Resolving disks and binaries in A-star debris disks

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Abstract

With a combination of high-resolution AO imaging and submillimeter, single dish mapping, we are investigating two projects involving debris disks around A-stars.

1. With 350μm observations from the CSO, we have spatially resolved the debris disk encircling the HR 8799 planetary system. The 350μm map exhibits an arc of emission with a bright clump at a distance consistent with that expected from simulations of dust trapped in a 2:1 resonance with the outermost planet. The distribution and location of the dust is a powerful tool to understand the migration and eccentricity history of the planets. The submillimeter map suggests that the planets migrated to their current locations and that the eccentricity is low, if the dust is trapped in a resonance.

2. A total of 416 A-stars within 75pc, have been observed with AO systems on 3-8m telescopes. From the WISE preliminary source catalog and sensitive *Spitzer* MIPS observations taken from the literature, we have identified a large subset of ~100 stars possessing IR excesses and ~120 stars with no excess. From these large-scale data sets, the frequency of binaries in debris disk systems is compared to the control sample of A-stars without dusty disks.

Observations

Submillimeter Near-IR

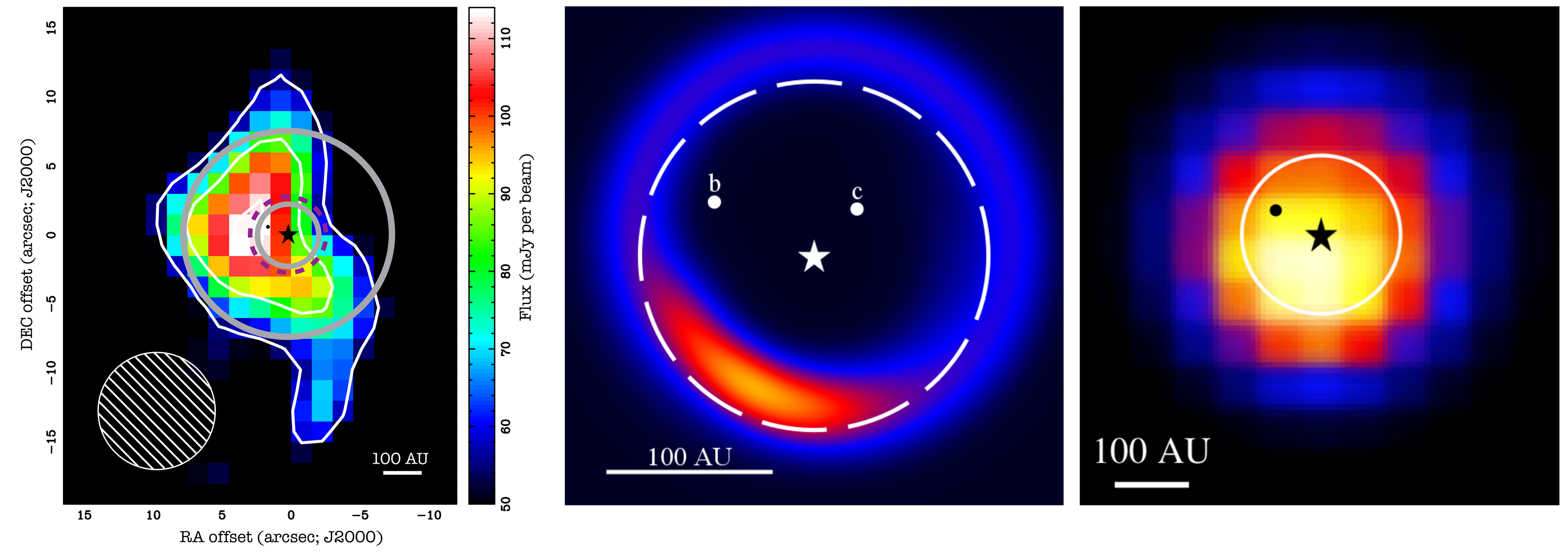
Submm: 350μm observations of HR 8799 were taken with the 10m Caltech Submillimeter Observatory (CSO) with the SHARCII 12x32 bolometer array; both are shown in the images above, on the left. Given the importance of calibration, a similar number of target and calibration observations were taken, sampling the same range of temperature, elevation and opacity.

