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Resolving structure in the HD100546 disk - signatures of planet building?

S. T. Maddison[1], C. M. Wright[2], D. Lommen[3], M. Burton[4], D. Wilner[5] and T. Bourke[5]

[1]Centre for Astrophysics & Supercomputing, Swinburne University, Australia,
email: smaddison@swin.edu.au

[2]UNSW@ADFA, Canberra, Australia
[3]Leiden Observatory, The Netherlands
[4]Department of Physics, UNSW, Australia
[5]Harvard-Smithsonian Centre for Astrophysics, USA

Several lines of evidence suggest that planet formation may be well underway within the circumstellar disk of the enigmatic Herbig Be star HD100546, including a cleared inner cavity, spiral structure, and similar dust mineralogy as seen in our own solar system. To learn more about the processes occurring in this disk we have conducted a multi-frequency observing program with the Australia Telescope Compact Array (ATCA).

We find the millimetre slope of the spectral energy distribution (SED) is $\alpha \sim 2.3$ (using fluxes integrated over the entire extent of the emission), suggesting a dust opacity index $\beta \sim 0.3$. From spatially resolved and temporally stable emission over $\gtrsim 3$ years, we find that the flux at 3, 7 and 16 mm is dominated by thermal emission from dust grains up to several tens of centimetre in size. At all millimetre wavelengths the peak emission is centered $\lesssim 0.5''$ west of the optical stellar position. There is however structure in the emission, especially at 3 mm where we detect a discrete clump about an arcsecond to the south-west coincident with features seen in HST ACS images, and a second clump about 2.5 arcsec to the north. Subarcsecond-resolution 3 mm images show a deficit of emission at the centre of the disk, in agreement with the inner cavity seen in infrared observations. We determine a dust disk FWHM of ~50–100 AU and mass of $\sim 10\ \mathrm{M_{Earth}}$.

The longer wavelength 3.5 and 6.2 cm emission is relatively stable on the time scale of months and years, and we find the centimetre SED is consistent with emission arising from free-free processes. The 3.5 cm emission is elongated orthogonal to the millimetre disk emission, suggestive of a wind, with the data indicating a wind mass loss rate of $\sim 10^{-8}\ \mathrm{M_\odot/yr}$.

We also present $HCO^+(1\rightarrow0)$ line data which demonstrates the presence of dense molecular gas in the disk, supported by our ^{12}CO $(4\rightarrow3)$ and $(7\rightarrow6)$ data from NANTEN2. The line profile is double-peaked, with component velocities at 3.5 and 7.0 km/s, in agreement with APEX $^{12}CO(3\rightarrow2)$ data. Each component is coincident with the position of HD100546, but with a slight spatial offset approximately along the disk major axis. If interpreted as Keplerian rotation, the radius of the molecular gas emission is ~350 AU, with the SE side approaching and the NW side receding from Earth.

Our new results show that the pebble-sized grains in the disk of HD100546 are amongst the largest yet observed, and combined with the cleared inner dust cavity might suggest that planet formation is indeed well underway, or that grain sizes are so large that they are becoming invisible at millimetre wavelength. The detection of a large molecular gas disk and a wind, along with ultraviolet accretion signatures, would suggest that the system is still quite immature. Perhaps the gas is needed to allow grains to grow to such large sizes in the inner disk.