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'Dust around Nearby Stars' The Survey Observational Results

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Abstract.
In this conference proceedings we summarize the key observational findings of the Herschel DUNES survey. We found 31 discs in our sample, equating to an increased dust incidence with Herschel of 20.2 ± 2.0% compared to previous measurement of ∼ 12.5 ± 5% with Spitzer for the same population of nearby, Sun-like stars. We identify no trend towards fewer discs around later spectral types, as had previously been reported for A-M stars. Around half of the discs exhibit extended emission, representing a vast improvement in the number of spatially resolved debris discs and thereby the quality of modelling that can be applied to those systems. We also identify unusual sub-groups of discs, including 'steep SED' sources with dust spectral indexes in the 70–160 μm range, steeper than the Rayleigh-Jeans tail which, whilst not unheard of, are more typically seen at sub-mm wavelengths and candidate 'cold discs' which are identified through their lack of significant excess emission at wavelengths shorter than 100 μm.

Keywords. stars: infrared, stars: circumstellar matter, stars: planetary systems

1. Introduction

Circumstellar dust around mature main sequence stars is a marker for the occurence of a planet(esimal) formation process because the dust we observe, being shorter lived than the star it orbits, must be continually replenished from larger bodies (Wyatt 2008, Krivov 2010). The large, 3.5 m mirror of the Herschel Space Observatory (Pilbratt *et al.* 2010) provides high angular resolution and a sensitivity capable to not only detect, but spatially resolve debris discs around nearby stars at flux levels only 10–20 times higher than that predicted for the Solar system's Edgeworth-Kuiper belt (EKB, Vitense *et al.* 2012).

The Herschel Open Time Key Programme (OTKP) Dust around Nearby Stars (DUNES, Eiroa *et al.* 2010) observed 133 nearby, Sun-like stars searching for evidence of excess emission at far-infrared wavelengths above that expected from the star. The survey sample consisted of 124 stars within a 20 pc volume (124 stars) along with specific targets out to 25 pc which were known to host a debris disc from previous observations (9 stars). All of the stars were observed with PACS (Poglitsch *et al.* 2010) using the 100/160 μm channels, integrating long enough on each target to detect the stellar photosphere at 100 μm with a signal-to-noise of $\geqslant$5. Several of the targets were also observed with the PACS 70/160 μm combination and/or with SPIRE (Griffin *et al.* 2010) at 250, 350 and 500 μm depending on the expected properties of the source. In addition to the 133 stars observed directly by DUNES, we share observations of another 106 stars with another Herschel OTKP studying debr is discs, DEBRIS (Disc Emission from Bias-free Reconnaissance in the Infrared and Sub-millimetre, Matthews *et al.* 2010). In this proceedings we only detail results from targets observed directly by DUNES.

Table 1. Survey observational results. Number of newly detected/resolved sources in brackets.

Type	**F**	**G**	**K**	**Total**
$N_{\rm obs}$ by DUNES	27	52	54	133
$N_{\rm obs}$ $d < 20$ pc	20	50	54	124
Non-excess	16	37	42	95
Contaminated	2	3	2	7
Excess	9 (2)	12 (3)	10 (5)	31 (10)
Excess $d < 20$ pc	4	11	10	25
Resolved discs	5 (4)	6 (4)	5 (5)	16 (13)

2. Overview

Here we present a digest of the observational results from the DUNES survey thus far, which are summarized in Table 1. A more in-depth summary can be found in the DUNES survey paper, Eiroa *et al.* 2013. All of the DUNES survey's Herschel data and ancilliary material (ancillary photometry, stellar models, etc.) will be made available through the virtual observatory at http://sdc.cab.inta-csic.es/dunes/.

Non-excess stars: In concordance with our stated survey objective, we detected the stellar photosphere of all our targets at 100 μm. Around the vast majority of the stars, $\sim$ 80%, we observed exhibited no significant far infrared excess emission. Assuming a typical dust temperature of 37 K, we placed 3-σ upper limits on the dust fractional luminosity at the (mean) level of $L_{\rm IR}/L_\star < 2{\times}10^{-6}$, around 20 times that of the predicted EKB. When aggregated, the measured 100 μm photosphere fluxes are in slight deficit compared to the predicted models based on a Rayleigh-Jeans extrapolation from mid-infrared wavelengths, which was also previously observed in the Spitzer 70 μm results of Hillenbrand *et al.* (2008), although in neither case is the deficit significant. α Centauri A, the nearest and brightest G-type star to us was observed with both PACS and SPIRE from 70–500 μm by DUNES and Hi-Gal. In the far infrared we me asured a significant deficit between the measured fluxes and extrapolated model at far infrared and sub-millimetre wavelengths. The deficit is attributed to the first direct detection of the temperature minimum of a star other than the Sun (Liseau *et al.* 2013). A major implication of this is that around Sun-like stars debris dust could 'hide' in this deficit, thereby causing dust masses around such stars to be underestimated.

Excess stars: We identified 31 debris disc stars in our sample, representing a disc incidence of 20.2 $\pm$ 2% (once those sources beyond 25 pc have been removed). This represents a real increase over the previous Spitzer measurement of $\sim$12% around the same sample (once contaminated sources identified by Herschel are removed) (Trilling *et al.* 2008). Furthermore, we see no evidence of a difference in the debris incidence around the F, G and K stars in our sample, contrary to Spitzer results. However, we do see trends between the dust and stellar properties; the radial extent of the discs increases with age, consistent with dynamical evolution of the disc occuring as an inside-out process.