NIR: As part of the ongoing VAST (The Volume-limited A-STar Survey) survey (R. De Rosa et al., in prep.); a large adaptive-optics multiplicity survey of A-stars within 75pc, we have obtained high resolution near-IR images for ~400 targets of the survey, using the AO systems of the CFHT, Gemini, Lick, Palomar , VLT and WHT observatories; shown in the images above, on the right.

References

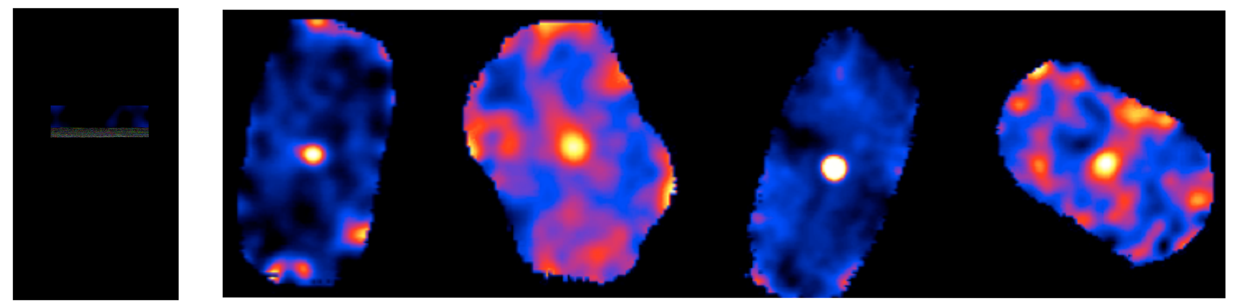
Dowell et al. 2003, Proc., 4855, 73; De Rosa et al., in prep.; Patience et al. 2011, A&A Letter, 531, 17; Pinte et al. 2006, A&A, 459, 797; Reike et al. 2005, ApJ, 620, 1010; Su et al. 2006, ApJ, 653, 675; Su et al. 2009, ApJ, 705, 314; Trilling et al. 2007,ApJ, 658,1289

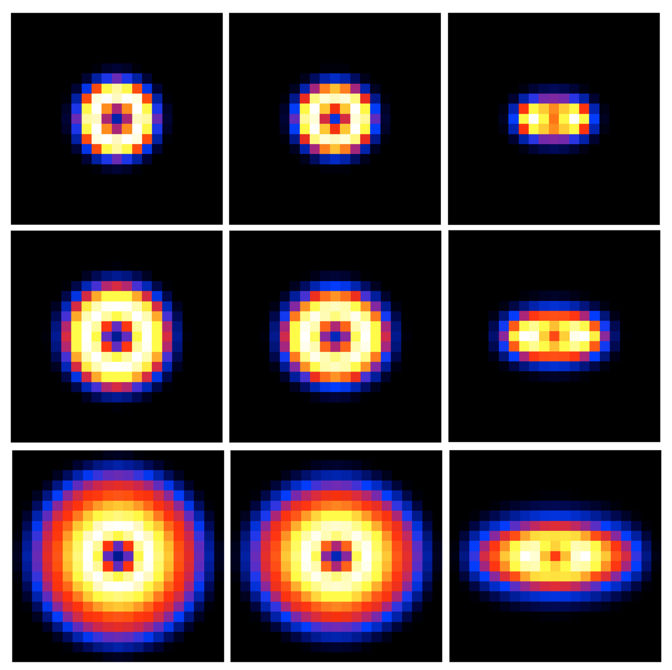
Spatially Resolved Imaging of the HR 8799 Debris Disk

