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How many FGK stars of the solar neighbourhood have a Kuiper belt?

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Abstract

In previous scientific meetings of the SEA we showed preliminary results of the DUNES (DUst around NEarby Stars) project, carried out with data from the ESA *Herschel* space observatory. The main objective of the project was to study main-sequence (MS) FGK stars of the solar neighbourhood in the far infrared, seeking for structures similar to the Edgeworth-Kuiper belt of our Solar System. These structures are the result of the evolution of protoplanetary discs made of gas and dust around pre-MS stars, which are transformed into gas-poor, tenuous and dust-dominated discs as the gas is dispersed and the dust is reprocessed through collisions of planetesimals, forming the so-called "debris discs". These discs are essential for understanding the formation of planetary systems. We present here the main results derived from the analysis of the full sample of objects studied in DUNES, which can be summarized in one number: 22% of MS FGK stars within 15 pc have debris discs.

1 Introduction

Star and planet formation are linked by the presence of a circumstellar disc built via angular momentum conservation of the original molecular cloud undergoing gravitational collapse (e.g. [2]). These primordial discs, formed by gas and small dust particles, evolve with the star during the pre-main sequence (PMS) phase. They experience gas dispersal and grain growth and are transformed from gas-dominated protoplanetary discs to tenuous, gas-poor, dusty discs, known as "debris discs". These discs consist of μm-sized particles with short lifetimes and need to be constantly replenished. Hence, they are second-generation discs, thought to be produced by the constant attrition –due to collisional cascades– of a population of planetesimals (e.g. [15], [6]).

The ESA *Herschel* space observatory (2009–2013) [12] has been fundamental, among other disciplines, in the study of debris discs, thanks to its 3.5 m aperture and its imaging photometers PACS [13] and SPIRE [5], which provide an increased sensitivity to debris discs (see Fig. 1 in [3]), a wider wavelength coverage, and the ability to spatially resolve many of the discs. An account of results of the pre-*Herschel* era can be found in the review by [15], whereas a much more comprehensive view, including some of the *Herschel* results, is given by [9].

This paper summarizes the results on the sample of solar-type (FGK) stars of the DUNES programme. Full details of the complete study can be found in the papers by [3] and [10].

2 The DUNES project

DUNES (DUst around NEarby Stars) is an Open-Time Key Programme (OTKP) of ESA *Herschel* space observatory. The main goal of the project was to search for analogues to the Solar System Edgeworth-Kuiper Belt around nearby solar-type stars. The presence of such a structure is apparent from the excess flux in the far-infrared bands. Some of the discs appear resolved, but in other cases the debris disc is only detected as a bump in the spectral energy distribution, overimposed to the photospheric emission.

As described by [3], the original DUNES stellar sample, from which the final sample was built, was chosen from the *Hipparcos* catalogue (VizieR online catalogue I/239/hip_main, [11]) following the only criterion of selecting MS stars –luminosity class V-IV/V– without any bias concerning any property of the objects. The restriction to building the final sample was that the stellar photospheric emission could be detected by PACS at 100 μm with a S/N$\geq$5, i.e. the expected 100 μm photospheric flux should be significantly higher than the expected background as estimated by the Herschel HSPOT tool at that wavelength. Two stars, namely τ Cet (HIP 8102, G8 V) and ϵ Eri (HIP 16537, K2 V), although fulfilling all the selection criteria described above, do not belong to the DUNES sample because they were included in the Guaranteed Time Key Programme "Stellar Disk Evolution" (PI: G. Olofsson).

The DUNES sample contains 177 FGK stars with $d \leq 20$ pc. *Herschel*/PACS observations at 100 and 160 μm were obtained, and were complemented in some cases with data at 70 μm and at 250, 350, and 500 μm SPIRE photometry. 123 objects were observed by the DUNES collaboration wereas the remaining 54 stars were shared with the OTKP DEBRIS (Disc Emission via a Bias-free Reconnaissance in IR and Sub-mm, [8]).

3 Excess incidence rates

Table 1 shows a summary of the excess incident rates in the full DUNES sample. In particular, the $d \leq 15$-pc subsample contains 23 F, 33 G, and 49 K stars; this subsample is complete for

F stars, almost complete for G stars and has a sufficiently large number of K stars to infer robust results. The incidence rates of excesses are 0.26 (6 objects with excesses out of 23 F stars), 0.21 (7 out of 33 G stars), and 0. 20 (10 out of 49 K stars), the fraction for the total sample with $d \leq 15$ pc being 0.22 (23 out of 105 stars). Those percentages do not change significantly if we consider all targets within $d \leq 20$ pc, which contains 51 F, 66 G and 60 K stars. We give in the table the 95% confidence intervals for a binomial proportion for the corresponding counts according to the prescription by [1]. Our results can be compared with those by [14] who carried out a study on the same main topics.

Table 1: Incidence of debris discs.

	F			G			K			FGK		
Sample	T	E	Frequency Interval 95%	T	E	Frequency Interval 95%	T	E	Frequency Interval 95%	T	E	Frequency Interval 95%
DUNES $d \leq 15$ pc	23	6	0.26 [0.12-0.47]	33	7	0.21 [0.10-0.38]	49	10	0.20 [0.11-0.34]	105	23	0.22 [0.15-0.31]
DUNES $d \leq 20$ pc	51	12	0.24 [0.14-0.37]	66	13	0.20 [0.12-0.31]	60	11	0.18 [0.10-0.30]	177	36	0.20 [0.15-0.27]

"T" and "E" mean "Total" and "Excess".

4 Other significant results

The analysis of the DUNES sample led to a number of interesting results:

1. The lowest values reached of the upper limits for the fractional luminosity, $L_{\rm dust}/L_*$, are around $\sim 4.0 \times 10^{-7}$; the median for the whole sample is 1.4×10^{-6}. These numbers are a gain of one order of magnitude compared with those provided by *Spitzer*. Although it may seem obvious, we must emphasize that the excess detection rates reported are sensitivity limited; therefore, they still represent lower limits of the *actual* incidence rates.

2. There are hints of a different behaviour in the fractional luminosities of the discs at lower and higher metallicities if we split the sample around $[{\rm Fe/H}]_{\rm mean} = -0.11$: the former seem to cover a narrower interval of fractional luminosities than the latter. By splitting the sample of stars with determinations of metallicities available (166 objects) around the median $[{\rm Fe/H}]_{\rm median} = -0.095$, there seems to be a slight deficit of debris discs at lower metallicities (16 discs out of 83 stars) when compared to the number at higher metallicities (20 discs out of 83 stars). This points in the same direction hinted by [7] and confirmed by [4].

3. Regarding the chromospheric activity, the incidence of debris discs is similar among inactive and active stars. There is a decrease in the average $L_{\rm dust}/L_*$ with decreasing activity/increasing rotation period. Since the stellar activity and the spin-down are

proxies of the age, this result suggests that as the stars get older, there seems to be a slow dilution of the dust in the disc with the effect of a decrease in its fractional luminosity.

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