Kuiper Belt dust and extrasolar debris discs

Jane Greaves,
University of St Andrews

Scottish Universities Physics Alliance

Kuiper Belt in the far-IR

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

Aumann & Good 1990, from IRAS

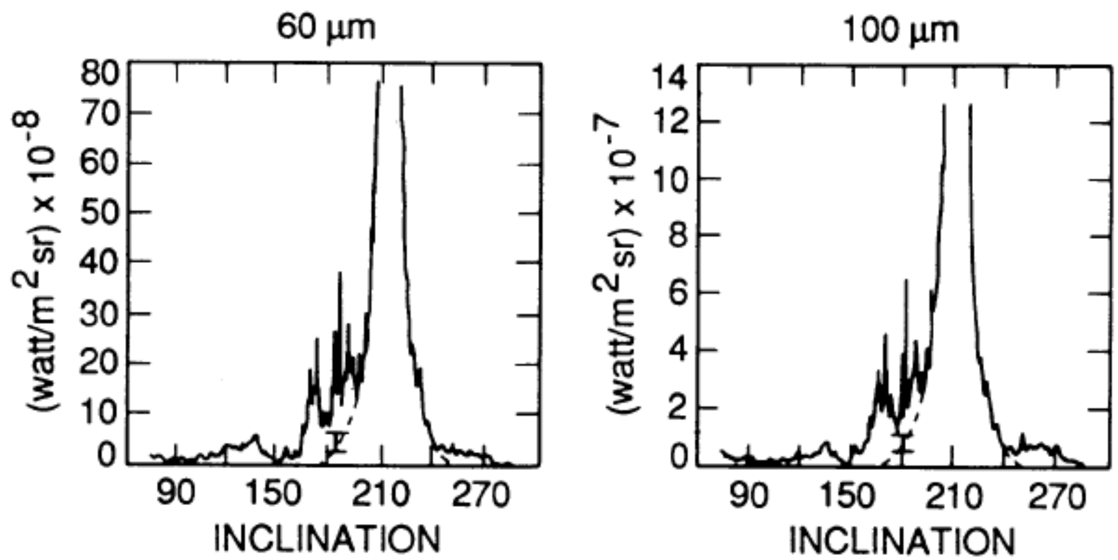
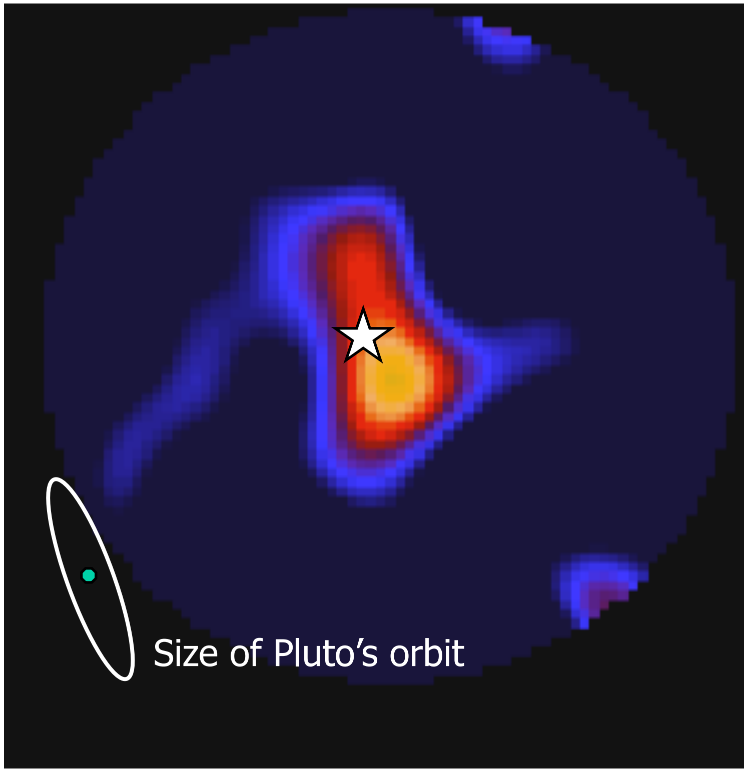


