THE CIRCUMSTELLAR DISK AND EXCITATION EFFECTS AROUND THE MASSIVE PROTOSTAR CEPHEUS A HW2

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ABSTRACT

We report new SMA 335 GHz continuum observations with 0.3" resolution, together with VLA (3,3) and (4,4) ammonia observations with 1" resolution toward the massive protostar HW2. The flattened dust disk structure observed by Patel et al. is preserved at the 0.3" scale, showing an elongated structure of 0.6" size (450 AU) peaking on HW2. An elongated ammonia core with a double peak separated by 1.3" with signs of heating at the inner edges of the gas facing HW2 is also observed. The double-peaked ammonia structure, as well as the double-peaked CH3CN structure reported previously (and proposed to be two independent hot-cores), surround both the dust emission as well as the double-peaked SO2 disk structures found by Jiménez-Serra et al. All these results argue against the interpretation of the elongated dust-gas structure as due to a chance superposition of diferent cores; instead, they imply that it is physically related to the central massive object within a **disk-protostar-jet** system.

We also see that the angular separation of the two peaks of the different molecular structures around HW2 decreases with decreasing beam size. We discuss the implication of the 'self-similar' double-peaked molecular structures inside of double-peaked molecular structures from 0.3" to 1" scales (200 to 700 AU).

