Resolving Structure in Transition Disks: Inner Holes

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Abstract

We are using millimeter interferometry to make high-resolution observations of nearby, gas-rich "transition" disks whose spectral energy distributions suggest the presence of large central holes, features that may be linked to giant planets in formation. We present new subarcsecond-resolution VLA 7 millimeter observations of the TW Hydrae disk that provide direct evidence for clearing of dust in the inner region, within ~4 AU of the star. We also present SMA 860 micron and IRAM PdBI 1.3 and 2.7 millimeter observations of the GM Aurigae disk which resolve clearing of dust within 24 AU of the star.

Please pardon the appearance!
Poster is in Boston (difficult to see from Porto; requires VLBI)

TW Hydrae

Using the VLA[1] at 7 mm we have obtained direct images of clearing in the inner ~4 AU of the protoplanetary disk around TW Hya. Central clearing is evident from the intensity distribution in the image plane (fig 1) and in the visibility domain (fig 2). Outer disk parameters were constrained using observations of the CO J=2-1 transition with the SMA (fig 3, Qi et al. 2004, 2006). Modeling of infrared deficits in the TW Hya SED (Calvet et al. 2002) predicts the observed inner hole and directly illuminated wall.

For details see Hughes et al. 2007, arXiv:0704.2422

1 - The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

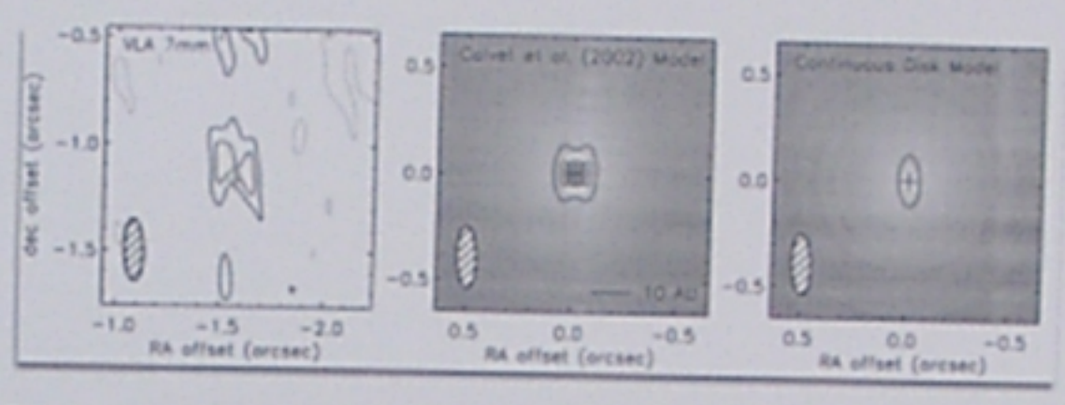

Fig. 1 – TW Hya observed with the VLA at 7 mm (left), compared with model of TW Hya disk from Calvet et al. 2002 (center), and a continuous model which extends in to the dust destruction radius at ~0.01AU (right). The ellipse in the lower left corner represents the synthesized beam with FWHM size 0.29" x 0.094" (PA 2°). Contours are [-2,2,3] x 0.23 mJy (the RMS noise). The cross marks the position used to generate the visibility function. The grayscale shows the models at full resolution.

