Detailed study of two debris disks seen by Herschel

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Introduction: To draw a complete picture of planetary systems as a whole, one needs to study all their constituents, from the largest gas giant planets to the smallest dust particles left behind after their formation, or reproduced by collisions. These so-called debris disk represent large reservoirs of material way beyond the snow-line, that may impact the later evolution of terrestrial planets. **HD 181327** is an F5.5V member of the **β Pic moving group (~12 Myr)** located **51.8 pc** away. Its far-IR excess ($L_{IR}/L_* \sim 0.2\%$) and recently **resolved images** reveal an **optically thin belt** of circumstellar material, presumed to result from collisions in a population of unseen planetesimals. As part of the **GASPS** open time key project, we obtained **Herschel/PACS far-IR photometric and spectroscopic observations.** Together with newly reduced **HST scattered light images** they provide the necessary measurements for an advanced analysis of the dust grains, that we complete with predictions on the gas content. Our study suggests that HD 181327 is prototypical of a star located at the end of the transition between gas-rich protoplanetary disks, to gas-poor debris disks. **q1 Eridani** (HD 10647) is a much older **F8V system (~1Gyr)**, known to host a **jupiter-mass RV planet at 2 AU**. We obtained new **PACS resolved images** of the q1 Eri disk, as part of the DUNES project, giving unprecedented information on the **thermal emission of the cold dust** surrounding the star. We developed a consistent modelling approach that provides clues on the possible interaction between the disk and hidden planets.

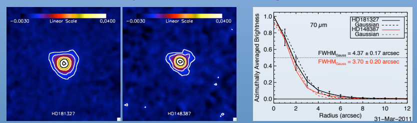
GASPS: Detailed modelling of the HD 181327 debris disk

The *Gas in Protoplanetary Systems* (GASPS) Open Time Key Programme is the first extensive, systematic survey of gas in circumstellar disks over the critical transition from gas-rich protoplanetary disks to gas-poor debris disks.

Herschel/PACS observations

HD 181327 was observed in the 3 PACS photometric bands (70, 100 and 160 µm) in chop-nod mode and calibrated with HIPE v4.2. The disk is marginally resolved showing extended emission at 70 µm (left: PACS 70 µm image, middle: PSF reference star, right: azimuthally averaged radial profiles for both stars, with Gaussian fits overlaid).

Line scan spectroscopy targeting [OI] at 63 µm and range scan spectroscopy targeting [CII] at 158 µm and [OI] at 145 µm were performed with no emission lines detected at the 3σ detection sensitivity (see table on the right).



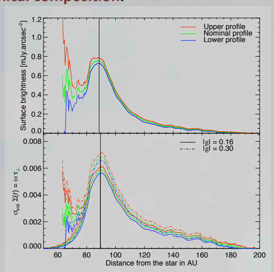
Gas disk modelling

The dust model was injected in the advanced thermochemical disk modelling code ProDiMo (Woitke, Kamp, & Thi 2009) to predict flux ratios in the OI, CII and CO (3-2) lines and derive a limit for the gas-to-dust (G/D) ratio in the disk, but the non-detections of OI and CII do not provide unambiguous constraints. However, coupling with other tracers, e.g. CO lines, offers a hope to put much better limits on the low gas content of debris disks, with ALMA for instance.

G/D	OI [63] (W/m²)	OI [145] (W/m²)	CII [158] (W/m²)	CO (3-2) (W/m²)
1000	2.9 e-18	1.60 e-18	2.6 e-20	1.7 e-19
100	8.3 e-19	1.6 e-20	5.3 e-20	1.6 e-19
10	2.1 e-18	8.2 e-21	2.2 e-19	1.3 e-19
1	2.4e-18	4.0 e-20	6.2 e-19	3.4 e-22
PACS (1σ)	*< 3.27 e-18*	*< 2.83e-18*	*< 2.66 e-18*	

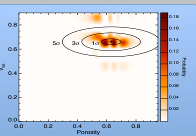
Dust models

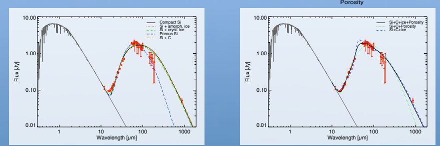
- We make a direct inversion of new HST/NICMOS scattered light brightness profile (Schneider et al. in prep.) to constrain the disk geometry. Knowing the disk's radial density profile allows a detailed study of the dust grain properties: we use the GRaTer code (Augereau et al. 1999) to compute a grid of models and we apply a bayesian analysis to fit the dust Spectral Energy Distribution (SED) and derive precise constraints on the grain size distribution and chemical composition.



