HIGH-VELOCITY CLUMPS IN THE L1157 OUTFLOW

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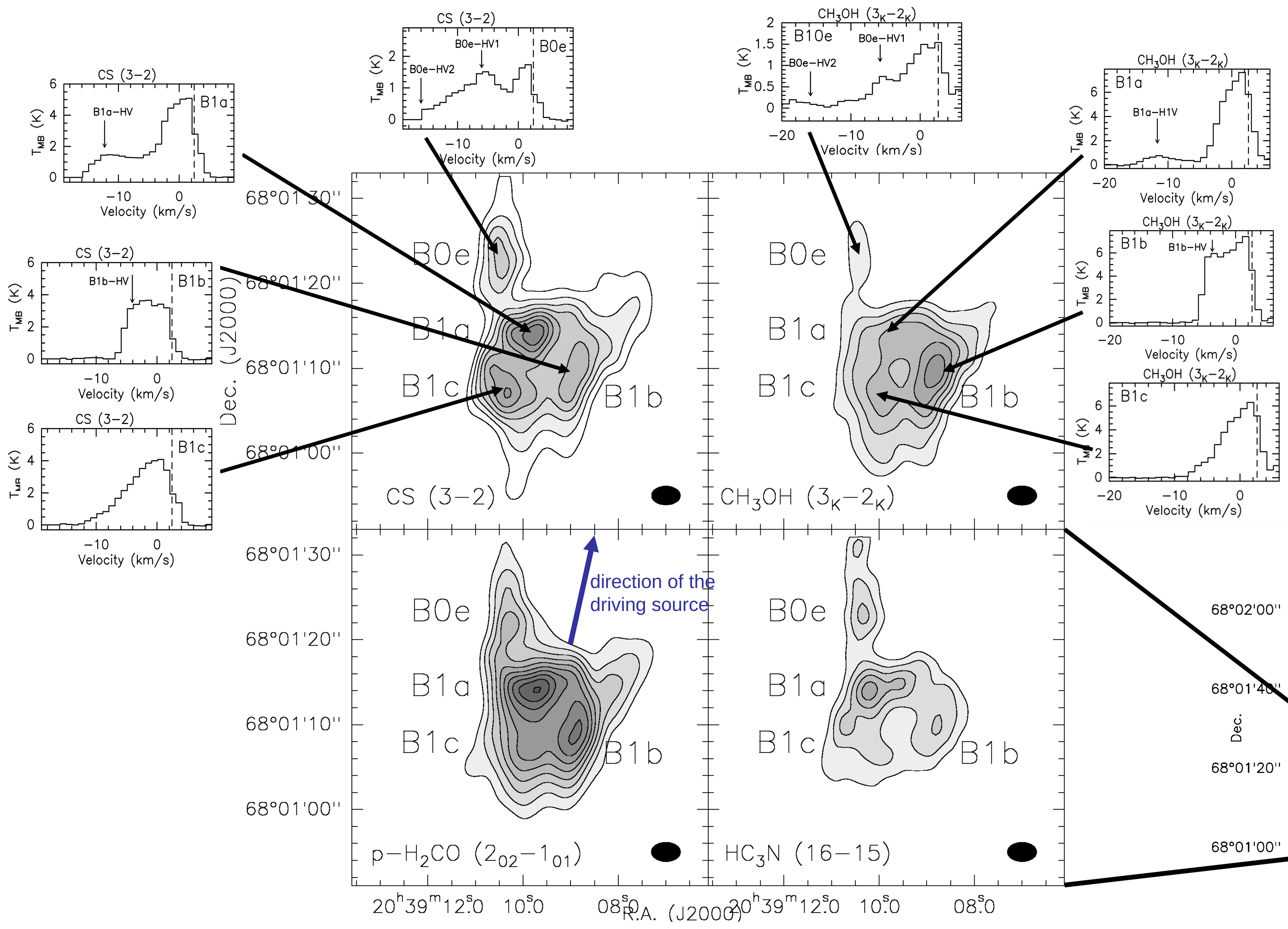
ABSTRACT

