

1. Description of the proposed programme (max. 6 pages)

1.1 Scientific Goals:

I. Introduction

A combination of optical, infrared, and millimetre observations has provided incontrovertible evidence that most stars are surrounded at birth by circumstellar accretion disks. In just a few million years, the disks evolve from gas-dominated protoplanetary disks to gas-poor planetesimal disks that may contain full-sized planets. At least some of these young disks have built the >250 exo-solar planets that have been found in the last 12 years, mostly around nearby main-sequence (MS) solar-like stars. *It is not known, however, whether planet formation is nearly as universal during disk evolution as is the formation of disks during star formation. Answering this question is crucial to understanding the incidence of planetary systems in general, and consequently also to the formation of Earth-like planets.*

Stars in the earliest stages accrete a significant part of their masses from the gas and dust available in the disks. Meanwhile accretion disks provide the raw material for the formation of planets. In the core accretion planet formation model, submicron-sized dust grains settle in the disk midplane and coagulate to form large dust aggregates, pebbles, and then larger rocky bodies (planetesimals). In the solar system, planet formation has resulted in a quasi-total depletion of the planetesimals inside the orbit of Neptune (with the noticeable exception of the asteroid belt between Mars and Jupiter). Leftover planetesimals not incorporated into planets are today arranged in the form of the Edgeworth-Kuiper Belt (EKB) beyond the orbit of Neptune that is dynamically sculpted and excited by the planets. Mutual collisions between EKB objects and erosion by interstellar dust grains release dust particles that spread over the EKB region. The emission from the EKB dust has been estimated to be the most luminous extended component in the solar system at wavelengths of about $100 - 150 \mu\text{m}$, where the dust emission peaks. Similarly, some MS stars are observed to be surrounded by cold, tenuous optically thin disks composed of short-lived $\sim\mu\text{m}$ -sized dust grains, resembling in many respects the EKB in our solar system. These so-called “debris disks”, which contain much less dust mass than young disks (typically $10^{-3} - 10^{-1} M_{\oplus}$), survive over billions of years, pointing towards the presence of large reservoirs of colliding asteroid- and evaporating comet-like bodies. Therefore, dust in debris disks is intimately connected to its parent bodies, invisible left-over planetesimals. Observing the dust emission is a powerful way to shed light onto their spatial and size distributions, properties and composition, and ultimately, their accretion history. Furthermore, dust sensitively responds to the gravity of planetary perturbers and thus can be used as a tracer of planets.

We propose a sensitivity-limited Herschel Key Programme that aims at finding and characterizing, with PACS and SPIRE, faint exo-solar analogues to the Edgeworth-Kuiper Belt in a statistical sample of 283 nearby stars. Our sample is volume-limited ($d < 25 \text{ pc}$) and covers a decade in stellar mass (from M- to A-type stars). It naturally includes a broad range of stellar ages (~ 0.1 to $\sim 10 \text{ Gyr}$), as well as stars with known planets. Our goal is to use the unique capabilities provided by Herschel to perform a deep systematic survey for faint, cold debris disks to find the fractional incidence of planetesimal systems in the solar neighbourhood.

II. Current Understanding of Debris Disks – Diversity and Evolution

The discovery of IR excesses around MS stars such as Vega, Fomalhaut and β Pic, made in the early 1980s by the IRAS satellite, came as a big surprise. Since the lifetimes of dust grains against radiative/wind removal and collisional disruption are much shorter than the ages of these stars, one must conclude that these mature stars are surrounded by significant amounts of circumstellar dust which is not primordial, but rather is produced by ongoing processes. In any debris disk model, dust production results from collisional events within a substantial population of larger bodies. For a handful of objects, resolved imaging has provided dramatic confirmation that debris disks generally resemble dust belts, with peak densities at tens to hundreds of AU from the central star and estimated masses from (sub-)millimetre unresolved observations as low as $10^{-3} M_{\oplus}$.

If the EKB could be observed from afar, it would appear as a cold ($\sim 30 - 40 \text{ K}$), extended (up to $\sim 100 \text{ AU}$) and faint ($L_{\text{dust}}/L_{\odot} \approx 10^{-7}$, Backman et al. 1995) dust disk with a huge central hole caused by the most massive planets (Moro-Martín & Malhotra 2005). Although the thermal emission from the EKB dust disk has not yet been detected, impacts of dust grains have been registered in-situ at distances up to 50 AU by Pioneer and Voyager spacecraft as they traversed the outer solar system (Humes 1980; Gurnett et al. 1997). During its orbital evolution, the μm -sized collisional debris can migrate inward due to drag forces and get trapped in mean-motion resonances with the giant planets. The biggest effect comes from Neptune which significantly prolongs the particle’s residence time inside about 40 AU (Liou et al. 1996). This pile-up of dust outside Neptune’s orbit is also enhanced by the significant fraction of the EKB objects (e.g., Pluto) trapped into resonant orbits by Neptune’s outward migration during the early solar system. Similar dynamical scenarios involving the presence of yet unseen planets have been proposed to explain some of the resolved structures in debris disks, in particular their ring-shaped appearance.

Since the discovery of debris disks, many new observational results and theoretical insights have been obtained from IR and (sub-)millimetre photometry. IRAS originally found that about 10% of early MS stars (A and F) had an excess at $60 - 100 \mu\text{m}$ in the range $10^{-5} < L_{\text{dust}}/L_{\star} < 10^{-4}$. Brighter disks were rare among stars

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older than about 0.1 Gyr as were disks with emission at 12–25 μm . Because of IRAS sensitivity limitations, however, little was known of any excess emission from stars of later spectral types (G, K, M) particularly for ages more than 1 Gyr. ISO added important information on age distribution of debris disks, finding a rapid falloff in incidence for ages greater than 0.4 Gyr (Habing et al. 2001; Dominik & Decin 2003). Spitzer has added a wealth of new information in recent years: a $15\pm 3\%$ detection rate for IR excess at 70 μm around F5–K5 mature (>1 Gyr) stars (Bryden et al. 2006; Trilling et al. 2007a); a higher incidence of dust emission for type A stars (Su et al. 2006) and a lower incidence for M stars (Gautier et al. 2007); and a marginally higher incidence around binary stars (Trilling et al. 2007b). The debris disk detection rate is not found to depend on metallicity (Beichman et al. 2006a) or on the presence of planets, although there is a suggestion that planets may make an existing disk brighter (Beichman et al. 2005).

Spitzer observations find that the typical debris disk around a solar-type star emits much stronger at 70 μm than at 24 μm , with the detection rate very low for hot dust at 10 μm ($<1\%$; Beichman et al. 2006b). Spectral energy distributions (SEDs) imply that the emitting material is located between 10 and 100 AU assuming grains 10 μm or larger (Beichman et al. 2006a). However, this distance estimate, as well as the dust mass and dust properties, are degenerate with the unknown particle size distribution. While the majority of the observed disks do not show spectroscopic features at mid-IR wavelengths, suggesting relatively large emitting grains ($> 10 \mu\text{m}$; Chen et al. 2005; Beichman et al. 2006b) resolved disks have emission much hotter than their blackbody temperatures, suggesting smaller μm -sized grains (Bryden et al. 2007). *Fundamental disk parameters are therefore poorly constrained and require either resolved imaging or better sampling of the SED at wavelengths $> 70 \mu\text{m}$.* Overall, Spitzer results clearly demonstrate that debris disks clearing processes are more effective in the inner regions (Su et al. 2006; Currie et al. 2007). The outer disks detected by Spitzer at 70 μm will be characterized by Herschel observations at longer wavelengths. Furthermore, the inside-out clearing of dust disks may leave substantial amounts of cold dust material that could have been missed with Spitzer at 70 μm , requiring observations with Herschel, which will provide greater sensitivity, lower confusion limits, greater contrast with the stellar photosphere, and coverage at longer wavelengths.

III. Scientific Objectives of the Proposed Observing Programme

The question of how common planetary systems are is of fundamental importance 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.

Our target sample (described in Sec.2.1 below) has been tailored to systematically search for analogues to the EKB around a large sample of nearby MS stars. The proposed PACS and SPIRE observations, combined with ancillary data, will be interpreted using state-of-the-art models developed within the team to infer the individual properties of the dust disks (mass, temperature, distance, grain size distribution), and to statistically discuss the incidence and evolution of planetesimal belts too faint to be detected from the ground, and too cold to be detected with previous space missions, including with Spitzer. The detected systems will be compared to our own EKB to evaluate whether the solar system is peculiar or rather common. Furthermore, since truncated cold disks may be a strong indication of interior planets, resembling the roles played by Neptune and Jupiter in the solar system, they would constitute the best candidates for probing the presence of long-orbital period exo-planets in the solar neighbourhood. The proposed observations build on the heritage of previous space missions and solar system studies. We will provide to the community a rich database to study planet formation and to prepare for future ground- and space-based instruments aiming in particular at detecting photons from exo-planets.

