OBSERVATIONS OF COOL DUSTY DEBRIS IN EXTENDED DISKS

- CHARACTERIZATION BEYOND INFRARED DATA

R. Nilsson[1,2], A. Brandeker[1], R. Liseau[3], C. Risacher[4], G. Olofsson[1], G. Pilbratt[5], M. Fridlund[5]

[1]*Stockholm Observatory;* [2]*Stockholm Astrobiology Graduate School;* [3]*Onsala Space Observatory;* [4]*European Southern Observatory (ESO);* [5]*European Space Agency (ESA)*

ABSTRACT

Previous observations with IRAS and ISO, and ongoing observations with Spitzer and AKARI have lead to the discovery of over 200 debris disk candidates, based on detected mid- and far-IR excess emission. In order to constrain the properties of these systems, e.g., to accurately determine the dust mass, temperature, and radial extent, follow-up observations in the submillimeter wavelength region is needed.

Here we present recent results from 870-µm measurements targeting candidate stars in the β Pictoris Moving Group, using the Large APEX BOlometer CAmera (LABOCA) on the 12-m APEX telescope, on Llano de Chajnantor, Chile. In addition to interesting results on the well-known βPictoris disk itself, a first detection of cold extended dust around HD 181327, as well as tentative detections of HD 170773 and HD 172555, were made.

INTRODUCTION

Circumstellar disks are the nurseries of planets, and the formation of disks is a natural outcome of star formation processes, where gas and dust contract under gravity, conserving angular momentum. Initial submicron-sized dust grows into kilometer-sized planetesimals within 10 Myr, but exactly how this proceeds is still unknown. While the gas is being cleared early on by radiation pressure from the star or incorporated into large gassy planets, dust is being continuously replenished by collisions of rocky bodies, leaving debris disks as left over traces of planet formation. Ultraviolet and optical light from the star is absorbed by the dust grains and reradiated in the infrared (IR), giving the typical IR-excess feature in the observed spectral energy distribution (SED) of the object. By combining complementary information gathered from other wavelength regions we can characterize circumstellar disk evolution and shed light on the universality of disk- and planetary systems. Previous studies at mid- to far-IR wavelengths have shown an excess emission which indicates circumstellar dust extending out to some tens of AU, but detection of an order of magnitude more extended, colder dust components requires sensitive submm-observations. If detected, a submm-excess may indicate the existence of Kuiper-Belt analogues, where dust particles are continuously produced by collisions of larger bodies.

COLD OUTER DUST DISKS

Observations: We have performed observations with the LABOCA bolometer array at the 12-m submm telescope APEX (Atacama Pathfinder Experiment), run jointly by Onsala Space Observatory, the Max-Planck-Institute for Radio Astronomy, and the European Southern Observatory (ESO), at an altitude of 5100 m in the Chilean Andes. LABOCA operates at a central wavelength of 870 µm (345 GHz) with bandwidth of 150 µm (60 GHz), covering a 11.4′ field-of-view with its array of 295 bolometers; each with a 18.6″ full-width at half-maximum (FWHM) beam. Eleven main-sequence stars in the β Pictoris Moving Group were selected in this first round of observations of a larger survey targeting debris disk candidates that are members of moving groups ranging in age from 10 to 100 Myr. Within each group, any differences in dust composition and mass would thus reflect inherent, age-independent, differences.

Results: Out of our sample of 11 stars we made at least two clear detections, and an additional two with 3-4σ certainty. RMS-noise weighted average maps of the four objects are shown in Figure 1. Calculating the minimum mass $M_{\rm dust} = F_\nu D^2/\kappa_\nu B_\nu(T_{\rm dust})$, with $\kappa_\nu = 2$ cm^{2}g^{-1} (see discussion in Zuckerman 2001 and Liseau et al. 2008) and assuming grain temperatures deduced from far-IR data (Holland et al. 1998; Rhee et al. 2007), we arrive at the masses presented in Table 1. For the undetected objects, an upper limit from the 3σ–flux density is given.