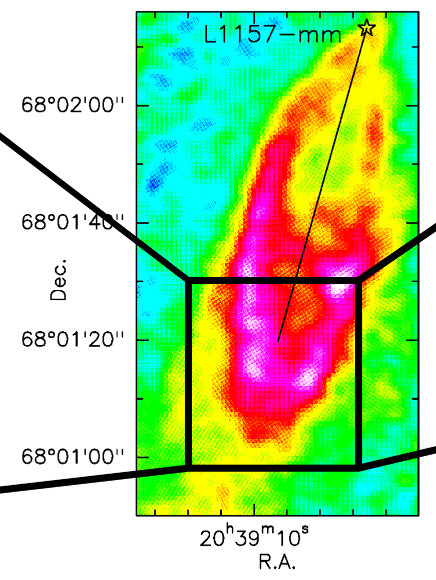
We present high spatial resolution (750 AU at 250 pc) maps of the B1 shock in the blue lobe of the L1157 outflow in four molecular lines at 2mm. The combined analysis of the morphology and spectral profiles has shown that the gas flowing at higher velocity (from 6 to 20 km/s with respect the systemic velocity of 2.6 km/s) is confined in a few compact (~ 5”) clumps while the gas flowing at lower velocity traces the wall of the gas cavity excavated by the jet and the apex of the bow shock. These results confirm the complexity, both in the morphology and in the chemistry, of the B1 region, likely induced by the shock originated by the interaction between the driving precessing jet and the ambient material. A large velocity gradient model applied to the CS (3-2) and (2-1) lines provides the gas density of the compact high velocity (HV) clumps in the range of $5\times10^3 \leq n(H_2) \leq 5\times10^5$ cm^3, indicating that the clumps tend to be less dense than the large scale emitting gas. The origin of the clumps is still uncertain: the observed clumpiness could be the result of local instabilities produced by the interaction of the driving jet and the ambient medium or the HV clumps could be already present in the ambient medium before the advent of the outflow and they are excited and pushed by the arrival of the expanding outflow cavity.

OBSERVATIONS

The observations were carried out with the Plateau de Bure Interferometer toward the bright B1 shock of the L1157 outflow . The CD configuration was used. We simultaneously observed the following lines: CS (3-2) at 146.969 GHz, HC_3N (16-15) at 145.561 GHz, p-H_2CO (2_{02}-1_{01}) at 145.603 GHz and CH_3OH (3_K-2_K) at 145.103 GHz. The final clean beam of the images is 3.48”x2.31 “ at 145 GHz.

