DUNES: DUst disks around NEarby Stars
(A Herschel Key Programme)

Cold Disks around Nearby Stars. A search for Edgeworth- Kuiper Belt analogues

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Summary: DUNES is a sensitivity Herschel Key Programme that aims at finding and characterizing faint exo-solar analogues to the Edgeworth-Kuiper belt in a statiscal sample of volume-limited, nearby (d < 20 pc), FGK main-sequence stars. It naturally includes a broad range of ages (0.1 to 10 Gyr) and metallicities, as well as tars with known exoplanets (in this case up to 25 pc). The goal is to use the unique capabilities provided by Herschel to perform a deep systematic survey for faint, cold debris disks in order to find the fractional incidence of planetesimals systems in the solar neighbourhood.

Context: The discovery in the early 80s by IRAS of IR excesses around MS stars came as a big surprise. Since lifetimes of dust grains against radiative/wind removal and collisional disruption are much shorter than the ages of the stars, one must conclude that these mature stars are surrounded by a significant amount of dust *–debris disks-* which is not primordial, but rather produced by ongoing processes. In any debris disk model, dust production results from collisional events within a substantial population of large bodies.

Current observational results and theoretical insights of debris disks are mainly based on data from infrared space missions (IRAS + ISO + Spitzer) and ground-based (sub)mm facilities (JCMT, SEST, IRAM, APEX). In particular, Spitzer has dramatically improved our understanding of debris disks in many different ways. Some of its main results are:

- Spitzer sensitivity: $L_{dust}/L_* >$ several times 10^{-6}
- ~15% IR excesses at 70 µm around F5-K5 mature stars (> 1 yr)
- Higher incidence of dust emission for A stars, lower for M stars
- Global decline of debris disk emission with stellar age
- For same age, large IR excess dispersion
- "Trend": higher incidence around binary stars
- No dependence on metallicity
- No dependence on planets, althought planets make disks brighter
- Debris disks around solar-type stars much stronger and frequent at 70 µm than at 24 µm
- Detection rate very low for hot dust at 10 µm (<1%)
- SEDs ➔ material between 10 - 100 AU, large grains, but also µm-sized grains
- Mass and dust properties degenerated because unknown particle size distribution

DUNES Scientific Objective. The question of how common planetary systems are is fundamental for Astrophysics. The proposed Herschel observations will provide new and unique evidence for the presence of mature planetary systems in the solar neighbourhood and in turn will address the universality of planets/planetary systems formation in disks around young stars. The sensitivity and spectral range provided by Herschel will offer the best chance of detecting fainter dust disks than was previously possible.

Specific Objective: i) Herschel as a finder of of faint exo-EKBs

- Nominal solar EKB brightness: $L_{dust}/L_* \sim 10^{-7}$
- Prediction of current solar EKB models: F(100 µm) ~ 6-9 mJy (at 10 pc),
  ➔ above the Herschel sensitivity limit (5σ, 1 hour, PACS100)

➢ **Fig. 1 (left panel): discovery space of Herschel at different bands.**
➔ **PACS100 µm most suitable band i) to identify the fainter disks** ever detected for dust temperatures ~20 – 100 K (optimum: EKB-like temperatures, **30-40 K**),
ii) to achieve dust emission similar to the EKB, **$L_{dust}/L_* \sim$ few 10^{-7}.**

➢ **Fig. 1 (right panel): expected Herschel detection rate based on Spitzer results.**
i) We expect to double the number of identified disks around nearby stars.
ii) A population of previously **unknown cold dust** would even increase this figure.

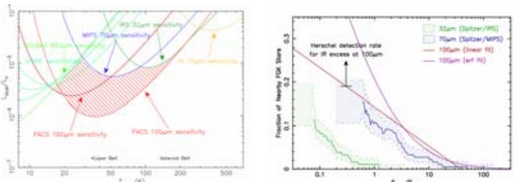

Fig.1. Left: Detection limits for a G5V star at 20 pc, following Bryden et al. (2006, ApJ 636, 1098). Assumed 1σ fractional flux accuracies are: 20% Spitzer/MIPS 70 µm; 2.5% Spitzer/IRS 32 µm; 10% PACS 100 µm; 100% (i.e. SNR = 1) PACS 160 µm. Right: Spitzer detection rates of IR excess as a function of the fractional monochromatic dust flux.