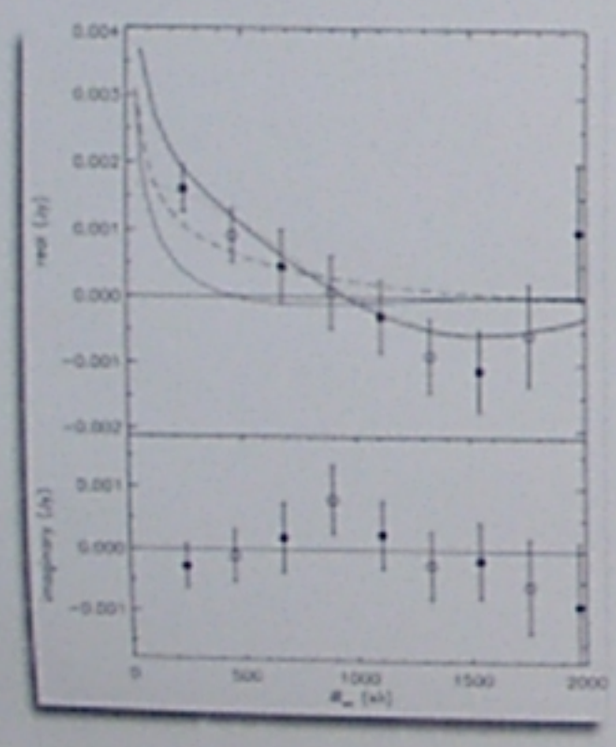

Fig. 2 – TW Hya visibilities observed at 7mm with the VLA, displaying a null near 1000 kλ (hole radius of 4.3±0.3 AU). Data are averaged in 430 kλ bins, and corrected for projection effects due to 7° inclination. Two overlapped independent sets of bins are shown (filled and open circles). Light solid line is Calvet et al. (2002) model with parameters derived from outer disk (below). Dotted line is for frontally illuminated inner edge of disk. Heavy solid line represents the sum of disk and wall components. For comparison, the function for a disk with no hole (dashed line) is also shown.

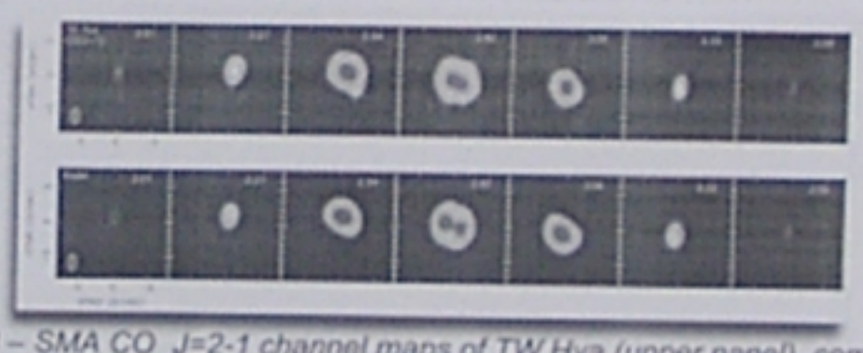

Fig. 3 – SMA CO J=2-1 channel maps of TW Hya (upper panel), compared with the Calvet et al. (2002) model (lower panel). Refer to Qi et al. (2004, 2006). Contour levels are [1,3,5,7,9,11,14,17, 20] x 0.42 Jy. The width of each channel is 0.26 km/s.

	value	source
Outer disk radius	200 AU	CO J=2-1
Inclination	7°	CO J=2-1
Stellar mass	0.6 M	CO J=2-1
Distance to system	51 pc	Mamajek (2005)
Dust opacity	--	D'Alessio et al. (2001)
Inner disk radius	4.5±1.0 AU	7mm data / SED
Width of wall	~0.5 AU	7mm data / SED
7mm flux of wall	1.7±0.8 mJy	7mm data

Table 1 – Parameters used for models shown in figures 1 & 2. Properties derived from CO J=2-1 are in Qi et al (2004, 2006). Quantities in gray were fixed during the fitting process , while those in white were allowed to vary to best match the data.

GM Aurigae

Using the SMA[2] at 860 mm (349 GHz) and the Plateau de Bure Interferometer at 1.3 and 2.7 mm, we have obtained direct images of clearing in the inner ~24 AU of the protoplanetary disk around GM Aur, in the image plane (fig 4) and the visibility domain (fig 5). Outer disk parameters were constrained using observations of the CO J=3-2 transition with the SMA (fig 6). Modeling of infrared deficits in the SED (Calvet et al. 2005) predicts the observed emission well.

2 - The Submillimeter Array is a joint project between the Smithsonian Astrophysical Observatory and the Academia Sinica Institute of Astronomy and Astrophysics and is funded by the Smithsonian Institution and the Academia Sinica