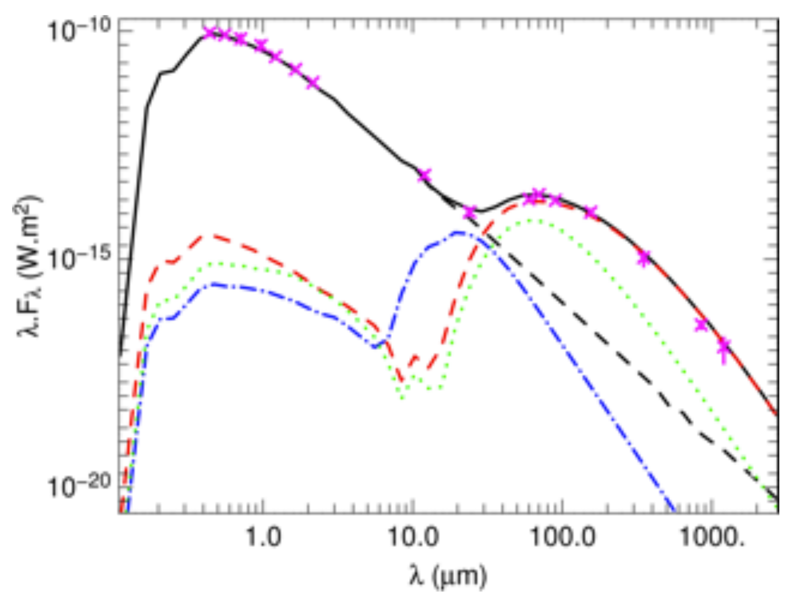


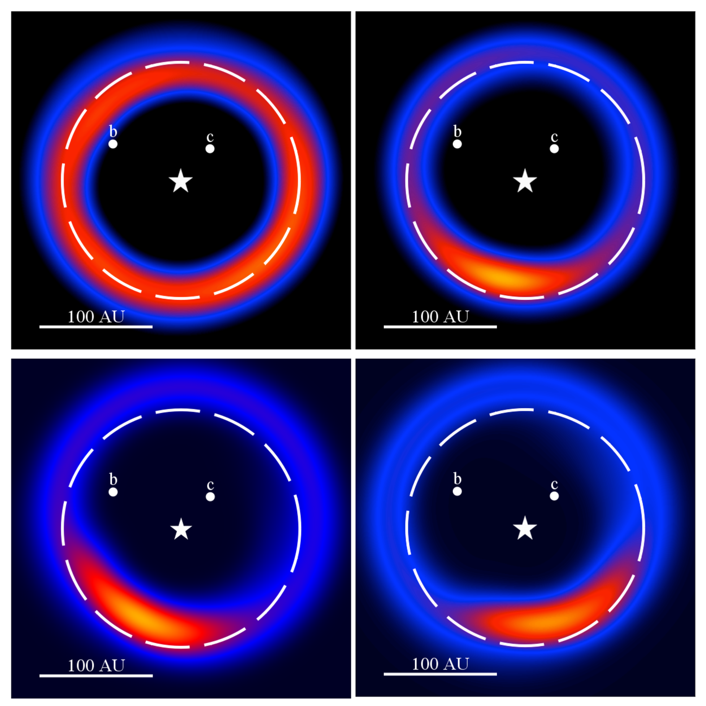
(left) The CSO 350μm image with the positions of the star (black star) and outermost planet (dot) indicated. The solid circles trace the locations of the inner and outer edge of the Kuiper belt used in the SED model and the dashed line shows the expected position of the 2:1 resonance. **(middle)** The disk surface density map from the simulation. The semi-major axis centres around the 2:1 resonance with the outer planet (dashed line), and the moderate eccentricities (~0.3) of the dust grains explain their displacement from the circular path. **(right)** The same numerical simulation convolved with an 8".5 Gaussian to compare with the brightness peak position in the CSO map of the same resolution. The 2:1 resonance is indicated by the white line.