The overall programme is designed to address several fundamental, specific questions that will help to evaluate the prevalence of planetary systems in the solar neighbourhood:

(i) Herschel as a finder of faint exo-EKBs. At 160 μm , Spitzer suffers from the presence of a short wavelength light leak that severely degrades Spitzer’s performance for sources with a bright photospheric component, i.e. almost all debris disk stars. At 70 μm , an important limitation on Spitzer results comes from the confusion limit to Spitzer’s sensitivity arising from a combination of interstellar cirrus and distant galaxies in the large beam of an 0.85 m telescope, limiting the its detection capability to cool disks brighter than $L_{\text{dust}}/L_{\star}$ several times 10^{-6} for the brightest stars. Our own EKB is thought to have a nominal brightness of $L_{\text{dust}}/L_{\star} \approx 10^{-7}$. Taking the present-day solar system EKB model of Backman et al. (1995) as a reference, the EKB SED peaks at $\lambda \approx 130 \mu\text{m}$, and most of the emission arises from the 70 to 250 μm wavelength range. At a 10 pc distance, a dusty EKB analogue would have a $\sim 7\text{--}9$ mJy flux at 100 and 160 μm , well above the sensitivity limit (5σ , one hour integration time) of PACS/100. The discovery space unique to Herschel, now using blackbodies, is displayed on the left panel of Fig. 1 (cross-hatched area) for a typical target star (G5V at 20 pc) over a range of assumed dust temperatures, where 3σ detection limits are shown in terms of the dust’s fractional luminosity ($L_{\text{dust}}/L_{\star}$). The figure shows in particular that Herschel PACS/100 is the most suitable filter to identify the faintest disks ever detected for dust temperatures in the range from ~ 20 K to ~ 100 K and, most importantly,

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is optimally sensitive to EKB-like temperatures (30-40 K). Herschel has the ability to push toward fainter dust emission more similar to that in the EKB. With a detection limit $L_{\text{dust}}/L_{\star}$ of a few 10^{-7} , this will thereby allow to place our own planetary system in context relative to its neighbours.

Expanding on the Spitzer results, we estimate that the proposed observations will double the number of identified disks around nearby FGK stars. This is illustrated in the right panel of Fig. 1 which summarizes the Spitzer detection rates for nearby FGK stars as a function of the disk to star flux ratio at 32 and 70 μm , with an attempted extrapolation to 100 μm . Depending on the functional form of the underlying distribution of debris disks fluxes (log-linear or log-normal relationship, solid lines on the figure), and temperature of the dust, getting signal-to-noise ratio (SNR) of 5–10 at 100 μm should provide a minimum detection rate of 20%, with higher rates possible if the distribution is rising, as suggested by Spitzer 32 μm and 70 μm data. *The presence of a population of previously unknown cold dust will furthermore increase the detection rates. We therefore expect our observations to identify $\sim 30\%$ of debris disks around nearby FGK stars, compared to $\sim 15\%$ with Spitzer.*

These estimates demonstrate the uniqueness and the strength of Herschel as the only facility for 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 collision of planetary bodies around nearby stars. Increasing the number of debris disk detections is helpful for a statistical analysis of trends in the debris disk properties.

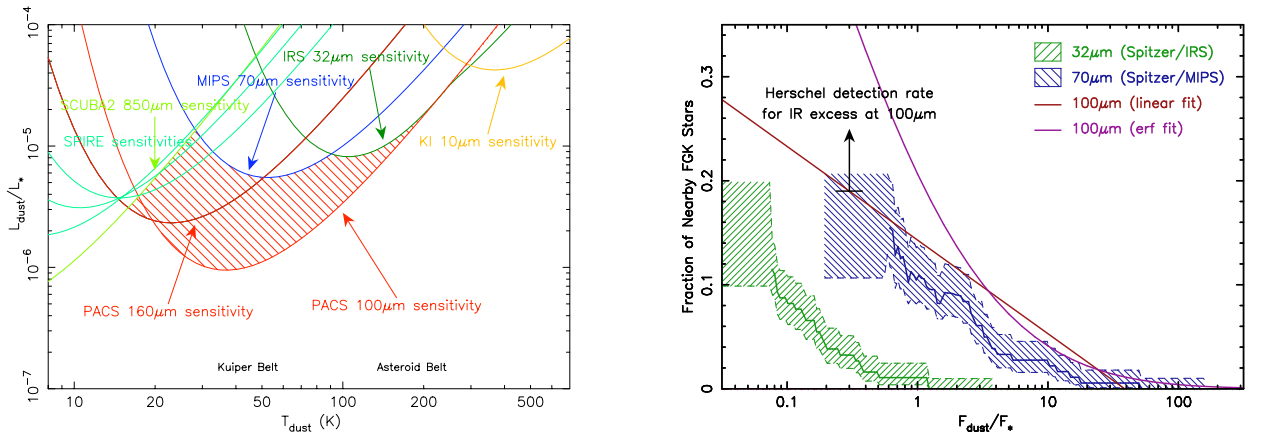


Figure 1. *Left panel:* Detection limits for a G5V star at 20 pc, following the Bryden et al. (2006) approach. The assumed 1σ fractional flux accuracies are 20% for Spitzer/MIPS at 70 μm , 2.5% for Spitzer/IRS at 32 μm , 10% for PACS 100 μm (i.e. SNR=10), and 100% for PACS 160 μm (SNR=1). *Right panel:* Spitzer detection rates of IR excess as a function of the fractional monochromatic dust flux, $F_{\text{dust}}/F_{\star}$. For Spitzer/MIPS at 70 μm , 182 F5-K5 stars were observed by Bryden et al. (2006) and Beichman et al. (2006b). For Spitzer/IRS spectra at 32 μm , 187 F0-M0 stars were observed by Beichman et al. (2006a, 2008). Uncertainties in the underlying distribution due to small number statistics (shaded regions) are large below the detection limits of each instrument/wavelength.

(ii) Dependence of planetesimal formation on stellar mass. The observation of a large unbiased stellar sample from 0.2 to $2M_{\odot}$, allows for a straightforward search for any correlations that may exist between debris disks and the properties of their host stars. The parameters of the central star influence the dust temperature, the disk brightness, and the disk evolution in various ways. Stellar mass/luminosity controls dust dynamics, as it determines the size limit for grains to be blown out by radiation pressure and the orbital velocities at a given distance, thereby altering impact velocities and collision rates. For late-type (K and especially M) stars, strong stellar winds must lead to strong drag forces, enhancing inward radial transport of dust. At the earlier stages, stellar parameters may affect planetesimal formation, for instance, by moving the position of the snowline which may demarcate the region of giant planet formation and hence its remnants in the form of an EKB. Young stars are commonly found to be surrounded by opaque circumstellar disks, independent of their spectral type. Planet hunting has mainly been focused on solar-like stars, but some recent surveys for hot Jupiters toward M stars have been largely unsuccessful suggesting lower-mass planets around lower-mass stars (Bonfils et al. 2005). For debris disks, a clear trend is observed with Spitzer at 70 μm , with excess more frequently detected around earlier type stars : $\sim 30\%$ for A stars (Su et al. 2006), $\sim 15\%$ for FGK stars (Beichman et al. 2006a, Trilling et al. 2007a), and 0% for M stars (Gautier et al. 2007). This trend may reflect different planetesimal formation efficiencies affecting the mass reservoir, and/or different evolution paths due to different physics dominating the global dust and planetesimal dynamics.

However, the measured incidences are also intimately related to the sensitivity limits and wavelength ranges of the instruments used to derive these numbers. This is illustrated in Sec. III.i where we have anticipated a debris disk incidence toward FGK stars that is two times larger with Herschel than that inferred with Spitzer. For lower mass stars, Gautier et al. (2007) did not identify any M stars with IR excess, but the weak limits they place on $L_{\text{dust}}/L_{\star}$ and disk incidence ($\leq 14\%$) are still marginally consistent with the dust emission from FGK stars. The existence of cold debris disks around M stars, missed by Spitzer, is supported by positive detections

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at (sub-)millimetre wavelengths by Lestrade et al. (2006), who find an incidence of excess emission around M stars that is consistent with that of solar-type stars.

It is therefore currently difficult to disentangle the properties intrinsic to planetesimal formation and disk dissipation processes from observational biases. Our limited knowledge of the location of the dust due to the incompleteness of the SED also adds to the difficulty to interpret current numbers. *Deep pan-chromatic Herschel observations such as those proposed here will allow us to better characterize known disks (see also Sec. III.v), and to address the question of how the planetesimal formation and evolution depend on the stellar mass.* For instance, were the incidence of disks around FGK stars lower than expected, it would demonstrate that observational biases were not dominating previous results but are intrinsic to the evolution of planetesimal populations around nearby solar analogues.

(iii) Collisional and dynamical evolution of exo-EKBs. The global decline of excess emission of debris disks with time is observationally established. ISO and Spitzer studies have measured decay timescales of 150 Myr for the inner hot disk as probed by mid-IR excesses (MIPS/24), and 400-500 Myr for the somewhat colder regions probed at 60–70 μm (Habing et al. 2001; Rieke et al. 2005; Su et al. 2006).

The age dispersion (from ~ 100 Myr to ~ 10 Gyr) in our large sample will allow us to revisit the ISO and Spitzer results for colder and fainter disks. A new analytic model for a long-term evolution of debris disks (Löhne et al. 2007) that extends and improves the previous ones (Dominik & Decin 2003; Wyatt et al. 2007) will be used to interpret the statistical data on the dust luminosity versus age. The model provides the total disk mass and the dust mass as a function of age and a few crucial parameters, such as the size-dependent critical fragmentation energy of solids, the “primordial” size distribution of largest planetesimals, as well as the characteristic eccentricity and inclination of their orbits. A synthetic population of disks generated with the model has been proven to reproduce the observed Spitzer/MIPS statistics of 24 and 70 μm fluxes and colours versus age.