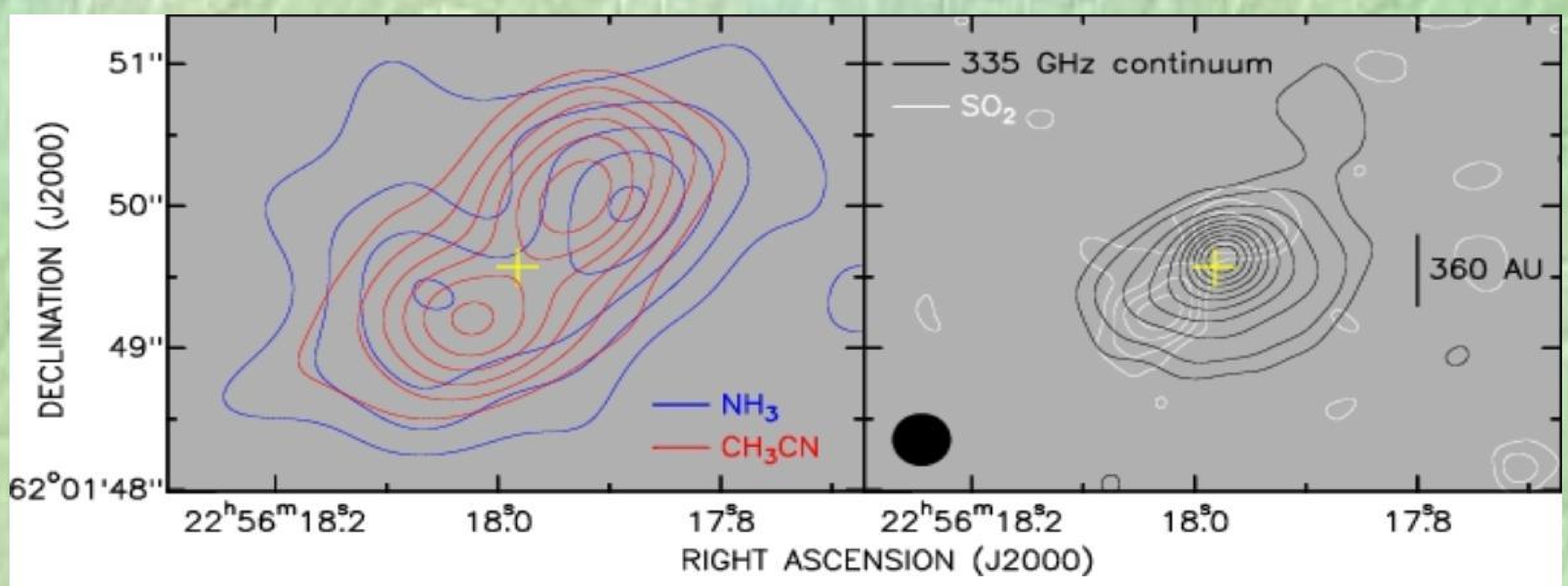

Fig. 2. *Left: (4,4)* ammonia emission in the velocity range from -7.5 to -2.6 km/s (beam = 1.1") superposed on the CH3CN map at 1 mm within the same velocity range (beam = 0.8"). The two peaks of the CH3CN structure have been proposed to be two independent hot-cores (Comito et al.). *Right:* Dust emission at 335 GHz (beam = 0.37") superposed on the SO2 map at 7 mm (Jiménez-Serra et al. 2007) (beam = 0.37"). The elongated dust continuum structure peaks on HW2 (cross), in between the two peaks of the SO2 structure. The mm/submm portion of the dust emission is optically thick (Comito et al.). The gas mass of the disk traced by the dust is (0.4-3)xC Msun, assuming a temperature of 160 K (estimated from the ammonia lines), and depending of the grain emissivity spectral index β= 1 to 2 ($C = \tau/[1-e^{-\tau}]$; τ = dust opacity) [Figure from Torrelles et al. 2007].

1. INTRODUCTION AND OBSERVATIONS

HW 2 is the brightest of the radio continuum sources detected in the star forming region of Cepheus A (725 pc distance) harboring a massive protostar of 15 Msun (Garay et al. 1996). What makes this a unique object is its association with similar phenomena as has been observed toward low-mass YSOs. The HW2 thermal biconical jet detected at the base (1") is driving the more extended (1') bipolar molecular outflow seen in HCO+ (Rodríguez et al. 1994, Gómez et al. 1999). Especially remarkable are the large proper motions observed in the two main components of the HW2 radio jet, moving away at 500 km/s from the central source in opposite directions and parallel to the HCO+ bipolar outflow (Curiel et al. 2006). These observations strongly support theoretical models of high-mass star formation through an accretion disk. This is in contrast to models requiring merging of low-mass stars where collimated jets are not expected.

The detection of a rotating disk of dust and molecular gas of 300 AU radius oriented perpendicular to, and spatially coincident with, the HW2 jet, has been reported through SMA observations with 0.75" resolution (Patel et al. 2005; **Fig. 1**) as well as with VLA and PdBI observations with 0.3"-0.6" resolution (Jimémez-Serra et al. 2007). These results gave additional support to the picture that during the formation of this massive object a disk-protostar-jet system has been formed. However, an alternative interpretation is that the disk structure and kinematics observed are due to the superposition on the plane of the sky of independent hot-cores (Comito et al. 2007, Brogan et al. 2007). Here we present new SMA continuum observations with 0.3" resolution and VLA ammonia observations with 1" resolution showing that the disk structure is not made up of these reported hot-cores.