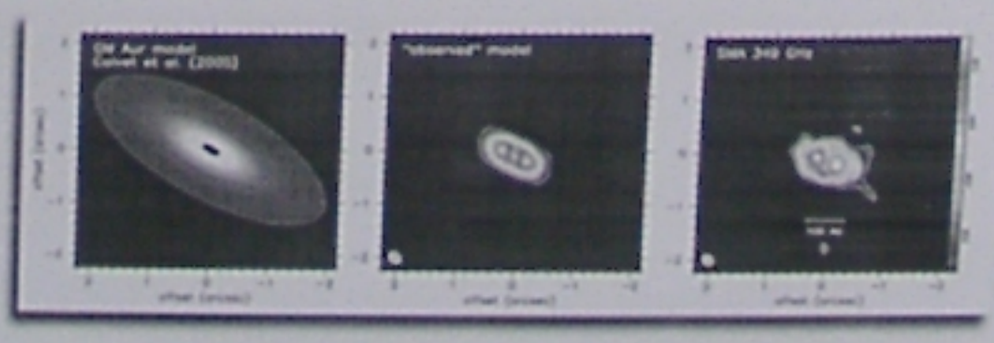

Fig. 4 – GM Aur observed with the SMA at 860 μm, compared with the Calvet et al. (2005) flared, irradiated disk model. The beam in the lower left corner has FWHM size 0.3" x 0.2" (PA 37°). Contour levels are [3, 5, 7, ...] x 4.5 mJy.

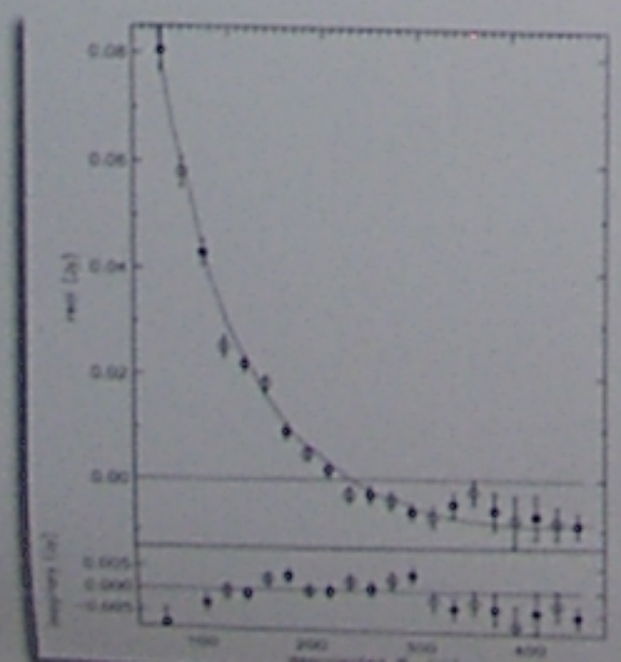

Fig. 5 – GM Aur visibilities observed at 1.3 mm with PdBI. Visibilities have been corrected for projection effects due to the 55° inclination, and binned in 30 kλ bins. As above, two sets of bins are shown. Error bars are standard error of the mean in each bin. Solid curve is the Calvet et al. (2005) model scaled by a factor of 0.9 (within the absolute calibration uncertainty).

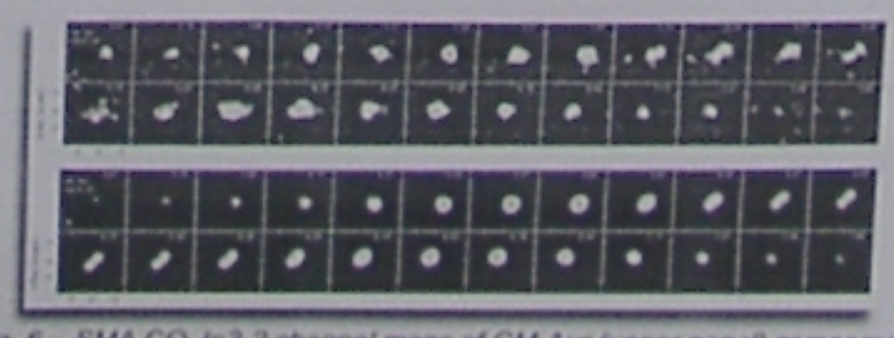

Fig. 6 – SMA CO J=3-2 channel maps of GM Aur (upper panel) compared with the Calvet et al. (2005) model (lower panel). Contour levels are [3, 5, 7, 9 ...] x 0.6 Jy. The width of each channel is 0.176 km/s.

	value	source
Outer disk radius	450 AU	CO J=3-2
Inclination	55°	CO J=3-2
Stellar mass	0.84 M	Dutrey et al. (1998)
Distance to system	140 pc	Bertout et al. (1999)
Dust opacity	--	Beckwith et al. (1990)

Table 2 – Parameters used for models shown in figures 4 & 5. Colors as in table 1.