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The dynamics of a young protostellar core

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Abstract. The first stages of star formation represent a research field of ongoing development from the theoretical point of view, and molecular line observations are needed to shed light on the dynamical evolution of star-forming regions and constrain theories. We have investigated the Barnard 59 core (hereafter B59), the very western end of the Pipe Nebula. This elongated and filamentary molecular cloud, located at a distance of 145 pc (Alves & Franco 2007), is known to have a low star formation efficiency (0.06%, Forbrich et al. 2009). The only active site of star formation is B59, with ~20 young stellar objects (YSOs) identified by the Spitzer Cores to Disks survey (Brooke et al. 2007). Using ammonia inversion transition lines (1,1) and (2,2), we achieved a comprehensive view of the kinematic properties of the source, investigating at the same time the role of protostellar feedback. Additional dust thermal emission was used to obtain dust temperature and H_2 column density maps. More details on the present work will be given in Redaelli et al (subm.).

1. Observations and data analysis

The ammonia (1,1) and (2,2) spectral data were acquired at the Green Bank Telescope (GBT) as part of the Green Bank Ammonia Survey (GAS) Large Program (Friesen et al. 2017). The achieved spectral resolution is $\approx 0.07\,\mathrm{km\,s^{-1}}$ and the angular resolution is $31.8''$, corresponding to 0.02 pc at the Pipe distance. The data were smoothed to a final resolution of $40''$ to improve the signal-to-noise ratio.

The spectral cubes were fitted pixel by pixel in order to obtain the following parameter maps: excitation temperature T_{ex}, kinetic temperature T_K, centroid velocity V_{lsr}, velocity dispersion σ_V, and ammonia column density $N(NH_3)$. Furthermore, we used Herschel SPIRE data at $250\,\mu$m, $350\,\mu$m and $500\,\mu$m to characterized the dust emission. These three photometric bands were fitted with a grey-body model to recover the H_2 column density and the dust temperature T_{dust} maps.

2. Kinematic structure

The source presents a cold ($T_K \approx 11$ K) region where $\log[N(NH_3)$ is large ($>14.4\,\mathrm{cm^{-2}}$), the centroid velocity shows a coherent structure and the velocity dispersion exhibits values as low as $0.11 - 0.13\,\mathrm{km\,s^{-1}}$ (see Fig. 1). Towards North, the temperature increases up to $16 - 18$ K, possibly indicating that another source of heating, in addition to the cosmic ray field or radiation field, is needed. This can be due to the activity of BHB07-11 (B11), the youngest YSO in the cluster (Class 0/I, circle marker in the figures) that is powering a bipolar outflow (Duarte-Cabral et al. 2012). The linewidths increment in this area can also be due to the protostellar activity.

3. Turbulence in the core

Using the σ_V and T_K maps we calculated the thermal σ_T and non thermal σ_{NT} velocity dispersion contribution and the sonic

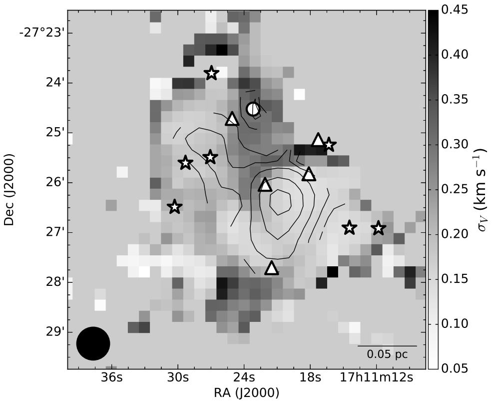

Fig. 1. σ_V map with log[N(NH_3)] contours (levels: 14.0, 14.2, 14.4, 14.6, 14.75). Markers show the YSOs positions (circle: class 0/I, triangles: class I or I/II, stars: class II) according to Brooke et al. (2007).

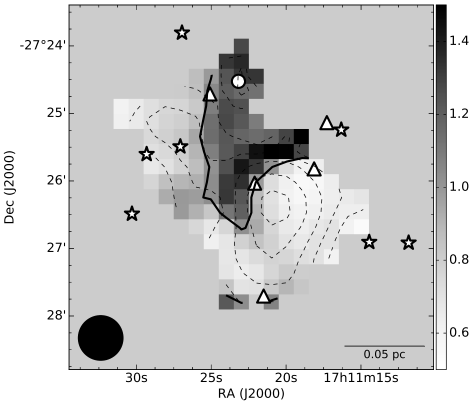

Fig. 2. σ_{NT}/C_S map. The dashed contours and markers are the same as in Fig. 1. The black curve represents where $\sigma_{NT}/C_S = 1$.

speed C_S, obtaining the σ_{NT}/C_S map shown in Fig. 2. The coldest and densest part of the core presents subsonic motions, with a sharp transition to mildly supersonic ones in the northern region. This enhancement in the turbulence level can be linked to the B11 activity, which is affecting the surrounding medium. Most of the other YSOs, and especially the most evolved class II ones, are located in subsonic, low velocity dispersion regions and most likely are foreground or background objects, not embedded anymore in the cloud.

3.1. H_2 and NH_3 comparison

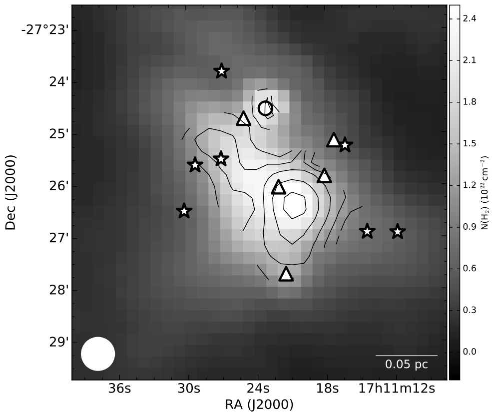

Fig. 3. N(H_2) map with log[N(NH_3)] contours. The levels and the markers code are the same as before.

Fig. 3 shows the N(H_2) map obtained from Herschel data with the contours from N(NH_3). As expected, ammonia is a good tracer of the cold gas (Ho & Townes, 1983), with the exception of the B11 envelope, which is very bright in Herschel data but seems to be depleted in ammonia. This can be due to chemical effects: at T $\approx$ 20 K (close to the values we found) CO starts to evaporate from dust grain and it can inhibit the formation of NH_3 precursors (Rodgers & Charnley 2008).

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