DUNES Observations of Cold Debris Discs

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DUNES

DUNES (DUst around NEarby Stars [1]) is one of several Herschel Open Time Key Programs looking at the formation and evolution of planetary systems from young gas-rich protoplanetary discs, to old and cold dust discs similar to the Edgeworth-Kuiper belt (EKB). Other programs include DEBRIS, DIGIT and GASPS [2]. Using the PACS instrument [3] on Herschel [4], the DUNES observing strategy is centred on the detection of the stellar photosphere at 100 μm with a signal-to-noise ratio of 5–10 for 133 nearby (d < 25 pc) Sun-like stars of spectral type F, G and K. This strategy has enabled us to detect flux excesses of a few mJy around these stars on top of the stellar photosphere (also at the level of a few mJy) [1,5].

Debris Discs

Debris discs around main sequence stars are believed to be the dusty by-product of an ongoing planet formation process. This is inferred from the lifetimes of the dust grains in these discs being much shorter than the age of the host star. The dust must therefore be continually replenished from collisonal grinding of a mass reservoir of larger (asteroid sized) bodies, implying the growth of rocky bodies up to several km in size in the system [6].

The discs we observe around other stars at far infrared wavelengths are analogous to the Edgeworth-Kuiper belt in the Solar System. If viewed from afar, the EKB would appear to be a cold (T ~ 30–40 K), faint ($L_{dust}/L_{\star} \sim 10^{-7}$) and extended (~ 100 AU) ring of dust [7] with a central void caused by the action of the giant planets [8]. It is exactly this sort of excess emission that the DUNES survey aims to find, locating solar system like discs around nearby sun-like stars.

Observation & Data Reduction

We have observed eight nearby (< 20 pc) main sequence dwarf stars with spectral types FGK. In each case, the star was observed to have a 100 μm PACS flux consistent with the stellar photosphere, or marginal (< 2σ) excess, but at 160 μm exhibited clear excess emission (see SEDs above right).

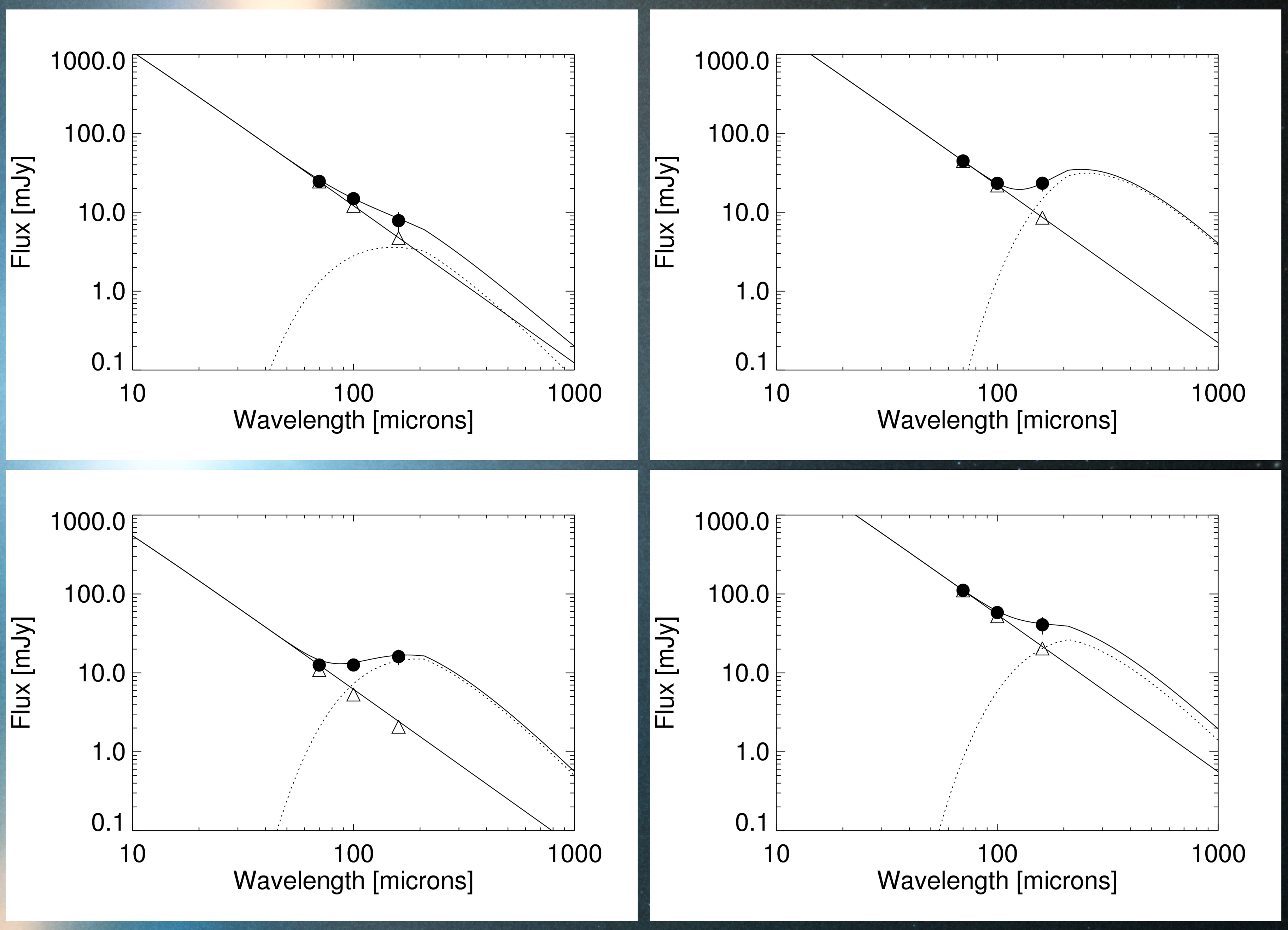
Observations were reduced in HIPE v4 700. Two scans at position angles of 70° and 110° were combined to produce a mosaic. Image pixel scales were 1'' for the blue bands, and 2'' for the red band.