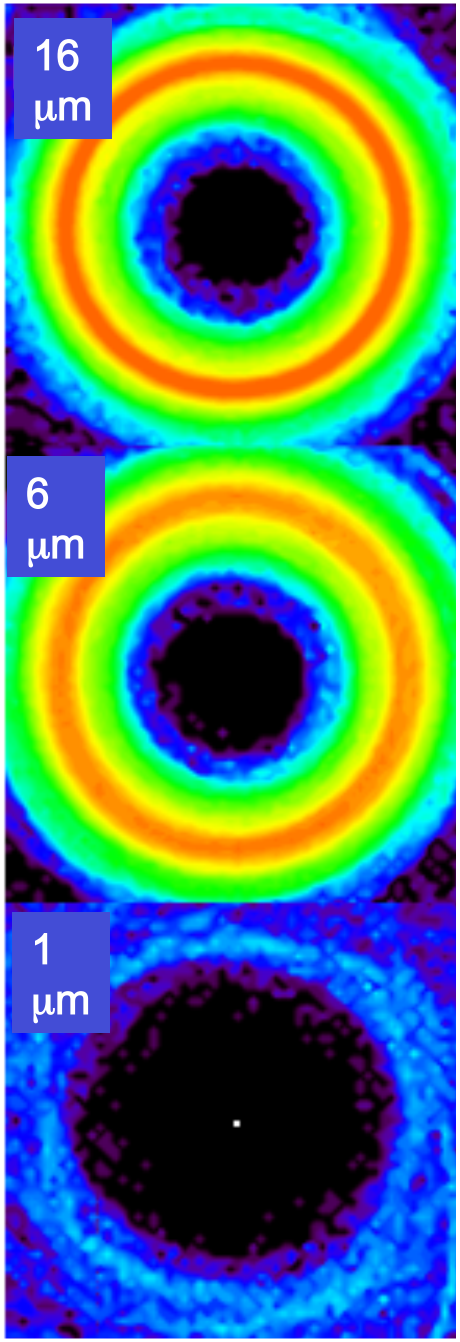
FIG. 4.—The *IRAS* data shown in Fig. 3 minus the model fit, i.e., the "residuals." The residuals are due to warm dust band, Galactic plane emission (*estimated as the dash-dot line*). The vertical bars at 180° inclination are the estimates of the peak flux a cold cloud surrounding the solar system could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

…but the Sun's debris IS faint



Greaves et al. 2004

- 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!



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

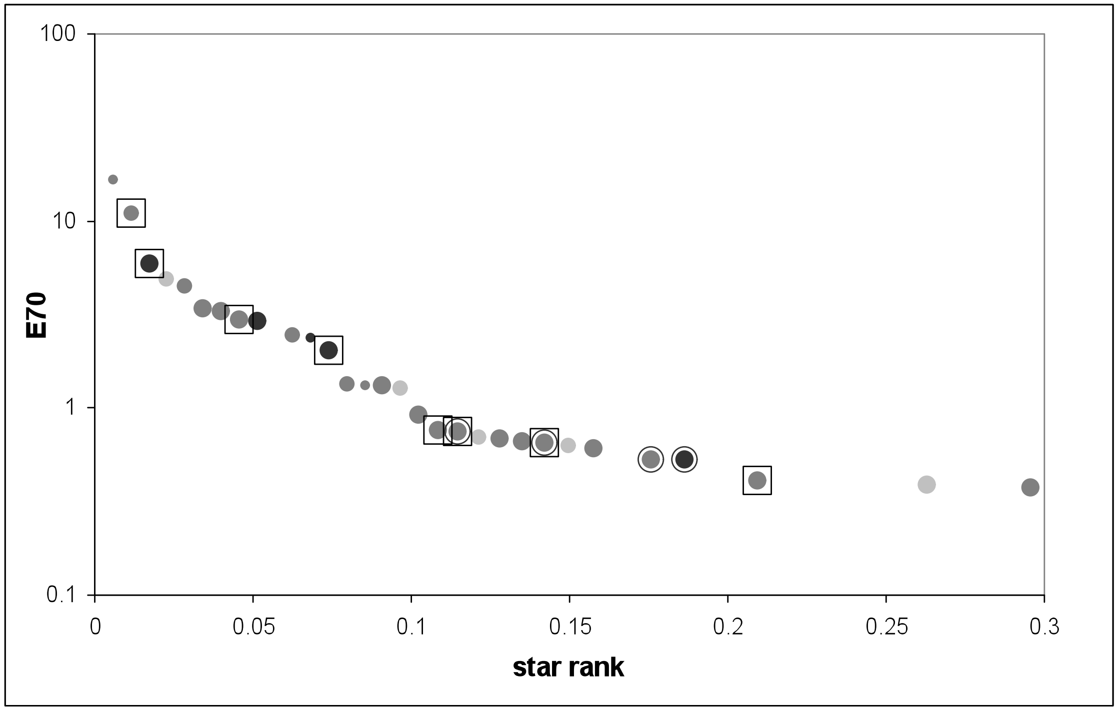
lasp.coloradu.edu/sdc/

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

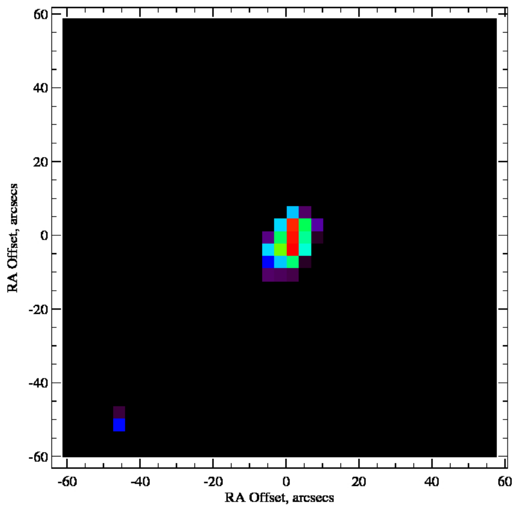
- e.g. other G2 V stars within 20 pc of the Sun:

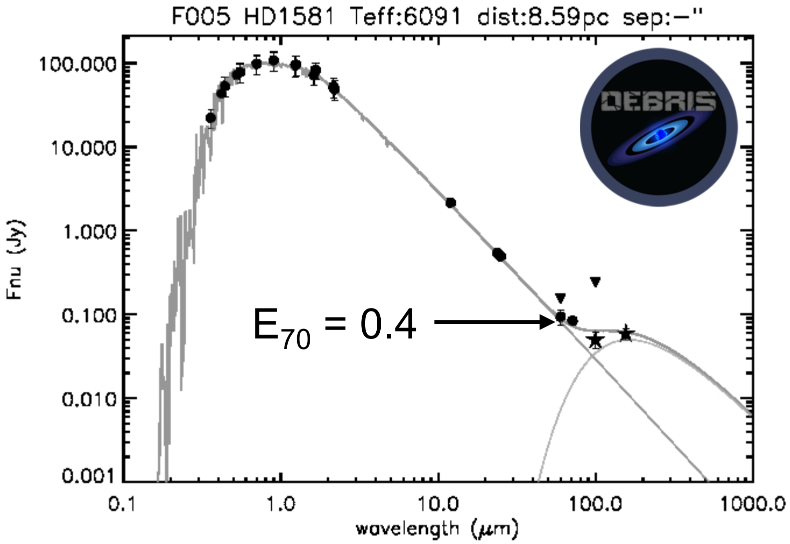
HD 102365	(9 Gyr)	$E_{70} = -0.2 \pm 0.2$
HD 146233	(5 Gyr)	$E_{70} = 0.1 \pm 0.4$
HD 136352	(12 Gyr)	$E_{70} = -0.1 \pm 0.3$
HD 38858	(5 Gyr)	$E_{70} = 9.3 \pm 0.7$
HD 217014	(7 Gyr)	$E_{70} = 0.3 \pm 0.2$
HD 130948	(1 Gyr)	$E_{70} = -0.3 \pm 0.2$

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, $L_d/L_* \sim 5\ 10^{-7}$ belt!





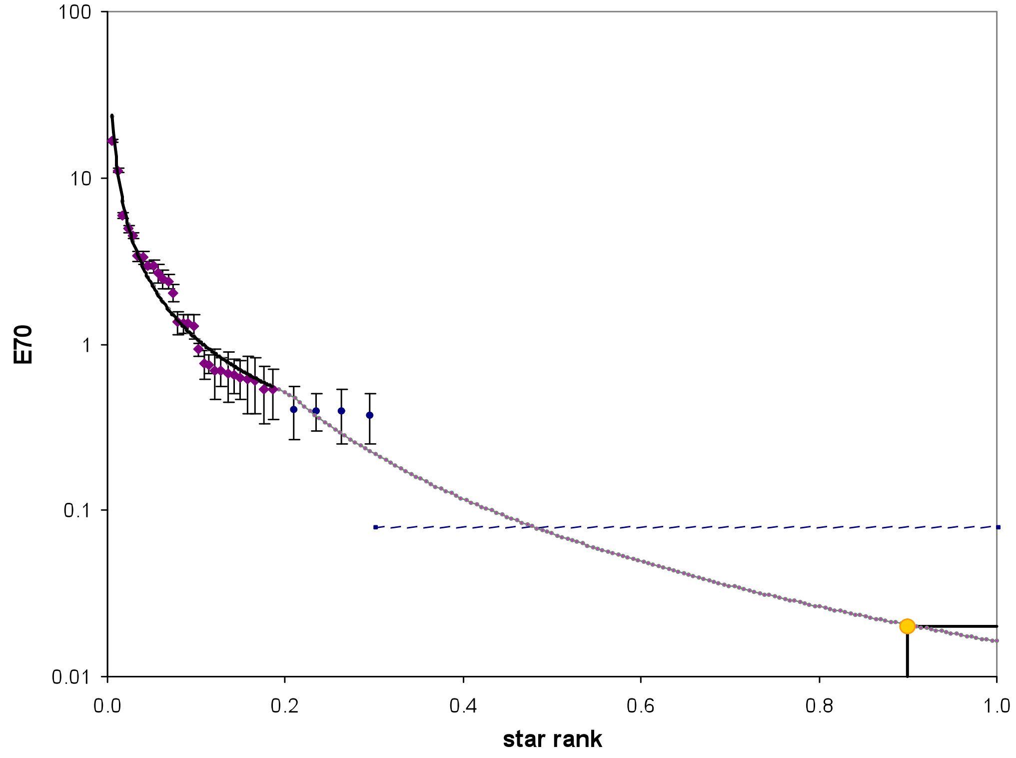
DEBRIS Key Project: PI Brenda Matthews, European PI Jane Greaves

