The impact of ALMA on debris disk research

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Outline

Debris disks are optically thin dust disks around stars produced by ongoing collisions of planetesimals left over from the planet formation process. They help us to improve our understanding of the formation and evolution of planetary systems. Our Herschel open time key program DUNES (DUst around NEarby Stars) aims at detecting debris disks with a fractional luminosity similar to the Edgeworth-Kuiper Belt (EKB) level around a volume limited sample ($d < 25$ pc) of FGK stars. We present observations of the DUNES science demonstration object q[1] Eri and ilustrate the need of ALMA observations. In addition, we present a study on the observability of the planet-disk interaction in debris disks with ALMA, a multi-wavelength study of the debris disk around HD 107146 and the impact of ALMA observations on this object, as well as three debris disks with unusual spectral energy distributions, revealed by DUNES observations.

Questions?

The author of this poster is present and happy to answer your questions!

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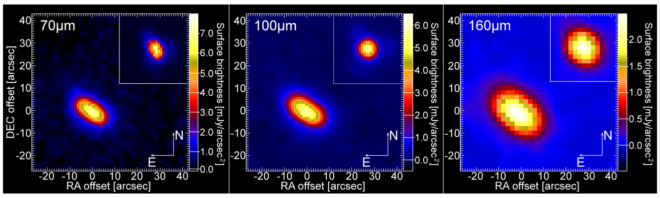
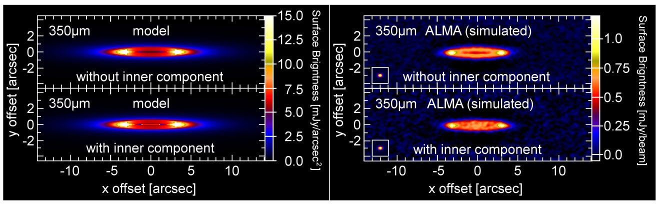
The q1 Eri debris disk

The q[1] Eri (F8V, $d = 17$ pc) debris disk has been spatially resolved by Herschel/DUNES at 70 μm, 100 μm, and 160 μm, and detected at 250 μm, 350 μm, and 500 μm [1]. Simultaneous modeling of images and SED reveals a heavy EKB analogon and additional evidence of an Asteroid Belt analogon. A giant planet ($a = 2$ AU, [3]) completes the known parallels to our solar system.



Herschel/PACS data of q[1] Eri. The PSF is shown in the upper right corner, respectively.

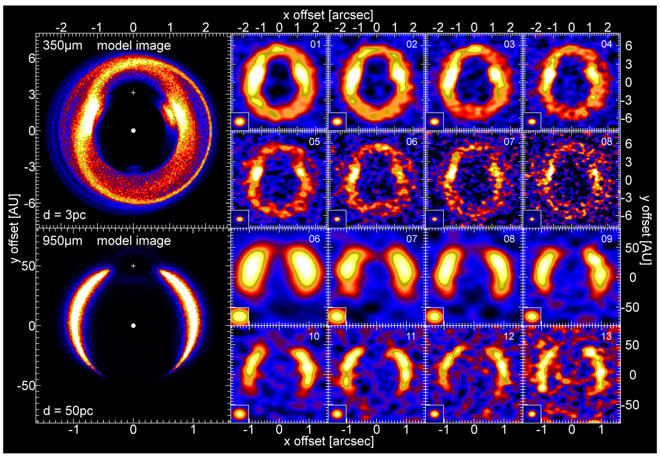
ALMA observations will resolve the inner component and thus put strong constraints on possible further planets [4]. ALMA multi-wavelength high resolution images will strongly constrain the radial dust distribution and allow detailed modeling of its composition.



Simulated ALMA observations of our best-fit model. Parameters for simulation: $\lambda = 350\,\mu$m, max. baseline = 260 m, PWV = 0.8 mm, time on target = 8 h. $1\sigma = 0.04$ mJy/beam.

