MILLIMETER IMAGING OF HD 163296: PROBING THE DISK STRUCTURE AND KINEMATICS .

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We report a detailed study of the disk associated to the HAe star HD 163296 (Isella et al., 2007, A&A in press), using observations in the continuum and CO lines obtained with three different interferometers, namely the Very Large Array (VLA) at 7mm, IRAM Plateau de Bure Interferometer (PBI) at 1.3 and 2.6 mm and the Submillimeter Array (SMA) at 0.87 mm. HD 163296 is a star of spectral type A1, mass of roughly 2.3 $M_\odot$, distance 122 pc (van den Ancker et al. 1998). Early OVRO observations (Mannings and Sargent, 1997) have shown the presence of a disk with a minimum mass ~ 0.03 $M_\odot$ and evidence of rotation from the CO lines. The disk is seen in scattered light by Grady et al. (2000, 1999), with radius of ~ 500 AU; it has an associated jet seen in Ly-α with HST, extending on both sides of the disk orthogonally to it (Devine et al. 2000, Wassell et al., 2006). Natta et al. (2004) found evidence of evolved dust in the outer disk of HD 163296 by comparing the VLA 7 mm flux to the OVRO observations.

The results we present here have much higher spatial resolution and wavelength coverage than what has been previously reported. They allow us to measure accurately the dynamics of the disk as well as the disk and dust properties and to test the capability of disk models to account for the observations. As we will show, they suggest that the HD 163296 system is probably evolving towards a debris disk phase.

Gas and dust properties have been obtained comparing the observations with self-consistent disk models for the dust and CO emission. The circumstellar disk is resolved both in the continuum and in CO. We find strong evidence (Fig. 1) that the circumstellar material is in Keplerian rotation around a central star of 2.6 $M_\odot$. The disk inclination with respect to the line of sight is $46^o \pm 4^o$ with a position angle of $128^o \pm 4^o$. The slope of the dust opacity measured between 0.87 and 7 mm ($\beta = 1$) confirms the presence of mm/cm-size grains in the disk midplane. The dust continuum emission is asymmetric and confined inside a radius of 200 AU while the CO emission extends up to 540 AU. The comparison between dust and CO temperature indicates that CO is present only in the disk interior. Finally, we obtain an increasing depletion of CO isotopomers from ^{12}CO to ^{13}CO and C^{18}O.

We argue that these results can be interpreted as clues to the evolution occurring in the HD 163296 system. The presence of large grains in the disk midplane, the equivalence between the dust and CO temperature, the drop in the continuum dust emission further out 200 AU, its detected asymmetry and, maybe, the CO isotopomers depletion, all support the idea that the circumstellar disk is probably harboring the formation of large bodies, being in between a Class II pre-main sequence disk and an older debris disk.

On the other hand, it is important to underline that HD 163296 strongly differs from the so called *transitional disks* (Calvet et al., 2005) characterized by a clearing of the inner disk supposed to be originated by the presence of a giant planet. In the case of HD 163296, it is the outer disk that appear dust depleted. This conclusion opens a number of theoretical problem about how dust grains can growth in the low density outer disk environment. In this respect the recently improved PBI array, the new CARMA array and ALMA will bring in the next future to real observational breakthrough in the comprehension of circumstellar disk evolution and planetary formation.

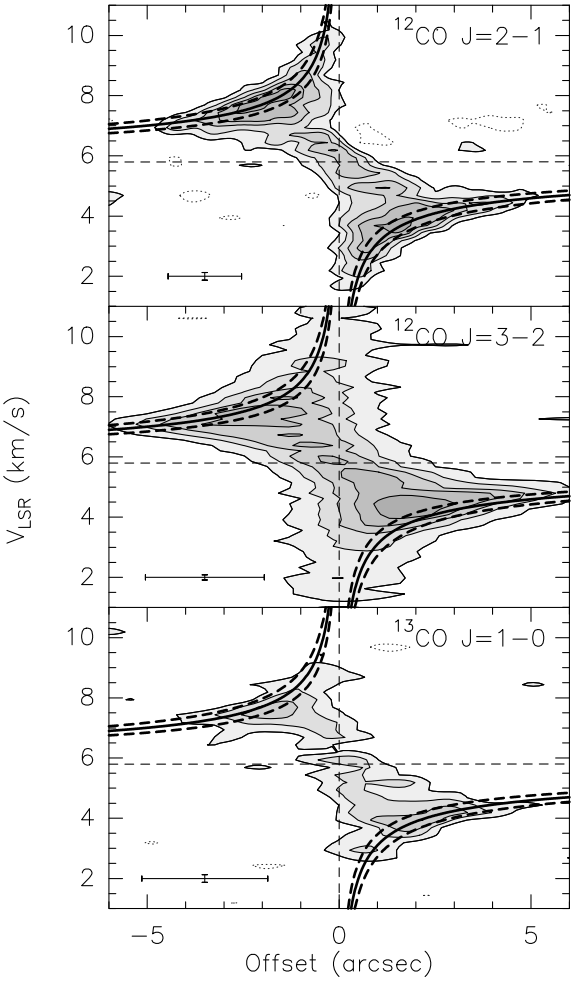

Figure 1: Velocity-position plots along the plane of the disk for the ^{12}CO J=2–1 (upper panel), the ^{12}CO J=3–2 (middle panel) and the ^{13}CO J=1–0 (lower panel) transitions. The angular offset is measured with respect to the phase center of the observations corresponding to the position of the central star. The contour levels are spaced by 2σ corresponding to 0.14 Jy/beam, 1 Jy/beam and 0.06 Jy/beam respectively. The cross in the lower left of each panel gives the angular and spectral resolution of the corresponding map. The thick solid lines marks the border where emission is expected for a Keplerian disk inclined by 45^o and rotating around a 2.0 $M_\odot$ point source; the external and internal dashed lines correspond to stellar masses of 2.5 $M_\odot$ and 1.5 $M_\odot$ respectively . The horizontal and vertical straight dashed lines mark the systemic velocity (5.8 km/sec) and the position of the continuum peak.