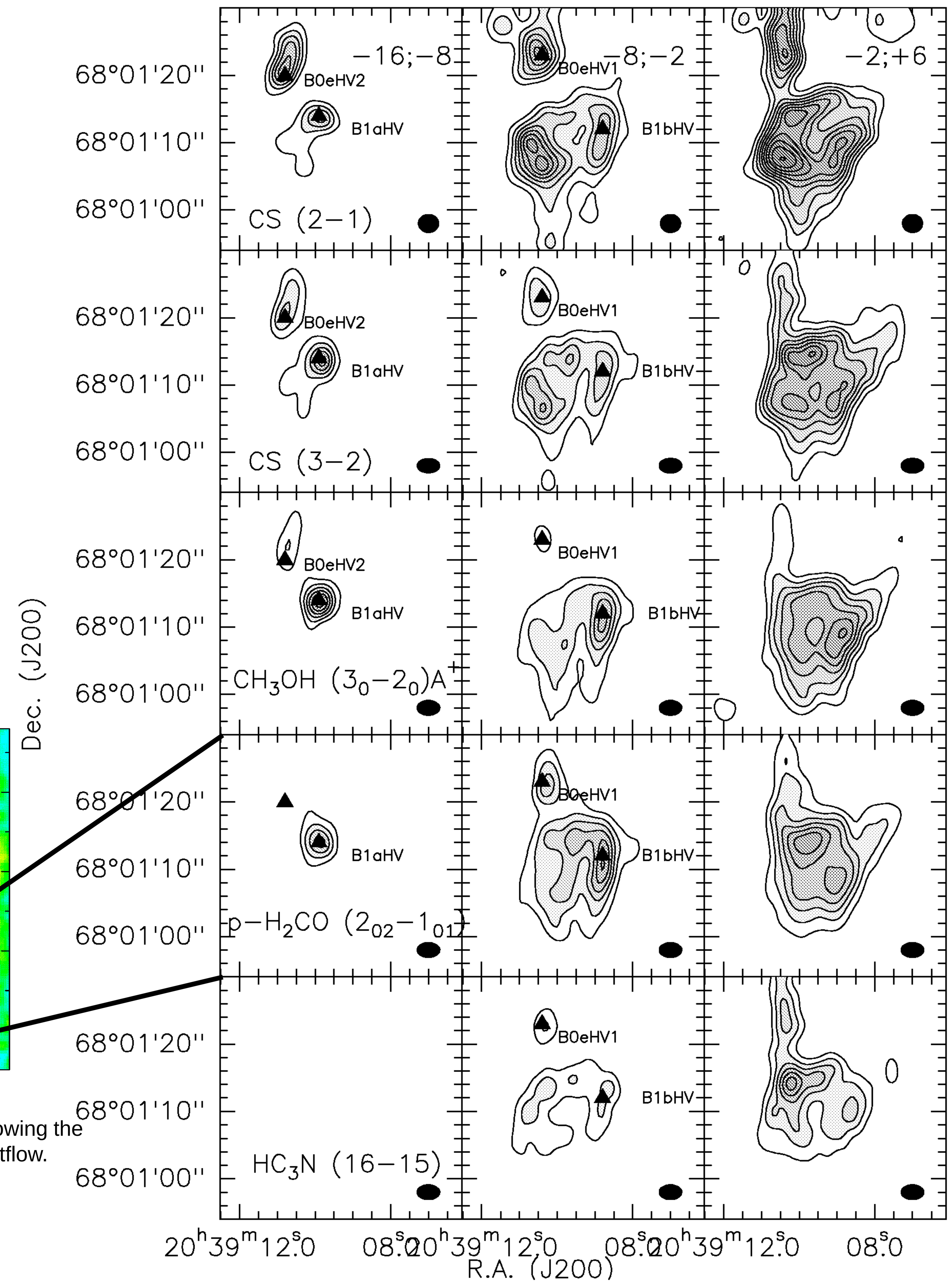


Line maps of the 4 observed transitions toward L1157-B1.



CO (1-0) map (from Gueth et al. 1996) showing the gas cavity in the blue lobe of the L1157 outflow.

Channel maps:
left -16<v<-8km/s, middle -8<v<-2 km/s, right -2<v<+6 km/s



LINE MAPS

Line maps of the observed species (fig. above) show and extended arch-shaped emission corresponding to the bow shock at the apex of a gas cavity and a few compact (~ 5”) clumps (B0e, B1a, B1b, B1c) whose intensity appears different in each species. We found multiple peaks in the line profiles extracted toward B0e, B1a, B1b, indicating the presence of multiple gas component along these lines of sight. The channel maps (fig. on the left) revealed that the gas flowing at higher velocity is confined in 4 compact clumps: **B0e-HV2** peaking at -16 km/s, **B0e-HV1** at -6 km/s, **B1a-HV** at -12 km/s and **B1b-HV** at -4 km/s.

