Astronomy reports

Millimetre observations of circumstellar disks around the young stars TW Hya and HD 100546

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Many young stars exhibit emission from circumstellar dust disks with properties similar to the early Solar System. Observations at millimetre wavelengths are especially important for characterising the physical properties of these disks because the disk material beyond a few stellar radii is at temperatures ranging from a few tens to a few hundreds of degrees, and the physical and chemical conditions can be probed in detail in this part of the spectrum.

The recent upgrade of the Compact Array with receivers for the 3-mm atmospheric window provides a new opportunity for high resolution imaging of protoplanetary disks located in the southern sky. We have observed the dust continuum and HCO^+ ($J = 1 - 0$) line emission at 89 GHz (3.4 mm) from two young southern disk targets, TW Hya, the closest known classical T Tauri star, and HD 100546, a nearby Herbig Be star whose infrared spectrum shows crystalline silicates, indicative of comet-like dust. These were observed using two compact antenna configurations of three antennas, with an angular resolution of about two arcseconds.

TW Hya is isolated from any molecular cloud but retains a face-on disk visible in scattered light that extends to a radius of at least 3.5 arcseconds, equivalent to a linear size of approximately 200 astronomical units (AU). Its disk has been detected in a number of molecular lines at submillimetre wavelengths using single dish telescopes. Modelling all available data suggests the TW Hya disk is substantially evolved, with indications of significant particle growth, i.e., evolution toward planet-sized objects.

HD 100546 is a nearby Herbig Be star and shows a disk-like scattered light distribution of substantial size, about 8 arcseconds (8,000 AU), as well as strong millimetre emission from dust. Mid-infrared spectroscopy shows remarkably strong crystalline silicate bands, similar to those observed in comet Hale-Bopp and indicative of substantial processing of the dust within the disk.

Figure 12 shows the 89 GHz continuum emission detected from TW Hya and HD 100546. The flux observed from TW Hya agrees well with expectations from its spectral energy distribution. Models that reproduce the far-infrared emission of HD 100546 using only an extended envelope do not account for the flux observed at 1.2 mm which suggests that a circumstellar disk component must be present in the system. The Compact Array observations provide the first direct evidence for this compact disk component.

Figure 13 shows the HCO^+ ($J = 1 - 0$) spectrum of TW Hya, integrated over the continuum position. The velocity and line-width of the narrow emission line are in agreement with single dish observations. The HCO^+ ($J = 1 - 0$) line emission from the TW Hya disk is spatially resolved, with a fitted Gaussian size of 3.2 arcseconds. Since the critical density of the HCO^+ ($J = 1 - 0$) line for collisional excitation is approximately 6×10^4 cm^{-3}, the detection of extended emission indicates high densities must be present to large radii, independent of any detailed physical and chemical model for the disk. No HCO^+ ($J = 1 - 0$) emission was detected toward HD 100546, a surprising result. Observations of the more abundant species CO in the 110 – 115 GHz range are needed.

Previous modelling of the TW Hya disk suggests that species like CO and HCO^+ are depleted due to a combination of photodissociation in the warm surface layers and freezing-out in the cold parts of the disk shielded from stellar activity. These models, based either on a radiatively-heated accretion disk structure or a passive two-layer disk structure, are consistent with the Compact Array observations, for both the size scale and the absolute intensity of the HCO^+ line. The models all have disk masses of 0.03 solar masses and disk radii of 200 AU. High depletion has been observed in other young disks of varying size and indicates that substantial depletion occurs throughout the disk, as expected for planet formation through accretion.

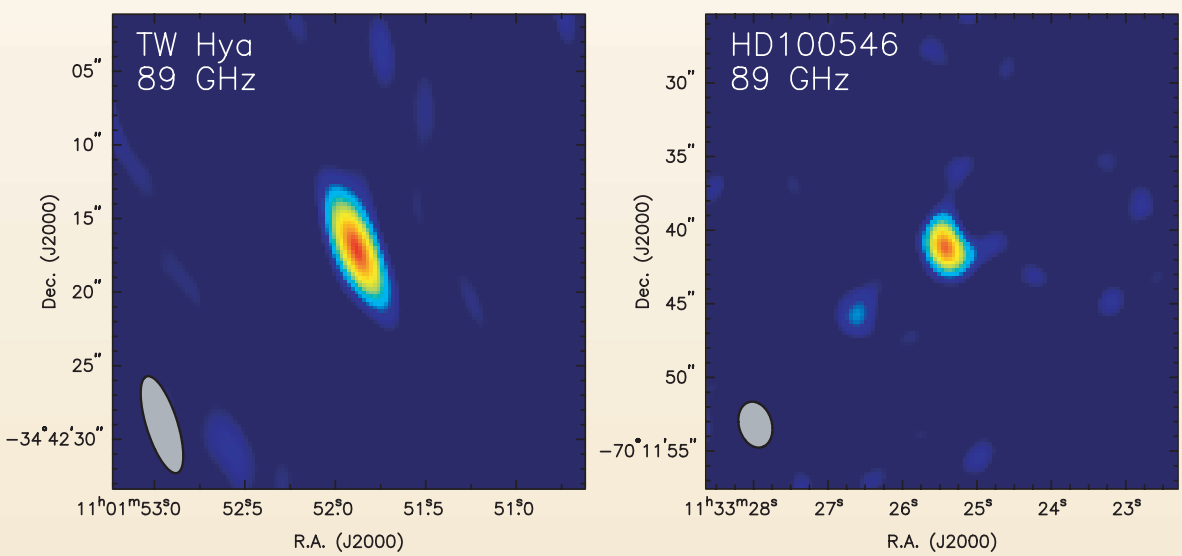

Figure 12 *Images obtained with the Compact Array showing radio continuum emission at 89 GHz from the young stars TW Hya and HD 100546.*