This analytical model builds on statistical collisional codes developed within the team (multi-annulus particle-in-a-box scheme, Thébaud & Augereau 2007, and Boltzmann-Smoluchowski code in orbital elements by Krivov et al. 2006). Both codes allow one to realistically follow the continuous and stochastic evolution of a debris disk maintained by a given planetesimal family, taking into account disruptive and cratering collisions and photogravitational dynamics of dust. The two codes have been used before in studies of EKB and debris disks and have been mutually cross-tested, yielding very similar results for identical setups. In comparison to known planetesimal accretion codes, both treat very accurately the dust end of the size distribution, covering the size range responsible for the emission in the far-IR. *Combining the models with SED (radiative transfer) codes (see Sec. III.v) provides a direct link to PACS/SPIRE observables.*

(iv) Presence of exo-EKBs versus presence of planets? A planet may affect a debris disk in various ways: dynamical stirring can increase eccentricity/inclination of planetesimals, which has a strong effect on the collisional dust production; the planet(s) can create an inner hole in the disk and can trap planetesimals during early outward migration, or can directly capture inward migrating dust into dust rings or clumps; finally, secular perturbations can also create disk structure such as offsets, warps, and gaps. The last two processes most specifically require spatially resolved observations to infer the presence of planets.

Indirect evidence for the presence of planets may nevertheless be inferred from the proposed, unresolved Herschel observations. Cold exo-EKBs with huge holes may be the result of efficient inner disk clearing by giant planets, although the proposed observations may not be able to exclude alternative scenarios (e.g. those involving the influence of remnant gas for the youngest objects). The dispersion in disk brightness with age as revealed by Spitzer may be another indication for the presence of planets in these systems. Episodic dynamical warming of the planetesimal system by larger planets can enhance the planetesimals’ collision rate and produce sudden bursts of strong dust emission. The gradual decline of disk mass with time (Sec. III.iii) would therefore include transient events, perhaps similar to the Late Heavy Bombardment in the young solar system, which is thought to result from a destabilized phase caused by a re-arrangement of the planetary configuration (Gomes et al. 2005). Our sample will be ideal for testing the variation of disk properties within an age bin, in order to evaluate the importance of stochastic events.

Our Herschel target sample furthermore includes 19 confirmed planet-bearing stars and reflects the stellar metallicity distribution in the solar neighbourhood. With the proposed observations, we will revisit the Beichman et al. (2005) tentative correlation of both the frequency and magnitude of dust emission (probed at 70 μm) with the presence of exo-planets. Because planets are preferentially found around stars with large metallicity, we will also search for possible relation between debris disk incidence and metallicity. Spitzer failed to identify such a relation (Bryden et al. 2006, Beichman et al. 2007), perhaps because the correlation is lost due to stochastic evolution.

(v) Dust properties and size distribution in exo-EKBs. The actual shape of an SED carries key information on the disk and dust properties that can be inferred using the radiative transfer models available in the team (Augereau et al. 1999; Wolf & Hillenbrand 2003). Exactly where the turnover in the spectrum comes between 70 μm and the submillimetre is a critical determinant of the properties of the emitting dust. Combined

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Spitzer, Herschel and, eventually, SCUBA-2 and LABOCA observations will allow the detailed modelling needed to determine grain sizes, location, mass, temperature, luminosity and mean dust lifetimes against collisions and drag forces.

To derive robust conclusions on the disk properties, it is essential that the interpretation of the SEDs is based on realistic grain optical properties to compute realistic dust opacities and temperatures (see e.g. Fig. 2, left panel). This includes the use of a suitable dust mixture in the models and of laboratory-determined optical material properties at long wavelengths and at low temperatures for each of the dust components (amorphous and crystalline silicates, iron, oxides, sulfides, carbonates, carbon, water ice). Most of the material data are available from the data base of the Jena laboratory (<http://www.astro.uni-jena.de/Laboratory/OCDB>), and are included in our models. The modelling process will be supported by further laboratory measurements in Jena whenever necessary.

Further, a robust modelling prediction of our two independent collisional codes (see Sec. III.iii), is the waviness of the dust size distribution caused by the blowout size cutoff. *This waviness must have a clear observable signature in the Herschel's far-infrared wavelengths*, which is a direct indication of ongoing collisional cascade in disks (Th ebault & Augereau 2007, Fig. 2, right panel). *The proposed pan-chromatic measurements will allow to search for this effect for the first time.* Overall, the proposed PACS and SPIRE observations, combined with the already available and tested modelling tools, guarantee a high scientific return and that many new scientific questions related to planet and planetesimal formation will be addressed.

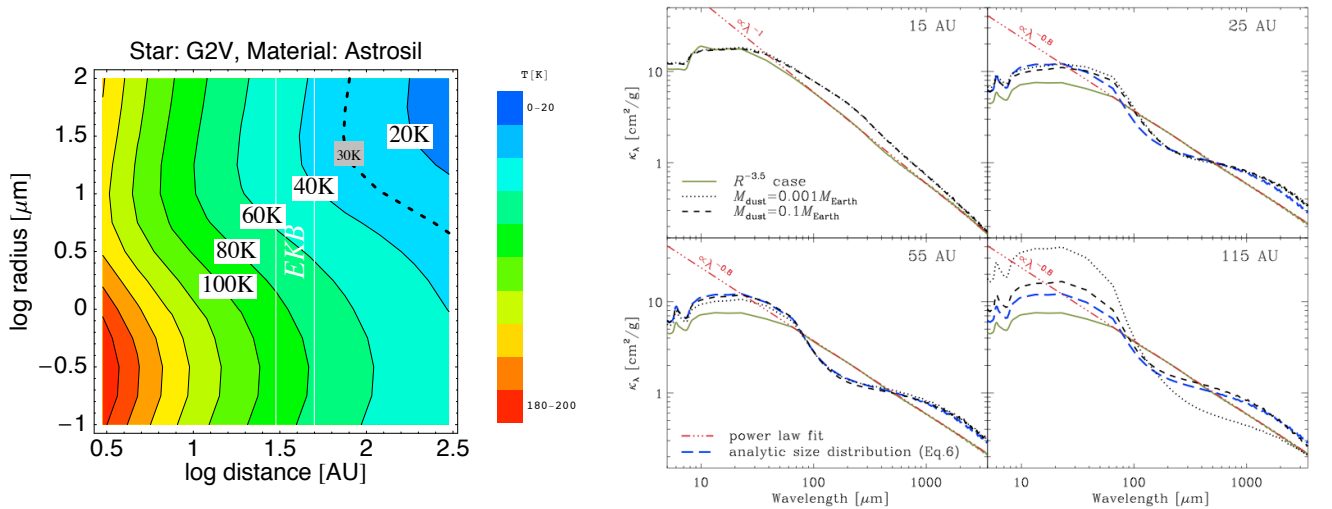


Figure 2. *Left panel:* Dust temperature of different-sized amorphous silicate (Astrosil) grains at different distances from a G2V star (5800 K , $1.0 L_{\odot}$). Probing the disk at 30-40 K (maximum sensitivity of PACS at $100 \mu\text{m}$) would be most sensitive to grains larger than about $10 \mu\text{m}$ in the classical EKB region and slightly beyond (30–100 AU) or to μm -sized grains at 100–300 AU. *Right panel:* Mean opacity as a function of distance from the star. The wavy size distribution expected for collisional systems directly impacts the opacity in Herschel bands (from Th ebault & Augereau 2007).

IV. Data summary and requested observing time: a Key Programme

We are proposing the study of faint extra-solar analogues to the EKB in a sample of 283 AFGKM stars to provide an unprecedented lower limit to the fractional abundance of planetesimal systems, and as a proxy to assess the presence of giant planets resembling the roles played by Neptune and Jupiter in the solar system. Additionally, our approach will allow us to address some fundamental issues, as specified in the previous section. Photometric observations are designed for photospheric detection at $100 \mu\text{m}$ and will cover the wavelength range from $70 \mu\text{m}$ to $500 \mu\text{m}$, i.e., the PACS and SPIRE range. *The requested amount of time is 315.5 hours.*

This ambitious project possesses by its own nature the character of being a Herschel Key Programme:

(i) It exploits the unique Herschel capabilities. Cold dust disks with fluxes at the level of the EKB have escaped the detection capabilities of previous far-IR space missions; neither ground-based submillimetre facilities like /SCUBA-2 or LABOCA have such capability (Fig. 1, left panel). ALMA and JWST will not work in the range appropriate to study such disks. As pointed out before, Herschel is the first space mission, and the only one within the next 15-20 years that has both the sensitivity and wavelength coverage needed to detect and characterize, faint cold dust disks caused by the collision of planetary bodies, placing in this way the solar system in a general context.

(ii) It requires a large observing time. The proposal obtains scientific sense when observing a statistically meaningful sample of stars, which translates into our request for 315.5 hours of observing time.