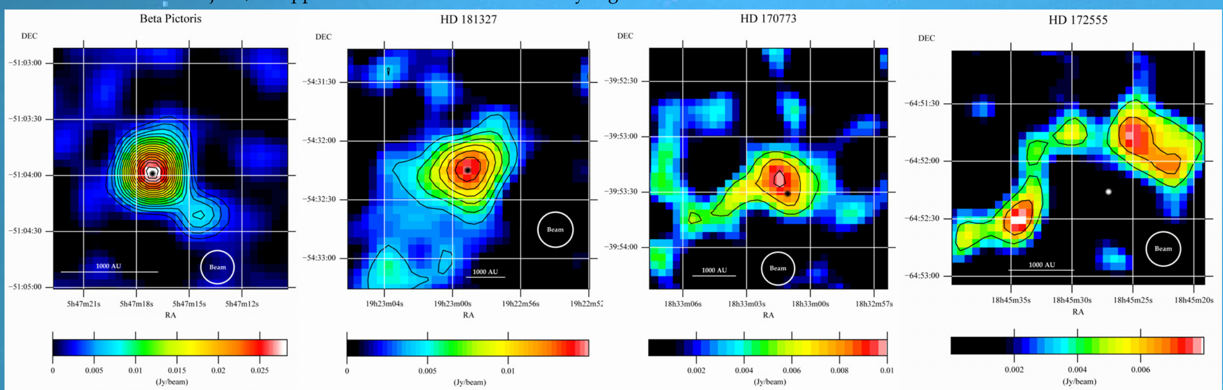

Figure 1 Maps of β Pic, HD 181327, HD 170773, and HD 172555 observed at 870 µm with LABOCA at the APEX telescope. Each map has been smoothed with a 18.6″ circular gaussian representing the FWHM of the beam. The first contour corresponds to 2σ with the following contours at increments of 1σ.

Discussion: The results for β Pictoris are roughly consistent with previous 850-µm data from SCUBA at JCMT (Holland et al. 1998), including the position of the offset south-west flux peak, lying almost in the disk plane. A similar feature, but located at a slightly different position, was found in the 1.3-mm image obtained with SIMBA at SEST by Liseau et al. (2003). An inclined dust ring around HD 181327 was resolved by HST NICMOS and ACS coronagraphic imaging in 2006 (Schneider et al. 2006). We now have the first submm detection of this source, providing a good measure of the remarkably high dust mass and enabling a better determination of the SED and physical grain characteristics. The peak flux in the map of HD 170773 seem to be offset the source center, but is most certainly connected with it. For HD 172555, the observed structure could indicate a very extended and asymmetric dust ring seen almost edge on. Further discussions about these and other results will soon be presented in Nilsson et al. (in prep.). Upcoming observations will help us determine the frequency of cold extended dust disks around main-sequence stars, investigate the physical properties of the grains, put constraints on disk evolution, and determine the suspected correlation with the existence of planets around these stars.

Object	Distance [pc]	Integrated flux density, F [mJy]	RMS noise, σ [mJy/beam]	Dust mass, $M_{\rm dust}$ [$M_{\rm Moon}$]
β Pictoris	19.3	102.3	1.1	6.8
HD 181327	50.6	77.0	1.9	46.7
HD 170773	36.1	42.6	2.4	19.7
HD 172555	29.2	51.8 (NW), 30.7 (SE) *	2.1	2.5 (NW), 1.5 (SE)
HD 15115	44.8	Undetected	2.1	<1.6**
HD 110058	99.9	Undetected	2.7	<3.7**
HD 131835	111.1	Undetected	3.7	<7.3**
HD 164249	46.9	Undetected	1.7	<1.7**
HD 181296	47.7	Undetected	2.3	<0.8**
HD 182681	69.1	Undetected	2.3	<3.0**
HD 191089	53.5	Undetected	2.5	<1.6**

Table 1 Integrated flux density (in a circle with a radius of 40″ around source), root-mean-square noise levels and derived dust mass for the 870-µm observations of main-sequence members of the β Pic Moving Group. *) North-west and south-east feature of HD 172555 calculated separately. **) Upper (3σ) limit on the dust mass for undetected sources.

References

Holland, W. S., Greaves, J. S., Zuckerman, B., Webb, R. A., McCarthy, C., Coulson, I. M., Walther, D. M., Dent, W. R. F., Gear, W. K.. & Robson, I., 1998, Nature, 392, 788
Liseau, R., Brandeker, A., Fridlund, M., Olofsson, G., Takeuchi, T. & Artymowics, P., 2003, A&A, 402, 183
Liseau, R., Risacher, C., Brandeker, A., Eiroa, C., Fridlund, M., Nilsson, R., Olofsson, G., Pilbratt, G. L. & Thébault, P., 2008, A&A, 480, L47
Rhee, J. H., Song, I., Zuckerman, B. and McElwain, M., 2007, ApJ, 660, 1556
Schneider, G., Silverstone, M.D., Hines, D.C., et al., 2006, ApJ, 650, 414
Zuckerman, B., 2001, Ann.Rev. A&A, 39, 549

The 5th Spitzer Science Conference "New Light on Young Stars: Spitzer's View of Circumstellar Disks", Pasadena, CA, USA, October 26-30, 2008

Contact: *ricky@astro.su.se*