- We show that simple grain compositions (icy silicates, porous silicates, etc.) fail at reproducing the observed SED from near-IR to sub-mm wavelengths. More sophisticated grain models are required, namely a mixture of porous (P = 63±21%) silicate + organic refractory grains (we fix $v_C = 2\ v_{Si}$), and amorphous water ice (v_{ice} = 0.67±0.07), to find an overall good fit to the observations. Assuming a single grain size distribution: $n(a) \propto a^{-\kappa}$ for grains larger than a_{min} and smaller than 8 mm, we find a_{min} = 0.81±0.31 µm and κ = -3.41±0.09, leading to a total mass M_{dust} = 0.051±0.016 M_{earth} up to 1 mm. The overall results agree well with previously modeled debris disks such as β Pictoris, HD 141569A or HR 4796.

Top: Bayesian probabilities, grain porosity and ice content knowing the data.
Bottom: Best-fit SEDs obtained assuming either 2-material grains (left) or 3 or 4-material mixtures (right).





Lebreton et al. accepted

DUNES: A Kuiper-like belt around the planet-host star q¹ Eri

The *Dust around NEarby Stars* (DUNES) key program is performing a deep and systematic survey for faint, cold debris disks down to « *Kuiper Belt* » *sensitivity level* ($L_{dust}/L_* \sim 10^{-7}$)

The Star

- Spectral type: F8
- Distance : 17.4 pc
- Age : ~2 Gyr

A Jupiter-mass planet

- M sin i: 0.93 $M_{jupiter}$
- Semi-major axis: 2.03 AU
- Eccentricity : 0.1

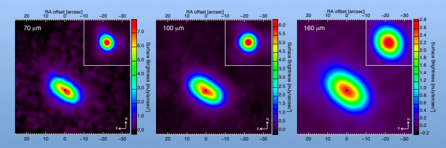
A Kuiper-like belt

IRAS, ISO and Spitzer: cold dust, with a luminosity a few 100 times that of the Kuiper Belt ($L_{disk}/L_{star} \sim 4\times10^{-4}$)

Sub-mm APEX/LABOCA images: disk extent is up to several tens of arcsec (*Liseau et al. 2008*).

HST images suggest a peak at 83AU (4.8", *Stapelfeldt et al., in prep.*)

Herschel/PACS observations



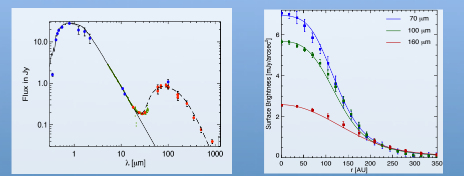
- Disk spatially resolved at all PACS wavelengths (insets show the PSF)
- Disk marginally resolved along the minor axis: inclination > 55 deg

Detailed simultaneous modelling of the SED and PACS images are required to unveil the disk structure, dust properties and dynamical history and **break the degeneracy** between disk geometry and grains properties.

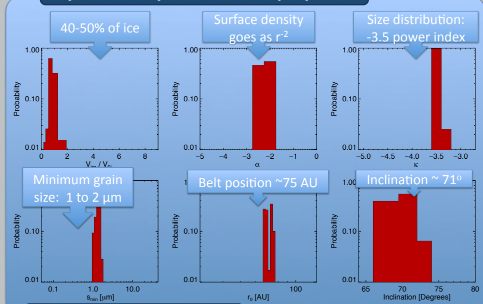
Best model for the SED and PACS radial profiles

Dust Ring :
- Mass : 0.04 M_{Earth}
- Surface density: r^{-2}
- Belt peak position: 75-80AU

Grain properties :
- Minimum grain size ~ 1.5 µm
- Size distribution: - 3.5 power law index
- Close to 50-50 silicate-ice mixture



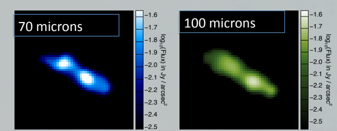
Bayesian analysis of the disk properties



Augereau et al. In prep.

Evidences for more planets?

- Possible **asymmetry** between the two sides
- **Collisional models** predict an **initial dust mass of ~1000 M_{earth}** (if the star is 2 Gyr), leading to 0.4M_{sun} for the whole protoplanetary disk. This could be reduced to ~100 M_{earth} if the disk is 0.5Gyr , or be an evidence for **delayed stirring by unseen inner planets**.



Deconvolution with the MCS algorithm (Magain, Courbin & Sohy 1998, ApJ 494, 472)