(iii) It has a high archival value. The observations will provide consistent photometry and images in the PACS and SPIRE bands of a volume-limited sample of nearby stars, only modulated by photospheric detection at $100 \mu\text{m}$, in the $0.2\text{--}2 M_{\odot}$ mass range. Herschel will be opening new observing windows and will preserve its uniqueness for many years. The data cover not only the more relevant range for the characterization of cold

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disks, e.g. the wavelength where the dust emission peaks, but also complete the SEDs of the stars. Together with ancillary data these stars will be among the best characterized stars across the whole electromagnetic spectrum.

1.2 Exploitation Plan:

The observed fluxes will be compared to the expected photospheric emissions derived from stellar photosphere models, thereby identifying stars with an infrared excesses (observed fluxes minus photospheric fluxes). In case of a non-detection in one or several band(s), upper limits will be estimated to further constrain the models. We will start with a simple analysis approach, estimating basic disk properties (temperature and bolometric luminosity). A first answer on how common stars are surrounded by cold disks will then be achieved. Basic disk properties with stellar properties (mass, metallicity, age, activity, binarity, known exoplanets) will then be investigated, looking for possible trends, that can be interpreted using the dynamical models available in the team (Sec. III.iii). We will pursue the modelling of individual objects with our radiative transfer codes, using realistic laboratory-determined, grain optical properties (Sec. III.v). This will allow to derive ranges for the dust mass, peak position for the disk surface density, minimum grain size, and mean lifetime against collisions for the observed dust grains. The models, as well as the shape of the SED (colours), will provide first hints for the presence of a waviness grain size distribution due to ongoing collisional cascade, and for a hole possibly due to gravitational perturbers inside the exo-EKB. The range of cold disk scenarios can then be inferred, and the solar system EKB can be placed in context, assessing how common or singular it is.

1.3 Other Facilities:

Parameters of the central star affect the disk properties and evolution in various ways. This is why the detection and detailed analysis of faint cold disks require a good knowledge of the stellar properties, like e.g. T_{eff} , luminosity, age, metallicity or activity. Complementary data characterizing the stars are necessary to fulfil our objectives. Stellar parameters can be obtained or estimated from public databases for a large number of stars in the sample, but not to the required extent; particularly, for K and M stars. Optical magnitudes, 2MASS, Spitzer/IRAC and MIPS data are available for a number of stars; in addition AKARI will complement the IR data. Consortium members have direct access to Spitzer data and some are involved in AKARI programmes observing stars in our sample. These data allow an extrapolation of the SEDs to Herschel bands in order to estimate photospheric fluxes. Normalized Kurucz and NextGen models are also needed to estimate photospheric fluxes, providing that appropriate stellar parameters from high resolution optical spectroscopy are well known. The team has the experience to undertake this task and already has its own high resolution spectra of a significant part of the stars obtained at Calar Alto, La Palma, and La Silla. We have been granted observing time to obtain further spectra, and plan to submit new observing proposals. We also have the tools for retrieving and analysing spectra available in public archives. These data will be used to estimate T_{eff} , $\log g$, and $[\text{Fe}/\text{H}]$, needed to synthesize accurate photospheric models. Stellar ages are needed to study the evolution of cold disks. Some, but not all, stars have age estimates in the literature. Age and activity of the stars will be consistently estimated from our spectra using tracers as CaII HK, Balmer lines, Li I, rotation and membership to moving groups. Age and activity can also be estimated from X-ray emission; ROSAT and XMM data will be used. We have submitted an XMM proposal to observe some of the stars not detected by ROSAT. Sub-millimetre data are also very useful to constraint dust properties or to provide upper-limits; SCUBA-2 and LABOCA data are accessible to the team. Our Herschel project will lead to discoveries deserving follow-up observations. We anticipate follow-up projects to carry out high spatial resolution observations (adaptive optics, coronagraphy and interferometry) of some extended or potentially extended disks. We also anticipate PACS line observations of some promising candidates to analyse the gas impact in the disk evolution and structures.

1.4 References:

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2. Technical Implementation (max. 3 pages)

2.1 Observations Strategy:

We aim to detect faint IR excesses as the signature of the existence of low-mass, cold disks, around nearby stars in the mass range $\sim 0.2 - 2 M_{\odot}$, i.e., spectral types from M to A. Expected flux levels produced by such disks are at the order of few mJy, i.e., of the same order or very few times the uncertainties of the measurements. Thus, to be successful we have carefully designed an observing strategy that utilizes the Herschel wavelength range where cold disks emit most of their energy and maximizes the instrumental sensitivity while reducing as much as possible background confusion. Furthermore, observing at several wavelengths will allow us to check whether small excesses are real or not, while also providing colours relevant to study the dust properties. We carefully constructed the target sample, assessing how well the stellar photospheres can be characterized and faint excesses can be detected on top of them. These considerations also drive the choice of the Herschel observing modes and parameters.

(i) Observing wavelengths. Dust temperatures depend on the stellar luminosity, distance to the star and dust properties. As an example, Fig. 2 (left panel) shows the dependence of dust temperatures on the distance to the star and grain sizes for the case of a G2 V star and astronomical silicate grains. It clearly demonstrates that a simple blackbody assumption fails. For EKB distances ($\sim 30 - 100$ AU), grains of about $10 \mu\text{m}$ in size would have temperatures in the range $\sim 30 - 50$ K. Assuming those grains, the bulk of the energy will be emitted in the wavelength range covered by the PACS photometric bands ($70, 100$ and $160 \mu\text{m}$).

The solar system EKB model of Backman et al. (1995) peaks at $\lambda \approx 130 \mu\text{m}$, and has similar flux levels at 100 and $160 \mu\text{m}$ ($\sim 1 \text{ MJy sr}^{-1}$). The sensitivity of PACS is better at $100 \mu\text{m}$ than at $160 \mu\text{m}$, 2.8 versus 4.1 mJy (5σ , 1 hour). In addition, at $100 \mu\text{m}$ the background confusion is lower (by a factor of $3-4$) and stellar photospheric fluxes are higher (by a factor ~ 2.5). PACS $70 \mu\text{m}$ has a sensitivity similar to $100 \mu\text{m}$ and is more competitive in terms of background and stellar photospheric detection. On the other hand, $100 \mu\text{m}$ provides a better contrast ratio between the emission of cold dust and the stellar photosphere, and it is in fact much more sensitive than $70 \mu\text{m}$ for probing cold disks with $L_{\text{dust}}/L_{\star}$ of the order of the EKB (Fig. 1, left panel).

Thus, $100 \mu\text{m}$ is the optimal choice as the reference wavelength for probing EKB analogues with a sensitivity at least at the level $L_{\text{dust}}/L_{\star} \approx 10^{-6}$. This band has the added value of providing a practically unexplored window and the potentiality of detecting very cold disks. We note that observations at any one wavelength cannot fully characterize the properties of the dust. Observations at other wavelengths are needed to unambiguously infer the presence of such disks in many cases. Data at $160 \mu\text{m}$ will be obtained in parallel with the $100 \mu\text{m}$ fluxes but only $\sim 10\%$ will be detected at the photospheric level. PACS $160 \mu\text{m}$ is less sensitive to faint disks (Fig. 1, left panel). Very faint disks detected at $100 \mu\text{m}$ might be elusive at $160 \mu\text{m}$, but even in these cases upper limits at $160 \mu\text{m}$ are very useful to constrain dust properties and the peak wavelength. We also note that $160 \mu\text{m}$ also opens a new window with the potential of discovering new disk scenarios.

Data at $70 \mu\text{m}$ with high SNR are also needed to fully accomplish our objectives. They are needed to fix the flux level of the stellar photospheres, to assess whether a faint $100 \mu\text{m}$ excess is present or not, and are useful to find the wavelength at which excesses appear and the turnover on the disk SEDs. Most of the stars in the sample (see below) have been observed by Spitzer using MIPS at $70 \mu\text{m}$. PACS $70 \mu\text{m}$ has a better sensitivity mainly due to the smaller beam which results in a lower confusion noise. However, it is not worth it to repeat Spitzer data with high SNR values. Thus, PACS $70 \mu\text{m}$ observations of our target stars will only be carried out in the following cases: stars not observed by Spitzer; stars not detected by Spitzer but detectable with PACS $70 \mu\text{m}$; faint stars (< 50 mJy at $70 \mu\text{m}$) for which Spitzer results and their quality are currently not available; stars with poor Spitzer $70 \mu\text{m}$ SNR ($< 3\sigma$). In addition, we will observe 8 high-SNR stars observed with Spitzer/MIPS at $70 \mu\text{m}$ to obtain a self-consistent calibration and integrate existing Spitzer $70 \mu\text{m}$ fluxes as part of the PACS colours. The $70 \mu\text{m}$ observations made will also improve the SNR at $160 \mu\text{m}$.

SPIRE observations at $250, 350$ and $500 \mu\text{m}$ will also be carried out. Although these data are less sensitive to cold disks than at $100 \mu\text{m}$, they allow us to trace the SED to sub-millimetre wavelengths required to study dust properties. In addition, we will be able to search for the imprint on the SED of a wavy size distribution (see Sec. III.v). In terms of SED modelling, even non-detections will provide highly useful upper limits constraining disk parameters and dust properties.