Resolved discs: One of the most powerful results from DUNES has been that half (16/31) of the detected discs were resolved, or had extended emission along the disc major axis. Three of the discs were known to be extended from previous Spitzer observations HIP 7978 (Liseau *et al.* 2010, Augereau *et al.* in prep.), HIP32480 (Stapelfeldt *et al.,* in prep.) and HIP107649 (Marshall *et al.* 2011, Löhne *et al.* 2012). Fixing the dust spatial location through this information, in combination with the high angular resolution of Herschel providing tight constraints (compared to the dust blackbody radius) even in those cases where the dust is unresolved, facilitated detailed modelling of the dust physical parameters in combination with these spatial constraints on the dust location.

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Unusual SEDs: Two sub-samples of unusual disc sources have been identified within the DUNES sample; 'steep SED' discs and 'cold disc' candidates. The first of these show a marked fall off of the disc emission at wavelengths between 70–160 μm, more commonly seen at sub-millimetre wavelengths. In these discs the shape of the SED is attributed to either a steeper particle size distribution than that attributed to a steady-state collisional cascade, or that the largest (dominant) dust grain size in these discs is relatively small, only 10s of microns (Ertel *et al.* 2012). The 'cold disc' candidates are unusual in that they only exhibit excess emission at wavelengths beyond 70 μm, whilst typical debris discs peak at wavelengths 60–100 μm. Such cold dust could be evidence of contamination by a background galaxy, but the number of candidates (7) precludes that all of these sources might be spurious (1.2% for all 7), although the probability for individual conta mination is high (39%) (Eiroa *et al.* 2012, Krivov *et al.* 2013, Marshall *et al.* submitted). Furthermore, a similar object identified in the DEBRIS survey was subsequently identified as the product of contamination through stellar proper motion (Kennedy, priv. comm.), such that confirmation of these objects is required.

Debris-Exoplanet correlations: In combination with the DEBRIS survey, we compiled a sample of all 35 radial velocity exoplanet host stars within 20 pc and subjected them to an analysis, correlating the dust, planet and stellar parameters looking for trends. Searching for trends linking the presence of dust and planets with the stellar properties we identified a trend between stars with low mass planets, sub-Solar metallicities and a detectable debris disc, finding 5/9 stars in our sample with such properties. We attribute the correlation between these parameters to evidence of planet formation by core accretion in these systems. These results will be presented in a companion papers detailing the observed sample and the statistical analysis (Marshall *et al.* in prep., Moro-Martín *et al.* in prep.). Further work on the correlation between exoplanets and debris discs by Herschel will be forthcoming from the open time programme SKARPS (Stars with Kuiper belts and Radial velocity Planets, Bryden *et al.* in prep.).

3. Summary

The DUNES survey has observed 133 nearby, Sun-like stars, detecting excess emission from 31 stars, of which 10 are newly identified debris discs. Half the detected discs are seen to be extended along at least their major axis, providing a constraint to the spatial location of the dust around these stars. We see no change in the relative fraction of discs around stars of different spectral type, in contrast to previous results from Spitzer.

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Discussion

METCHEV: How do you explain the lack of dependence of the debris disc detection frequency on spectral type?

MARSHALL: I think the key here is that for all the stars in our 20 pc sample we are sensitive enough to detect the photosphere at 100 μm and can often (but not always) detect the photosphere at 160 μm. We are therefore more sensitive in terms of $L_{\rm IR}/L_\star$ than Spitzer (by a factor of $\sim$ 5), which was much more strongly volume-limited by spectral type for photosphere detection, particularly for K stars, due to the higher confusion noise level. Since we have information across the peak of the dust SED for all our discs (when combined with previous Spitzer 70 μm measurements) and a constraint on the stellar flux, we can determine the presence of cooler and fainter dust than previously possible - indeed, half of our new debris discs (5/10) are found around K stars.

WEINBERGER: Could you comment further on how you estimate the contamination rates and whether updated Herschel deep extragalactic counts have been included?

MARSHALL: The contamination rates for our sample were determined using the Herschel PACS cosmological survey number counts in Berta *et al.* 2011 and the contamination estimates based on the flux limited DEBRIS survey in Sibthorpe *et al.* 2012. The actual probability of contamination was based on the probability of chance alignment within the PSF FWHM of a background source with a brightness of the same level of flux as the measured 100 μm excess.

WEINBERGER: Follow-up: Are there individual cases of nearby stars re-observed with Herschel where proper motion definitely confirms whether an asymmetry in the disc moves with the star?

MARSHALL: Excepting the obvious case of the ring around Fomalhaut, I cannot think of another disc that Herschel observed and resolved that was known to be asymmetric from e.g. HST scattered light observations. However, that is more due to the fact that asymmetric discs are rare and the angular resolution of Herschel, whilst vastly superior to previous far infrared satellite observatories, is still relatively poor in the grand scheme of things (PSF FWHM 6.7$''$ at 100 μm). As previously highlighted, one of the key results from Herschel/DUNES has been being able to detect the extended emission from a large fraction of the detected debris discs.

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