Fig. 1 demonstrates the uniqueness of Herschel as the only facility in the foreseeable future that has both the sensitivity and wavelength coverage needed to detect and characterize the thermal emission from faint dust disks produced by the collisions of planetary bodies around nearby stars.

Specific Objective: ii) Collisional and dynamical evolution of exo-EKBs

Global decline of debris disk emission with time established by ISO and Spitzer. Decay timescales: i) ~150 Myr of the inner hot disks probed by mid-IR, ii) ~500 Myr for the colder regions probed at 60-70 µm.
DUNES targets (age range ~100 Myr – 10 Gyr) *will allow us to revisit ISO and Spitzer results for colder and fainter disks* Statistical analysis of the dust luminosity versus age will be carried out using analytical models and collisional codes developed within our team.

Specific Objective:iii) Presence of exo-EKBs versus presence of planets.

Planets may affect debris disks in various ways: i) dynamical stirring of planetesimals affecting collisional dust production, ii) creation of holes, warps, offsets; iii) trapping of planetesimals or capture of migrating dust into rings or clumps. *Those effect can be inferred indirectly from resolved (and unresolved) Herschel observations searching for signatures on the IR emission.* The programme includes stars with planets allowing us revisiting and extending the tentative Spitzer correlation of both the frequency and dust brightness emission with the presence of planets.

Specific Objective: iv) Dust properties and size distribution in exo-EKBs.

Disk and dust properties will be inferred from SEDs using radiative tranfer models available in the team. *Robust conclusions* can be derived *on the basis of realistic grain* optical properties, dust opacities and temperatures **(Fig. 2, left).** In addition to available data bases, our team can carry out laboratory measurements of dust properties whenever necessary.

A robust modelling *prediction of our codes is the waviness of the dust size distribution* caused by the blowout size cuttoff. *This waviness must have a clear observable signature in the Herschel's bands, which is a direct indication of ongoing collisional cascade in disks* **(Fig. 2. right).** *The DUNES Programme will allow us to search for this efect for the first time.*

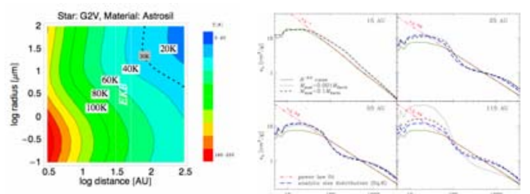

Fig2. Left. Dust temperature of different-sized amorphous silicate grains at different distances from a G2V star. Probing the disk at 30-40 K (maximum PACS 100 sensitivity) would be most sensitive to grains larger than about 10 µm in the EKB regions and slighly beyond (30-100 AU) or to µm-sized grains at 100-300 AU. Right. Mean opacity as a function of distance from the star. The wavy size distribution expected from collisional systems directly impacts the opacity in the Herschel bans.

Specific Objective: v) Dependence of planetesimal formation on stellar mass.

Central stars influence dust temperatures and dinamics, planetesimal formation, disk brightness and disk evolution. *Deep pan-chromatic DUNES Herschel observations will allow us to perform a detailed characterizacion of disk properties versus stellar masses/luminosities. They will also address the question of how the planetsimal formation and evolution depend on the stellar properites.*

DUNES Observational Approach:

i) Photospheric detection at 100 µm (set DUNES integration time)
-Justification/aims: Herschel PACS 100 is the most sensitive regime to detect faint, cool disks (exosolar-EGK). See Fig. 1.

ii) Pan-chromatic observations: PACS160 + PACS 70 + SPIRE
-Justification/aims: Characterization of dust and disk properties. See Fig. 2.

DUNES targets: Total sample: 133 + 106 = 239 AFGKM stars with large range of ages and metallicities.

✓ **FGK main sequence stars**
- d < 20 pc
- unbiased
- excluded: high background

✓ **Sample: 133 stars**
- included are stars with known planets (up to d <25 pc)
- included are known Spitzer detections (disks)

✓ **In addition 106 stars** shared with DEBRIS Herschel KP (mainly A and M stars)