(ii) Target selection. We have defined a volume-limited stellar sample by selecting from the Hipparcos catalogue AFGKM MS stars up to a distance of 25 pc. From this sample, targets were selected on the basis of the expected signal-to-noise ratio of the stellar photosphere at $100 \mu\text{m}$, the most suitable Herschel band for the detection of EKB analogues. The photospheric fluxes at the PACS and SPIRE bands have been estimated with Kurucz (AFGK types) and NextGen photospheric models (M stars) normalized to the available optical and near-IR photometry. Photospheres of each star have been synthesized using as a first option spectroscopic effective temperatures T_{eff} when available, photometric (Strömgren) T_{eff} as second option, and as latest option standard T_{eff} -spectral type relations. In the latter case, we have checked Hipparcos spectral types with our own estimates based on observed $B - V$ colours and absolute M_V magnitudes.

2. Technical Implementation (cont.)

The noise budget comprises the sky background fluctuation (source confusion) and the instrument-related noise levels. At far-infrared wavelengths the contamination by galactic cirrus and the contribution of unresolved extragalactic background sources limit the sensitivity that can be achieved on a particular region of the sky. At $100\ \mu\text{m}$ the typical (all-sky average) confusion noise level is $\sim 0.6\ \text{mJy}$, but at low galactic latitudes ($|b| \lesssim 10^\circ$) it can be up to two orders of magnitude higher. We have used the Herschel Confusion Noise Estimator to determine the noise levels due to confusion in PACS and SPIRE bands. The predicted sensitivities (5σ , 1 hour) of the Herschel instruments have been taken from the relevant Observer’s Manuals and converted into the $1\text{-}\sigma$ instrument noise for one AOR repetition. The noise levels decreases with on-source integration time, scaling as $t_{\text{int}}^{-1/2}$. For PACS two different detector readout modes are possible (Direct Mode and Double Differential Correlated Sampling, DDCS), the latter of which could have in-orbit noise levels a factor of two worse at 70 and $100\ \mu\text{m}$. For computing the expected signal-to-noise ratios of the stellar photosphere, we assumed that the optimal Direct Mode will be used for reading out the PACS detectors. In Sec 2.4 we are addressing how the poorer PACS sensitivity of the DDCS readout mode would affect our observing programme.

For each target star the number of repetitions of the PACS 100/160 μm AOR has been increased until the instrument noise is below the confusion level and the signal-to-noise is above 5. We stop this procedure once a SNR of 10 has been reached. Using this approach, we can assure to get down to the lowest observable L_{dust}/L_\star values. There are no further biases for or against including a target candidate into the sample.

The number of stars satisfying these selection criteria are 23, 89, 94, 66, and 16 for spectral types AFGKM, respectively. We have checked this target list for potential duplications using the Reserved Observations List search tool and removed 5 stars from the sample. The AFG stars, therefore, constitute a sensitivity-limited sample nearly complete up to 25 pc (K-type stars are incomplete in Hipparcos beyond ~ 15 pc). The completeness of the M stars is uncertain given the poor knowledge of the low-mass star population at even small distances from the Sun. The mass distribution of the final sample populates the $0.2 - 2\ M_\odot$ mass range reasonably well. Also the metallicity and age distributions reflect the ones in the solar neighbourhood. We note that 19 stars with known exoplanets are in the sample. For the great majority of targets, PACS point-source photometry is used since EKB-sized disks will not be spatially resolved. The small-source photometry observing mode is only used for stars closer than ~ 7 pc, where a 100-AU disk is potentially resolved.

2.2 Observation Time Requirements:

According to the HSpot time estimator, a PACS photometer AOR in point-source mode takes 153 sec per repetition, plus an additional 3 min for spacecraft slewing and target acquisition. We concatenated PACS AORs of the same target, thereby saving these 3 min in between PACS $100\ \mu\text{m}$ and $70\ \mu\text{m}$ observations. For the PACS small-source mode 13.5 min per repetition are needed. Concerning SPIRE photometry mode, one repetition is sufficient to reach the confusion noise level ($\sim 5\ \text{mJy}$ all-sky average). For this AOR 579 sec are required per source. After multiplying the number of repetitions needed to reach the SNR criterion, we arrive at a total time of 315.5 hours (see table below).

Observation summary table and total time requirement

Spectral type	A	F	G	K	M	Total
Number of stars	20	89	93	65	16	283
Time required for PACS 100/160 μm AORs (hours)	3.7	46.1	87.6	70.9	17.1	225.4
Time required for PACS 70/160 μm AORs (hours)	0.1	4.4	17.5	14.8	7.8	44.6
Time required for SPIRE AORs (hours)	3.2	14.3	15.0	10.4	2.6	45.5
Subtotal (hours)	7.0	64.8	120.1	96.1	27.5	315.5

2.3 Time Constraints: There are no identified time constraints.

2.4 Robustness:

In case of a significant deterioration of the performance of the PACS instrument, we will adapt both sample size and on-source time. One large uncertainty, as far as sensitivity is concerned, is the detector readout mode adopted once Herschel is in orbit. Should the optimal Direct Mode not become available, the sensitivities can be up to a factor of 2 worse at 70 and $100\ \mu\text{m}$, and slightly in the red band at $160\ \mu\text{m}$. In this case, we will increase the maximum number of AOR repetitions to reach the signal-to-noise threshold of 5 at $100\ \mu\text{m}$; namely to 50, 90, 80, and 80 repetitions for FGKM stars, respectively. (Due to their intrinsic brightness, no change is required for A stars.) We deem the smaller sample size (about 170 stars or $\sim 60\%$) an acceptable but undesirable price to pay given these circumstances. In the event of lower overall PACS sensitivities, we will prioritize those targets with highest signal-to-noise ratio at $100\ \mu\text{m}$.

For SPIRE, no contingency planning is required because the sensitivity is always limited by the confusion noise. Even with an instrument sensitivity 300% worse than expected, the instrumental noise is still lower than the confusion noise level.

3. Data Processing Plans (max. 2 pages)

3.1 Data Processing Plans:

The observational data will mainly be reduced using the Herschel Data Processing System. We plan to maximise our knowledge of the data reduction steps and instrument behaviour for the observing modes used in our proposal (PACS point-source photometry, PACS small-source photometry and SPIRE photometry). This will require attending Herschel Science Centre data processing workshops, following the latest developments and improvements in pipelines and calibration, and interacting whenever possible with instrument experts. The starting point for the data reduction will be the PACS and SPIRE pipelines. We will improve the automatic and default data reduction by making use of the Herschel Interactive Analysis package. All observations will be processed interactively, making sure that, at each step, the result obtained is optimised. Particularly for level-2 and level-3 products (as described in the AO policies and procedures document, chapter 11), we plan to investigate improvements of the algorithms of data processing to obtain high quality images and photometry for the sources in our proposal. For detections of extended disks around the star, we will investigate the improvement of the data reduction, developing algorithms particularly suited for accurate photometry of a faint extended source around the stars.

Advances in the instruments knowledge and calibration during the mission will result in updates of the Data Processing pipelines and Interactive Analysis. As a consequence, automatically generated data products will have to be regenerated several times during the mission. Products that have been interactively reduced by the consortium members will have to be upgraded to avoid becoming obsolete. The consortium will ensure that the necessary manpower is available to interactively process and upgrade our products, such that most up-to-date data are made available to the community (see Sec. 4.1). In particular, it has been agreed that a number of students and consortium members will perform these tasks. Our data reduction does not require any particular hardware capabilities.

It is an important asset that a significant fraction of consortium members has extensive experience in reduction and analysis of far-infrared astronomical data. In particular, members of our group have closely been involved in astronomical programmes of ISO, Spitzer, and AKARI observatories.

3.2 Product generation justification:

As a final result of the data processing, we will provide highly processed image products, and a photometric catalogue for the three PACS bands (at 70 μm , only when available) and the three SPIRE bands, for each of the sources in our list. For those cases in which the disk has been resolved and extended emission has been detected, an additional photometric catalogue will be provided with the characterisation of the disks' extended emission. Highly processed products and catalogues will be accompanied by the corresponding explanatory documents, and their formats will conform the guidelines specified by the Herschel Science Centre. Catalogues and highly processed products will be sent to the Herschel Science Centre for their access by the astronomical community through the Herschel Science Archive.

As mentioned in the previous section, the generation of the highly processed images and catalogues will entail the investigation of algorithms, and the development of tools for data reduction and photometry especially suited to our type of observations. The implementation of these tools will be carried out in the context of the Herschel Data Processing/Interactive Analysis system. That is, the code of the implementation will be Jython/Java and the interfaces will follow the guidelines given by the Herschel Science Centre for the provision of external tools. This includes documentation and the adoption of the recommended software standards.