Planet-disk interaction

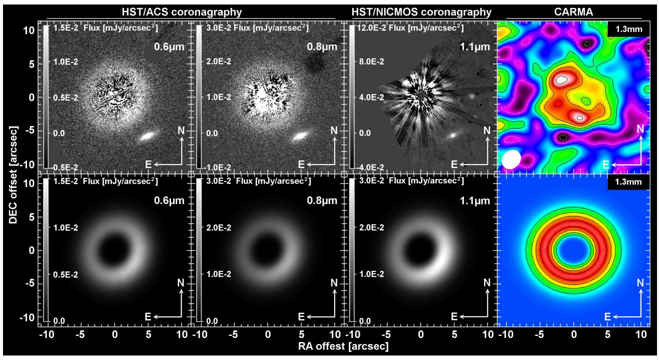
We perform dynamical simulations to study the observability of structures induced in debris disks by planet-disk interaction with present and future instruments [4]. ALMA provides unique opportunities for such observations, but is limited by its sensitivity, not its resolution, due to the low surface brightness of debris disks.

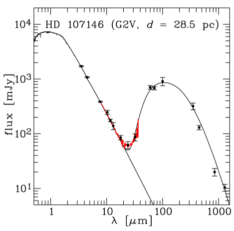


Simulated ALMA observations of planet-disk interaction. Parameters for simulation: PWV = 0.8 mm, time on target = 8 h. The numbers represent the predefined array configurations (CASA). The color scales have been adjusted to fit the dynamic ranges. Top: Initial ring of debris at 5 AU, planet ($M_p = 1\,M_J$) at 3.1 AU (2:1 resonance, e.g., ϵ Eri planet & inner disk [5]), $d = 3$ pc. Total flux: Scaled to the level of the ϵ Eri inner disk. Bottom: Ring of debris at 50 AU (e.g., EKB or HD 105), planet ($M_p = 1\,M_J$) at 50 AU, $d = 50$ pc. Total flux: Scaled to HD 105 level.

The HD 107146 debris disk

Combined multi-wavelength modeling of images and well sampled SED (star: G2 V, $d = 28.5$ pc) reveals a broad (~ 90 AU) ring at $R \sim 130$ AU [6]. CARMA observations [7] show two peaks, consistent with dust trapped into resonance by a giant planet. We find the smallest dust grains present to be significantly (5 times) larger than the radiation blow-out size, contradictory to the known physical processes taking place [6].

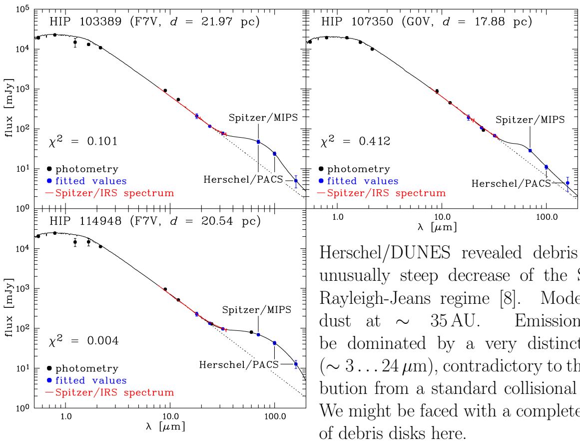




Top: *Resolved observations (upper) and modeled images (lower). Maximum baseline for the CARMA observations: 148 m. Contours start at -1σ (white) and $+1\sigma$ (black), increments: $1\sigma = 0.35$mJy/beam. White ellipse: beam FWHM. Peak surface brightness in the CARMA map: $\sim 5\sigma$.*
Left: *Photometric data along with applied stellar photosphere model and simulated SED from our best-fit model.*

If the structures can be confirmed, with its high surface brightness the HD 107146 disk will provides excellent conditions to study planet-disk interaction in debris disks with ALMA [4]. High resolution multi-wavelength images by ALMA will strongly constrain the dust composition and lower dust grain size.

A particular kind of debris disks



Photometry & best-fit model of the three particular SED sources.

Herschel/DUNES revealed debris disks with unusually steep decrease of the SED in the Rayleigh-Jeans regime [8]. Modeling reveals dust at ~ 35 AU. Emission seams to be dominated by a very distinct grain size ($\sim 3 \ldots 24\,\mu$m), contradictory to the size distribution from a standard collisional cascade [9]. We might be faced with a completely new kind of debris disks here.

References

[1] Liseau et al. (2010); [2] Augereau et al. (in prep.); [3] Butler et al. (2006); [4] Ertel et al. (in prep.); [5] Backman et al. (2009); [6] Ertel et al. (submitted); [7] Corder et al. (2009); [8] Ertel et al. (in prep.); [9] Dohnanyi (1969)