

- Kuiper Belt dust will have low surface brightness in the far-IR/submm
  - hence high confusion with small aperture
    - and too cool to emit much in short-IR?
- optical is very promising
  - multi-wavelength for dust colours
    - sizes, composition
  - image structures within belt
    - times of origin, dynamical sculpting
  - only possible from outside the asteroid belt!