3.3 Archival Value:

Our project will produce a complete data set of a well defined sample of nearby AFGKM MS stars, only constrained by the sensitivity limits of our survey. Data should here be widely understood as those obtained with Herschel, of unique nature, plus complementary data including high resolution spectroscopy and multiwavelength photometry from the optical to the (sub-)millimetre ranges and X-rays, as well estimates of star parameters, and a set of disk models and photospheric models. Such a data set possesses an attractive profile for scientists interested in many different kinds of studies, e.g. stellar astrophysics or exo-planetary systems, and it has a lasting value projected into the era of ALMA, JWST, or future space missions searching for Earth-like planets. Data produced in the framework of this project will be archived at LAEFF following the standards and requirements defined by the International Virtual Observatory Alliance (IVOA). LAEFF provides a long stability and security environment for the data and has proved experience, managing the largest astronomical data centre in Spain. It also plays an active role in Euro-VO and IVOA.

The archive will be publicly available to the astronomical community after the proprietary period has ended. In addition to VO access and tools, a simple-to-use interface to access the archived data, in the wide sense defined above, visualize it, retrieve selected subsets, and make some data analysis will be implemented. The archive will also have the ability of exploring any public catalogue and astronomical services. This web-based access will require no installation or configuration of specific tools and will be designed to be compatible with the common browsers. The archive will make a privileged use of DAMA, Darwin Archive Madrid (<http://sdc.laeff.inta.es/darwin>, at present for internal use but soon available). DAMA is a VO-oriented

3. Data Processing plans (cont.)

application to get all information relevant to stars in the Hipparcos catalogue. It explores all VizieR catalogues and other astronomical services, searching for observational data and stellar parameters related to an user-defined sample of stars. DAMA also has tools to estimate some stellar parameters, retrieve whole spectra that can be analysed by the users, and has the ability of identifying missing information or insufficient characterization of the stars, helping in this way to our project with respect to complementary data and follow-up. In addition, the archive will be linked with a consortium webpage with internal and external updated information concerning the project; documents describing the observations, archive services and tools; repository of papers produced by the project, and outreach material (see Sec. 4.2).

4. Management and Outreach Plans (max. 2 pages)

4.1 Management Remarks:

We have collected the necessary expertise directly related to the proposed Herschel observations and to auxiliary observations required for the analysis and interpretation of the Herschel data, as well as experts on databases, archives and Virtual Observatory (VO). Members of our consortium have in-depth first-hand knowledge of Herschel and have significant relevant expertise and experience relating to IRAS, ISO, AKARI, and Spitzer; have extensive experience in the analysis and modelling of circumstellar disks, in particular debris disks; have good knowledge of the solar system EKB; have expertise in laboratory work with dust particles; have archiving experience; and have managed large groups. Furthermore, team members have extensive experience in different aspects of stellar astrophysics, requires as a basis for an adequate interpretation of the observations.

We possess the ability to perform the data reduction of the observations, ensuring data products will be timely produced, archived and provided to the wide community. At the same time, the consortium has the capability both of performing the initial broad analysis and interpretation of the data as well as the more profound analysis involving modelling of cold circumstellar disks. We expect our project will produce results, some unforeseen, deserving follow-up observations and might provide new research avenues. The team includes experts capable of developing follow-up science, e.g. high contrast, high spatial resolution analysis of disks or gas impact on the dust dynamics. PhD students and young postdocs already form part of the consortium and more will be attracted; in this way our project also covers the important aspect of training young scientists.

(i) Organisational Structure

The project can be divided in four working areas with specific tasks: **(a)** data acquisition and reduction, **(b)** complementary data and follow-up observations, **(c)** analysis, interpretation and modelling, and **(d)** archiving and website. Team members collectively have the expertise to cover all tasks. A management structure providing the required tracking and coordination of the work to be performed in each specific activity has been put in place to ensure successful accomplishment of the scientific goals. Individual members will contribute to one or more of the areas according to their expertise and commitment.

The consortium is organized as follows:

- *Management.* Lead: Eiroa. Overall coordination, ensuring responsibilities and tasks are smoothly and timely accomplished, supported by Pilbratt (Europe) and Stapelfeldt (U.S.), with various consortium members assigned for specific areas/tasks.
 - *Acquisition and data reduction.* Lead/Coordination: Heras. Specific tasks include:
 - 1. Observing preparation, including target list and AOR production and management. Lead: Rodmann.
 - 2. Data reduction, calibration, and quality control. Lead: Heras. Data processing, calibration and data quality assessments will mainly be centered around ESA, Madrid, and U.S. team members, given the favoured geographical locations close to the Herschel Science Centre (ESAC) and the NASA Herschel Science Center (Pasadena), and the close collaboration of the Herschel ESA team members in the consortium with the instrumental teams. PACS lead: Lorente/Ardila. SPIRE lead: Olofsson/Walker.
 - *Complementary data and follow-up observations.* This task includes the collection of existing data, and the definition and implementation of observations supporting our Herschel data; as listed below. These activities are coordinated by the top-level management. Part of this work is already well in progress, as described in Sec 1.3.
 - 1. Spectroscopic characterization of our programme stars by high-resolution, optical spectroscopy. Ensure analysis of photospheric modelling. Lead: Montesinos.
 - 2. Spectral energy distributions (optical, 2MASS, IRAS, ISO, Spitzer, AKARI, (sub-)millimetre. Lead: Bryden/Stapelfeldt.
 - 3. High stellar energy radiation field (UV and X-ray). Lead: Sanz.
 - 4. Collecting data from public archives and databases. Lead: Solano.
 - 5. Follow-up data. Initiatives by consortium members following initial results are to be expected in some areas, e.g. assessing the impact of gas on the dust dynamics by PACS line observations of promising candidates, high spatial resolution (coronagraphy, interferometry) observations of stars with disks.
 - *Analysis, Interpretation and Modelling.* Lead: Augereau. IR excesses, dust and disk properties, statistics, correlation with stellar parameters; comparison with the Solar-System EKB; detailed modelling using different approaches and disk scenarios; dust properties and laboratory analogues.
 - *Archiving and website* Lead: Launhardt/Solano. Consortium website. Archive: data products, photometric tables and images; ancillary data, including those obtained by the consortium; VO tools; links to relevant web pages and archives; outreach, project description, publications. This dataset will be the legacy of our programme and we will be happy to offer it for ingestion into the Herschel Science Archive.
- The described organizational structure has been chosen to naturally enable us to work “together apart”, with a consortium geographically spread out. Further elaboration and periodic assessment will take place in consortium meetings, beginning with the “kick-off” meeting in spring 2008 (see below).

4. Management and Outreach Plans (cont.)

(ii) Schedule

We plan for a 6-year lifetime for the project from its inception to end (see table below). Science based on the use of our data might spawn additional programmes on an even longer time frame.

Since routine science observations will only commence after the first six months in flight of Herschel, the first data will be available to us in 2009. It is unclear to us when we will have the complete dataset, it will depend on the scheduling of Herschel. On the assumption that most of our required observations will be carried out in the first of routine operations, we foresee a first data release to the community in 2010. This release would consist of tables with flux measurements with errors and quality flags, and images. Subsequent data releases with improved processing of the data and additional analysis are planned to take place over the following years. Consortium meetings of different kinds will take place as required over the lifetime of the project.

- Already in the proposal preparation process a number of meetings have taken place in different locations.
- On the assumption that our programme is among the successful projects to be announced after the time allocation process in January 2008, we will organize a “kick-off” meeting to consolidate the organizational structure and the observing programme based on the possible comments and/or recommendations issued by the Herschel Observing Time Allocation Committee (HOTAC).
- Subsequent meetings will be organized according to coordination needs of the specific tasks and heavy work phases; examples are coordination of data reduction groups, data reduction problematics and pipeline improvements; first-look results and first analysis; interpretation and modelling; data releases and archiving. Some of these meeting will require the attendance of all members; some will be specific and will require the limited attendance of those directly involved with the meeting topic.
- Telecons will be held on a regular basis (bi-monthly) to update and exchange information within the team and when the workload recommends it.
- We also plan to organize a large workshop/conference open to the participation of the community in 2011
- Final consortium meeting, foreseen for end of 2012.

The table below shows an overview of the activities over the lifetime of the project, together with the estimated resources in full time equivalents (FTEs) as a function of year.

Activity Plan/Resources (FTE)

Activity/Year	2007	2008	2009	2010	2011	2012
Prep. activities. AOR	+(0.5)	+(0.5)				
Data Acquisition (depending on scheduling)			+	+(?)		
Data processing			+(2)	+(1)	+ 0.5	
Ancillary Data	+(2)	+(2)	+(2)	+(2)	+(2)	+(1)
Analysis and Interpretation			+(2)	+(2)	+(2)	+(1)
Detailed Modelling			+(1)	+(2)	+(2)	+(2)
Archiving/Release		+(0.5)	+(0.5)	+(0.5)	+(0.5)	+(0.5)
Total resources	(2.5)	(3)	(7.5)	(7.5)	(7)	(4.5)

(iii) Resources

Consortium members have committed fractions of their available time to this project. The total amounts to 4-5 FTEs every year, where importantly PhD students and Postdocs in the consortium are not included. As more PhDs and postdocs will become involved, we find we can safely conclude that we will have the required resources to carry out all our planned activities.

4.2 Outreach:

Herschel was developed, built, and will be launched and operated thanks to the taxpayers of many countries, from Europe and overseas. We intend to pay the public back with new results and serendipitous discoveries in the field of dusty disks around nearby stars.