CSO 350μm images of: Uranus **(1st right)** - taken the night of observation of HR 8799 and several M-dwarf members of Taurus **(far right)** - equivalent brightnesses of the HR 8799 disk, taken during the same observing run. These unresolved, point source images represent the beam shape of the CSO.









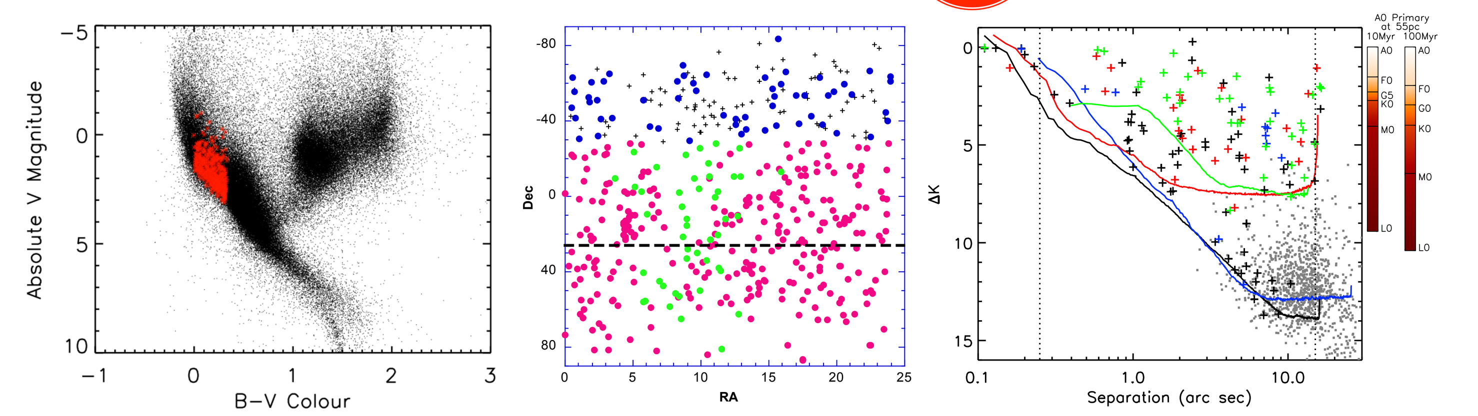
(**Left**) Model ray tracing images at a wavelength of 350μm generated with the MCFOST code for combinations of three outer disk sizes and disk inclinations are shown: (top row, from left to right) 200 AU outer disk with inclinations of 0°, 30° and 60°, (middle row) 300 AU outer disk with same sequence of inclinations, and (bottom row) 500 AU outer disk with same sequence of inclinations. Each image has a size of 1200 AU × 1200 AU and the pixels match the size of the CSO map pixels. The dynamic range is a factor of 10.

(**Middle**) The fluxes of the HR 8799 star/disk system are plotted as a function of wavelength (purple crosses), along with the SED model with the parameters similar to the model of Su et al. (2009) with an outer radius of the Kuiper belt of 300 AU (solid black line). Contributions from the stellar flux (black dashed line) and scattered and emitted light from the asteroid belt (blue dash-dot line), the Kuiper belt (dashed red line), and outer halo (green dotted line). As seen in the resolved map, the emission is largely confined to a radius of 300 AU.