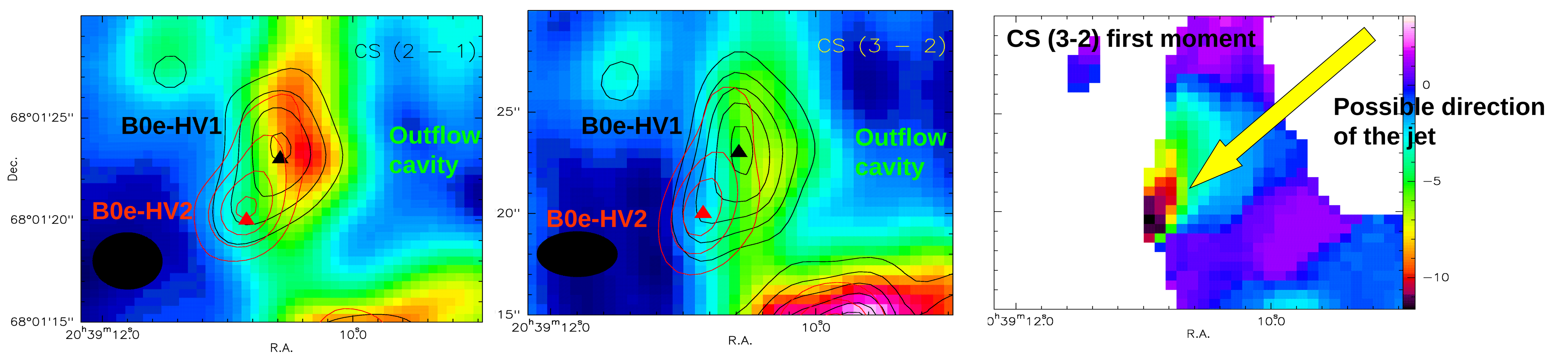
LVG fitting of the HV clumps

clump	N(CS) cm^2	Size “	$n(H_2)$ 10^4 cm^3
B0e-HV2	4(12)-1(13)	3	5-10
B0e-HV1	6(13)-1(14)	5	0.5-1
B1a-HV	2(13)-7(13)	4	5-50
B1b-HV	2(13)-8(13)	7	2-10

The compact emission from the HV clumps having size ≤ 7” does not suffer of flux filtering therefore we applied an LVG code (Ceccarelli et al. 2003) to the two CS lines (3-2) and (2-1) to derive their physical conditions. In the table we report the derived density of H2 and the CS column density, adopting a clump size of 5”+/-3” and a gas temperature of 55 - 132 K (Codella et al. 2009). The results of the LVG fitting indicate a lower gas density of the HV bullets with respect to the large scale emitting gas ($10^5 \leq n(H_2) \leq 10^6$ cm^3).

Zooming in B0e

In the figures on the rigth we plotted the CS (3-2) and (2-1) emission of the three spectral components detected toward the B0e region: the two HV clumps B0e-HV2 at -16 km/s (red), and B0e-HV1 at -6 km/s (black), and the low velocity gas peaking at 1.2 km/s (colors). As one can see the position of the peaks of the two highest velocity clumps is external with respect to the walls of the cavity traced by the low velocity gas. In addition, the first moment of the CS(3-2) (last figure on the rigth) shows a gradient with mean velocity increasing from the internal wall of the cavity towards the outside, in the direction of B0e-HV2, indicating an acceleration of the gas in this direction.



On the origin of the HV clumps

The observational characterist of the HV clumps suggest different hypothesis about their origin. It could be the precessing jet that is now impacting at the B0e position producing an acceleration of the gas outwards of the cavity. In this scenario the observed clumpiness could be the result of local instabilities produced by the interaction of the driving jet and the ambient medium. Alternatively, the slightly lower density that we found in the compact clumps with respect to the bulk of the outflowing gas can support the hypothesis that the clumps are not formed by the outflow but can, at least partially, be present in the cloud before the arrival of the outflow and they are excited and accelerated by the arrival of the expanding outflow cavity. Indeed clumpiness in the interstellatr medium has been extensively observed (e.g. Viti et al. 2003, Morata et al. 2005).

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