The dissemination of our findings will be made along two lines: (1) An *interface to Google Sky*, allowing the user to “walk” across the sky and discover for all out target stars basic information, follow links to public databases, watch the programme status, and even view first results. This data will be put into Google Sky by using a Keyhole Markup Language (KML) file, as described by Scranton et al. (2007). We will make available a KML file on the team webpage and maintain it as new results become available. (2) A *web page dedicated to the interested layman*, giving an overview of the our Herschel observing programme and inviting to learn more on infrared astronomy, circumstellar disks, SEDs, etc. We are striving to regionalise the web page as much as possible to make it accessible also for the non-English speaking public. Our team is truly international and contains native speakers of English, Spanish, French, German, Italian, Swedish, Russian, and Japanese.

We have identified four main themes our outreach activities will be centred upon: (1) *Collisions in the Sky* (debris disks and the solar system’s Edgeworth-Kuiper Belt); (2) *Our Solar Neighbourhood* (main sequence, distance scales, emptiness of space); (3) *The Cold Universe* (electromagnetic spectrum, heat radiation, infrared astronomy); (4) *Sweet Spots in Space*: (celestial mechanics, importance of L2 for future space mission).

5. List of Consortium Members

ALPHABETICAL ORDER

Olivier Absil. Laboratoire d'Astrophysique de Grenoble, France. Post-Doc (Marie Curie Intra-European Fellowship). *Role:* analysis and interpretation. Follow-up: stellar interferometry, high contrast imaging of stars with cold disks (nulling interferometry, coronagraphy). *Qualifications/Research interests:* circumstellar dust disks, extrasolar planets, life outside the Solar System, optical/infrared stellar interferometry, high contrast imaging: nulling interferometry, coronagraphy. Pioneering detections of exo-zodiacal dust disks toward nearby Main Sequence stars (in particular toward Vega and τ Ceti). Fraction of time: 15 %.

David Ardila. Spitzer Science Center, Caltech, USA. *Role:* Data analysis and interpretation. *Qualifications/Areas of Interest:* comparison between cold dust population revealed by Herschel with warmer dust populations. The effect of planets on the dust characteristics. Observing experience of debris disks in the optical (Hubble), near-IR (NICMOS), and mid IR (Spitzer). Fraction of time: 10-15 %.

Jean-Charles Augereau. University of Grenoble, France. Assistant Professor. *Role:* Lead: analysis, interpretation and modelling. *Qualifications/Areas of Interest:* radiative transfer in debris disks, dust mineralogy, dust production mechanisms and collisional evolution of planetesimals, formation of structures in dusty disks due to planets, coronagraphic imaging and interferometry of debris disks, extensive studies of dust disks (HST & Spitzer), debris disks modelling (SED fitting and dynamical modelling). Fraction of time: at least 25 %. Plans to get PhD students/Post-doc(s) at the time Herschel will fly.

David Barrado Navascués. LAEFF-INTA, Madrid, Spain. Staff. *Role:* Multi-wavelength ancillary data. Age estimates. *Qualification/Areas of Interest:* time evolution of circumstellar disks; experience in space observations in the X ray and FIR domain; experience in ground-based in optical and near-IR (photometry and spectroscopy). Fraction of time: 15%.

Amelia Bayo. LAEFF-INTA, Spain. PhD Student. *Role:* Data reduction. Analysis. Development of analysis tools for the Virtual Observatory. *Qualifications/Areas of interest:* formation and evolution of low mass stars (ClassII/ClassIII transition state); infrared spectroscopy and photometry, spectrophotometry and SED modelling (in the cool dwarfs regime). Involved in the testing and development of analysis tools for the Virtual Observatory.

Charles Beichman. Michelson Science Center, Caltech/JPL, USA. Director. *Role:* Data analysis and interpretation. *Qualification/Areas of Interest:* Synergy between Spitzer and Herschel. Multi-wavelength analysis. Extensive observing experience and analysis of debris disks with Spitzer data. Fraction of time: 5%

Geoffrey Bryden. JPL, USA. Research Scientist. *Role:* Data reduction. Data analysis and interpretation. Comparison with Spitzer results. *Qualifications/Areas of Interest:* Distribution of $L_{\text{disk}}/L_{\star}$ for sun-like stars and thereby placing the solar system's emission in context. Relationship between planets and debris. Data reduction and analysis for Spitzer surveys of nearby solar-type stars.

William Danchi. NASA Goddard Space Flight Center, USA. Senior Astrophysicist. *Role:* complementarity between debris disk results at high angular resolution scales (warm dust) and the measurements from Spitzer and Herschel on the cold dust population. *Qualifications/Areas of interest:* extensive observing experience at wavelengths from the $1 \mu\text{m}$ to 1 mm, analysis of data, and some theory. Fraction of time: 10 % (before launch), 20 % (after launch).

Carlos del Burgo. DIAS, Spain, Research position. *Role:* Data analysis. *Qualifications/ Areas of Interest:* IR emission of dust. Experience with analysis of IR satellites (ISO). Fraction of time: 5-10%.

Carlos Eiroa. Universidad Autónoma de Madrid, Spain. Professor. *Role:* Lead of the project. *Qualifications/Areas of interest:* Evolution of circumstellar disks; relation to star properties. Earth-like exoplanets. PI of EXPORT consortium (100 % of the La Palma International Time (1998)). Fraction of time: 50 %.

Malcolm Fridlund. ESA, Project scientist (ESA) for CoRoT; Study scientist for Darwin since 1996. *Role:* Target selection. Preparatory work for project. Data interpretation. Exoplanetary aspects. *Qualifications/Areas of Interest:* Time evolution of circumstellar disks and outflows. Planets and planetary disks. Experience in space research in the UV, Optical, FIR/submm domain and experience in groundbased submm/mm line and continuum work. Working on definition of exoplanetary programmes. Fraction of time: 10% (before launch); 20% (after launch).

Misato Fukagawa. Nagoya University, Japan. Postdoc. *Role:* Complementary information from the AKARI results. High spatial resolution follow-up works. *Qualifications/Areas of Interest:* Link between warm dust population and cold dust detected by Herschel. Relation to our Kuiper Belt. Experience with mid-IR data reduction, AKARI and Spitzer. Member of the AKARI debris disk team. AO coronagraphic/polarimetric imaging of protoplanetary/debris disks. Fraction of time: 10 %.

Beatriz M. González-García. INSA at ESAC, XMM-Newton INSCON (INSA contractor), Spain. *Role:* Complementary data: X-ray emission. *Qualifications/Areas of Interest:* General knowledge of Herschel capabilities after attending to Herschel Workshops (Les Houches and HSpot Workshop at ESAC). Experience in the reduction and analysis of NIR photometry (at medium-size telescopes). Development of a semi-automatic pipeline for the calculation of chemical abundances in high resolution optical spectra. Experience in satellite operations as INSCON of XMM-Newton satellite.

Eberhard Grün. Max-Planck-Institut für Kernphysik, Heidelberg, Germany. Emeritus. *Role:* Relation to solar system dust disks. *Areas of Interest/Qualifications:* In-situ measurements and astronomical observations (ground-based HST, ISO, Spitzer) of solar system dust. Fraction of time: 5 %.

Ana M. Heras. ESA, Scientist at the Herschel Science Centre. *Role:* Target selection, data processing, data analysis. *Qualifications/Areas of interest:* Debris disks and their association with planets, debris disks formation and composition. Experience in data reduction and analysis of ISO data, experience in calibration of infrared instruments. Fraction of time: 15%.

Inga Kamp. ESA-STScI/University of Groningen, NL (1.1.2008) Assistant Astronomer/Assistant Professor. *Role:* Follow-up gas observations with Herschel. *Qualifications/Areas of interest:* Characterization of gas in debris disks. Mod-

5. List of Consortium Members (cont.)

elling gas chemistry/photoprocesses in debris disks, radiative transfer, stellar atmosphere abundance analysis (NLTE). Fraction of time: 5-10%.

Alexander Krivov. Astrophysical Institute, University of Jena, Germany. Professor. *Role:* dynamical and collisional modelling of debris disks, analysis of size and spatial distributions of material in debris disks, using circumstellar dust as tracer of small bodies and planets. *Qualifications/Areas of interest:* orbital dynamics of cosmic dust and small bodies, simulations of collisional processes, extensive modelling of debris disks and EKB, numerical codes for modelling dynamical and collisional evolution, interpretation of in-situ measurements of solar system dust. Fraction of time: 10-15%. PhD and diploma students will be available as well.

Ralf Launhardt. Max Planck Institute for Astronomy, Heidelberg, Germany. Staff astronomer. *Role:* data base, collecting / providing complementary data / observations. *Qualifications/Areas of interest:* Project scientist: astrometric exoplanet search with PRIMA at VLTI; RV exoplanet search around young stars; breadboarding of an achromatic phase shifter for Darwin; interferometric studies of gas and dust in protoplanetary disks. Fraction of time: 10%.

René Liseau. Chalmers University of Technology, Onsala Space Observatory, Sweden. Professor of Radio Astronomy. *Role:* Target selection. Preparatory work for programme. *Qualifications/Areas of interest :* Time evolution of circumstellar disks and outflows. Experience in space research in the FIR/submm domain and experience in groundbased submm/mm line and continuum work. Modelling of disk spectra. Fraction of time: 10%.