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

Aumann & Good 1990

  - KB peaks at ~3 10^{-8} W m^{-2} sr^{-1} at 60 microns
    - take bandpass of 40 micron; belt ~10 deg high
  - gives 1 MJy (±0.5 MJy from different scans)
    - but, COBE upper limit is ~0.33 MJy for features a few degrees across in latitude

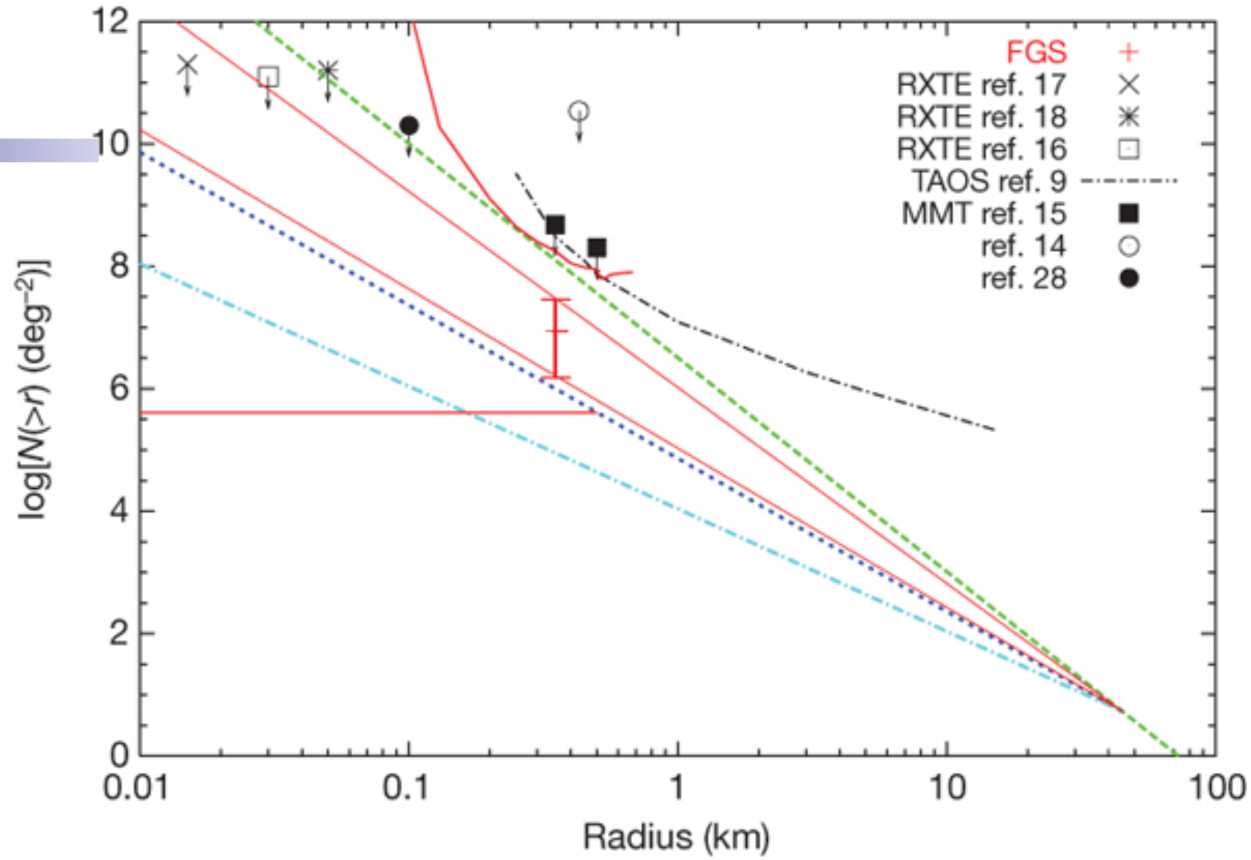
Backman et al. 1995

  - from exo-belts, similar flux at 60 & 70 microns
  - and Sun = 100 MJy at 70 microns
    - if seen at ~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 Booth et al. 2009
    - 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
  - <u>only possible from outside the asteroid belt!</u>