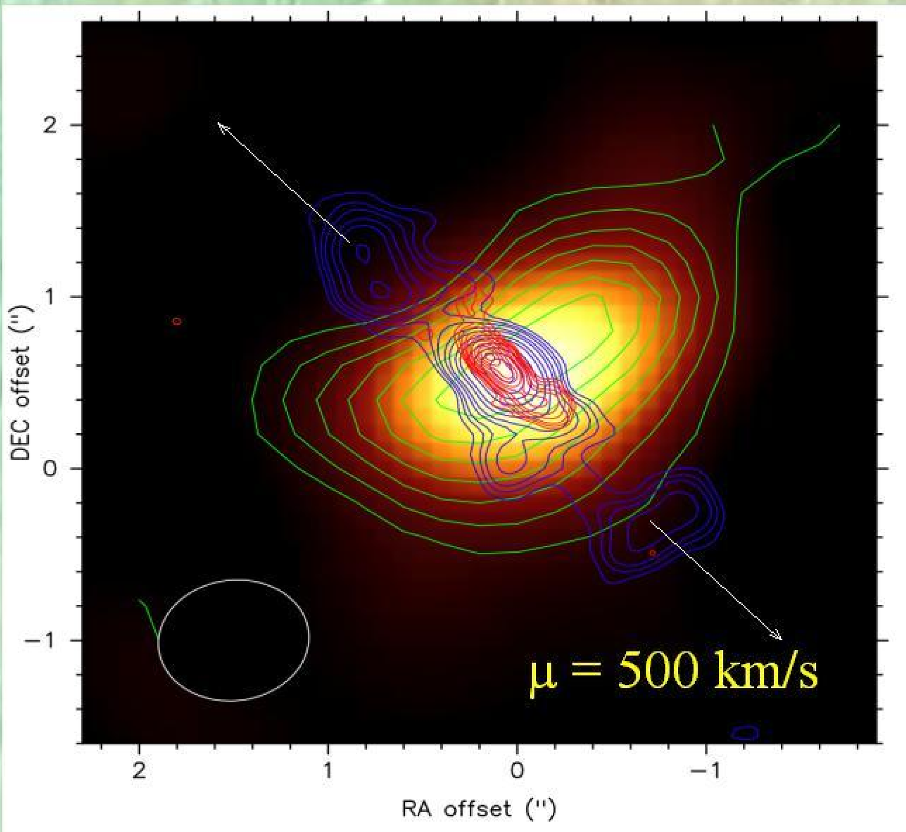

Fig. 1. SMA 330 GHz dust continuum (colour image) and CH3CN emission (green contours) observed with a beam of 0.75" (Patel et al. 2005). Blue contours show the well collimated jet at 3.6 cm continuum, whereas red contours show the inner part of the jet at 1.3 cm. Arrows indicate the direction of the proper motions of the two main knots of the biconical jet moving at 500 km/s in opposite directions (Curiel et al. 2006), perpendicular to the dust-gas disk structure, and parallel to the HCO+ bipolar outflow observed at scales of 1' (Gómez et al. 1999). [Figure from Patel et al. 2005]

2. DISK-PROTOSTAR-JET SYSTEM

Our new 335 GHz continuum observations show that the disk structure of the dust emission observed by Patel et al. (2005) is still preserved at 0.3" scale, with a single continuum peak on HW2 (**Fig. 2**). The elongated dust structure is similar in size and orientation to the molecular SO2 disk structure detected by Jiménez-Serra et al. (2007), but with the dust continuum peaking in between the two peaks of the SO2 structure. Both the dust continuum and SO2 structures are engulfed by the double-peaked ammonia structure that we have also detected as well as by the double-peaked CH3CN structure detected by Comito et al. (2007) and proposed to be delineating two hot cores (HC2 and HC3) (**Fig. 2**). Our results argue against the interpretation that the elongated structure observed perpendicular to the HW2 jet and proposed to be a disk by Patel et al. (2005) (**Fig. 1**) is due to a chance superposition of different hot cores (HC2 and HC3) given that they have an angular separation (1") that is significantly larger than the size of the elongated dust structure (0.6") (**Fig. 2**). Furthermore, the fact that a main single continuum peak on HW2 is observed, gives additional evidence that the observed dust structure is dominated by the gas directly associated with HW2. We note that notwithstanding the importance of chemistry, with molecules being enhanced and depleted depending on the physical conditions, dust emission is much less affected by such chemical effects and hence is a more reliable indicator of the structure of material in the immediate vicinity of HW2.