Torsten Löhne. Astrophysical Institute, University of Jena, Germany. PhD student (PhD expected in mid-2008). *Role:* dynamical and collisional modelling of debris disks. *Qualification/Areas of interests:* simulations of collisional processes, modelling of debris disks, development of numerical codes.

Rosario Lorente. ESAC, European Space Agency, Herschel Resident Astronomer. *Role:* Data reduction, analysis *Qualifications/Areas of Interest:* Herschel knowledge. Involvement in KP GT debris disk programme. Experience in IR missions ISO, AKARI: data reduction and interpretation. Fraction of time: 10%.

Jesus Maldonado. Universidad Autonoma de Madrid, Spain. PhD Student. *Role:* Target selection. Spectroscopic characterization of target stars. Data reduction *Qualifications/Area of interest:* Observing experience and analysis of cool stars with high resolution optical spectra: spectral classification, radial and rotational velocity determinations, Lithium abundance, chromospheric activity indicators and membership to young stellar kinematic groups.

Jonathan Marshall. The Open University, UK. PhD Student (2nd year). *Role:* Data analysis and interpretation *Qualifications/Areas of Interest:* Debris disk detection and modelling, statistical analysis of the observed sample.

Raquel Martinez. Universidad Complutense de Madrid (UCM), Spain. PhD student. *Role:* Spectroscopic characterization of target stars. *Qualifications/Area of Interest:* Experience in the reduction and analysis of high resolution optical spectra. Experience in the determination of age, activity and kinematics through the analysis of such spectra.

David Montes. Dpt. Astrophysics, Universidad Complutense de Madrid, Spain. Prof. *Role:* Spectroscopic characterization of the target stars. Determination of accurate fundamental stellar parameters as well as age, rotation, stellar activity and kinematics. *Qualifications/Areas of Interest:* experience in the analysis of high resolution optical spectroscopic observations. Strong track record in the spectroscopic analysis of cool stars: spectral classification, radial and rotational velocity determinations, Lithium abundance, analysis of the optical chromospheric activity indicators and membership to young stellar kinematic groups. Fraction of time: 10 %.

Benjamin Montesinos. CSIC Spain. Staff Researcher. *Role:* Ancillary data. Data reduction. Stellar characterization *Qualification/Areas of Interest/:* evolution of circumstellar disks; relation to star properties; stellar activity; the Sun as a star. Fraction of time: 20 %.

Alcione Mora. Universidad Autonoma de Madrid, Spain. Postdoc. *Role:* Target selection. Estimates of photospheric fluxes. Ancillary data. *Qualifications/Areas of Interest:* observing experience (echelle spectroscopy, visible and near infrared photometry and long slit spectroscopy). Determination of stellar parameters using high resolution spectra and broad and narrow band photometry. Spectral synthesis using Kurucz's codes (high resolution spectra, SED construction). Fraction of time: 15 %.

Alessandro Morbidelli. Director of Research of CNRS at Nice Observatory, France. *Role:* Data analysis and interpretation. Solar System EKB in context. *Qualifications/Results:* planet formation and disk evolution. Extensive studies of the evolution of the Solar System Kuiper belt. Fraction of time: 10%.

Harald Mutschke. Astrophysical Institute, University of Jena, Germany. Staff Researcher. *Role:* interpretation and modelling of SED, optical properties of dust, laboratory data. *Qualifications/Areas of interest:* laboratory infrared spectroscopy of dust particles, running a data base of optical constants of dust materials. Fraction of time: 10%.

Takao Nakagawa. ISAS/JAXA, Japan. Staff astronomer *Role:* Complementary data, in particular AKARI. *Qualifications/Areas of Interest:* Dissipation of the inner part of the debris disk. Follow-up observations of debris disks found in the AKARI survey. Experience with mid- and far-IR observations and data reduction (AKARI and Spitzer). Member of the AKARI debris disk team. Co-I of the AKARI all-sky survey. Fraction of time: 10 %.

Göran Olofsson. Stockholm Observatory, Sweden. Professor, CoI for SPIRE. *Role:* Data analysis and interpretation. Ancillary data: differential coronagraphy and spectroscopy of disks. *Qualifications/Areas of Interest:* CoI for SPIRE. PI for Herschel GTO observations of the six biggest debris disks. Experience of instrumentation and observations in the optical and IR regions, including construction of dedicated instrument for disk observations. Fraction of time: 10 %.

Plans to get student/postdoc for the project.

Göran Pilbratt. European Space Agency, Herschel Project Scientist. *Role:* Herschel knowledge provision. Involvement in proposal preparation. Data reduction and interpretation. *Qualifications/Areas of Interest:* Star/planet formation and observational and theoretical connections between the two, occurrence of IR excess and nature/physics of emitter as function of stellar properties. Involvement in KP GT debris disk programme. Fraction of time: 10 %.

Ignasi Ribas. Institute for Space Sciences (CSIC-IEEC), Barcelona, Spain. Staff researcher. *Role:* Multi-wavelength characterization of the target stars. *Qualifications/Areas of Interest:* Determination of accurate fundamental stellar properties (age, rotation, stellar activity, kinematics). Debris disks. Fraction of time: 10 %.

5. List of Consortium Members (cont.)

Aki Roberge. NASA Goddard Space Flight Center, NASA Postdoctoral Fellow. *Role:* Planning/proposing for ancillary observations at optical and UV wavelengths, including coronagraphic imaging. Follow-up: studies of the secondary gas in young debris disks; *Qualifications/Areas of Interest:* extensive studies of gas in debris disks and protoplanetary disks; searches for new debris disks with Spitzer. Fraction of time: 25 %.

Jens Rodmann. ESTEC/ESA, Noordwijk, The Netherlands, Postdoc. *Role:* Preparatory work, target selection, AOR preparation; data reduction, SED modelling, dynamical modelling, last but not least public outreach. *Qualifications/Area of interest:* Experience in data reduction and analysis of space telescope data (HST, Spitzer); extensive modelling of debris disk SEDs for Spitzer FEPS project; tools available for fitting debris disk SEDs and modelling dynamical evolution; great interest in vulgarisation of astronomical topics to the general public. Fraction of Time: 100% before proposal submission; 20-25% before launch; 50% (after launch).

Jorge Sanz Forcada. LAEFF-INTA, Spain. Research position. *Role:* Ancillary data: X-rays. Interpretation. *Qualifications/Areas of Interest:* X-rays emission, stellar formation in X-rays, Stellar activity (if any). Long-time experience in X-rays analysis of stellar coronae. Fraction of time: 10%.

Enrique Solano. INSA-LAEFF, Spain. Staff *Role:* Archiving, Complementary data: Virtual Observatory Tools. *Qualifications/Areas of Interest:* Principal Investigator of the Spanish Virtual Observatory Member of the Euro-VO DCA Board and the IVOA Executive Committee. Fraction of time: 5 - 10%.

Karl Stapelfeldt. NASA/JPL/Caltech, USA. Research Scientist. *Role:* PI US team. Data analysis and interpretation. *Qualifications/Areas of Interest:* Resolved disk images. Spitzer/MIPS associate team member. Fraction of time: 10 - 15% (after launch).

Philippe Thébaud Associate Professor, Paris Observatory, France (currently on extended leave at the Stockholm Observatory, Sweden). *Role:* Modelling. *Research interests/Qualifications:* debris disk modelling (collisions and dynamics); planet formation in binary systems. Fraction of time: 10%.

Helen Walker. Mars Express Payload Operations Service Project Scientist, STFC Rutherford Appleton Laboratory, UK. *Role:* Data reduction and interpretation. Ancillary data: Spectroscopic and photometric characterisation of targets. *Qualifications/Areas of Interest:* Experience with data analysis of infrared data from IRAS and ISO of circumstellar dust and debris disks, comparison with lab spectra, some modelling. Fraction of time: 10-15%.

Glenn White. The Open University, and The Rutherford Appleton Laboratory, UK. Professor. *Role:* Data analysis and interpretation. Ancillary data. Cross correlation with FIR data (AKARI/Spitzer/JCMT Legacy Surveys). *Qualifications/Areas of Interest:* Fundamental disk parameters, relationship to planet formation. Extensive observing experience at wavelengths from the optical to 1 mm studying star formation, planet formation and protostellar disks, analysis of data, and some theory. Fraction of time: 10%.

Sebastian Wolf. Max Planck Institute for Astronomy (MPIA), Germany. Staff. *Role:* disk modelling to support data analysis (fitting of observables). *Qualifications/ Areas of interest:* Head of Emmy Noether Research Group at the MPIA. Fraction of time: 5-10%.

6. Observations Summary List

AOT	Time (hr)	SSOs	Timings	Groupings	Follow-up
PPhoto	270.0			100	
SPhoto	45.5				

Notes (if applicable): In total we plan to observe 666 AORs, distributed as follows:

- 283 in PACS 100/160 μm point-source or small-source photometry mode
- 100 in PACS 70/160 μm point-source or small-source photometry mode
- 283 in SPIRE point-source photometry mode

We request 100 concatenated PACS photometer observations to link the PACS 100/160 μm and PACS 70/160 μm AORs for those target stars where both are required.

7. Alternative Observations Summary List

AOT	Time (hr)	SSOs	Timings	Groupings	Follow-up
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