Disc Properties

Using simple models we have estimated the range of temperatures, masses and fractional luminosities represented by these cold excess sources. We find, from the 100-160 μm colour, dust temperatures in the range 10–30 K, implying peak in emission beyond 200 μm. The disc fractional luminosities lie between 0.2–2.0 x10^{-6}. These are very similar to the expected EKB values, which combined with the lack of infrared excess at wavelengths < 100 μm, make these promising targets for studies of solar system like dust discs, quite different from previously known discs. The discovery and further study of these objects is an unexpected result of and made possible by *Herschel*'s unique capabilities.

Image: ESO/L. Calçada

Spectral Energy Distributions



Example SEDs of four of the eight cold disc candidates. In the figures, the predicted photospheric emission is denoted by the triangular data points and straight line, the observed fluxes are denoted by the filled circles. Uncertainties are 1-sigma and include calibration and sky noise. The dotted curve represents the blackbody emission fitted to the data points and the solid curve is the model of the combined stellar and disc emission from the system.

Discussion

In our analysis, the disc SEDs are fitted with temperatures from 15–50 K. For a peak in dust emission at 160 μm, equivalent to 30 K, the disc extent for black body grains would be 190 AU around an F0V star; 76 AU from a G2V star; 23 AU from a K9V star. For the case of the coldest disc around an F star, this would be an on-sky extent of 10'' at 20 pc, and for most of these sources the extent is expected to be much less (disc radial extent in the range 30–50 AU). One of the discs presented here is resolved at 160 μm.

An alternative scenario to the transport dominated one presented above is that these discs are "dynamically cold" [9]. In this case, the low collision velocities (due to small e, i) between dust producing planetessimals creates an imbalance between the rate at which small grains are produced and the rate at which they are destroyed, favouring destruction of small grains. This preferentially removes small dust grains from the system, leaving it colder and fainter (as small dust grains dominate the total contribution to the optical depth) than a disc with a standard steady state [10].

See Also

Poster by S. Ertel

References

[1] Eiroa et al., 2010
[2] Augereau et al., 2008
[3] Poglitsch et al., 2010
[4] Pilbratt et al., 2010
[5] Liseau et al., 2010
[6] Backman & Paresce, 1993
[7] Backman et al., 1995
[8] Moro-Martín & Malhotra, 2005
[9] Thébault & Wu, 2008
[10] Strubbe & Chiang, 2006