3. DOUBLE-PEAKED MOLECULAR STRUCTURES INSIDE DOUBLE-PEAKED MOLECULAR STRUCTURES

The question arises as to the meaining of the double-peaked molecular structures observed in SO2 (Jiménez-Serra et al. 2007) inside of the double-peaked molecular structures observed in CH3CN (Comito et al. 2007) and in NH3 (this work), all these structures observed within the same velocity range. Furthermore, the angular separation of the two peaks of the different molecular structures found around HW2 decreases with decreasing beam size (**Fig. 3**). This is the first time that this behaviour has been reported at (sub)arcsecond scale toward a high-mass star forming region. As an **open issue**, we present here three different interpretations, not necessarily independents: **(i)** each of the different molecular peaks trace molecular fragments from the remnant of the parental core from which the central massive disk-protostar-jet system has been formed; **(ii)** chemical and excitation effects produce different spatial molecular peaks for different molecular transitions (we note that the two [4,4] ammonia peaks are closer than the corresponding [3,3] ammonia peaks, **Fig. 3**, suggesting that the inner edges of the ammonia structure facing HW2 is being heated by the massive protostar); **(iii)** a more or less continuous structure but with chemical variations becomes denser and thinner as we probe closer to the massive protostar, giving rise to concentric flattened structures of similar shape and orientation. A beam-averaged radius of the structure growing with increasing beam size would then produce the concentric double-peaked molecular structures (**Fig. 3**). This scenario might be tested by observing with the VLA the ammonia emission with higher angular resolution (0.3"). If this scenario is correct, a smaller separation between the corresponding double ammonia peaks should be measured. On the contrary, if the spatial separation between the ammonia peaks does not change when observed with higher angular resolution, it would indicate that chemical and excitation effects are the dominant effects in producing the different double-peaked molecular structures.

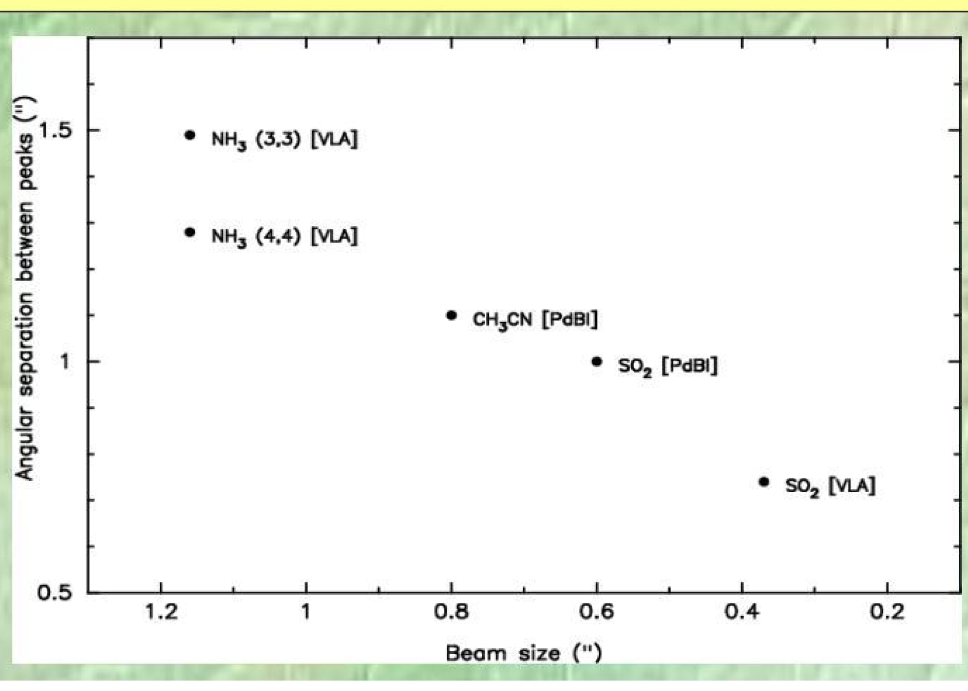

Fig. 3. Angular separation of the two peaks of the different molecular structures found around the masive protostar Cep A HW2 as a function of the observing beam size. The separation decreases with decreasing beam size.SO2 (PdBI and VLA; Jiménez-Serra et al. 2007), CH3CN (PdBI; Comito et al. 2007), NH3 (VLA; this work). [Figure from Torrelles et al. 2007].

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