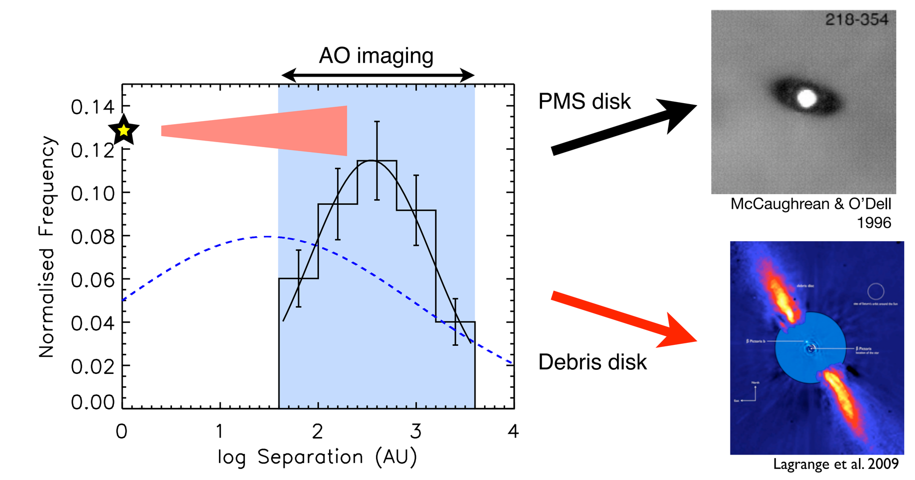
(**Right**) Simulations of surface density from the N-body numerical model at four wavelengths, increasing from upper left to lower right: 24μm, 70μm, 350μm, and 850μm. The dynamic range is a factor of 10, and the simulation is smoothed to a resolution of 1. 5, matching the capability of ALMA. All figures are contemporaneous in the evolution. Future observations with ALMA will quantify the location of the inner edge of the disk and any asymmetric structures with much greater sensitivity and pointing accuracy.

Binaries in A-star Debris Disks

AO observations



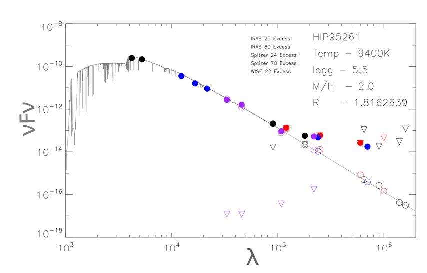
(left) Targets of the VAST survey; a large scale AO multiplicity study of A-stars within 75pc, are indicated by the red points in the colour-magnitude diagram of the Hipparcos catalog. **(middle)** Positions for a subset of sample, observed at the Gemini North, CHFT, Palomar and Lick observatories. **(right)** Crosses mark the 5σ detected companions for a subset of the survey, where the colours represent the observatories where the data was obtained.

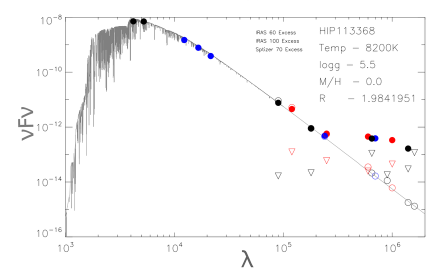


Separation distribution histogram of resolved binary companions. The blue region marks separation range that the survey is sensitive to; ~10AU-1000AU. We are investigating the frequency of binary systems with that of debris disks.

Disk Excess Measurements

Hipparcos and 2MASS observations have been used to derive best fit photospheric spectrums, based on atmospheric models for our targets. For the targets where the data is available we have measured the predicted photospheric fluxes at 22μm (WISE), 24μm and 70μm (*Spitzer*), and compared these with the observed values. We have currently identified; 44 warm debris disks, where excesses are seen at 22μm and/or 24μm, with a control sample of 134 targets where there is no excess, and 68 cold debris disks, where there is excess at 70μm, with a control sample of 16. The initial results of the frequency of multiplicity amongst these data sets are given below.





	Excess sample	Control sample
Warm debris disks	18±6%	39±5%
Cold debris disks	38±7%	31±14%
Warm & Cold debris disks	38±7%	47±6%

Future Work

With this data we will investigate binary companion separations with that of the identified debris disk types. The results of this survey will allow us to test models that investigate how debris disk respond to a companion star. What is the incidence of A-star debris disks in binary systems? Do debris disks in binary systems posses truncated disks or is dust swept out into otherwise forbidden orbits?