Probing the Earliest Phases of Star Formation: Observations of Two First Core Candidates

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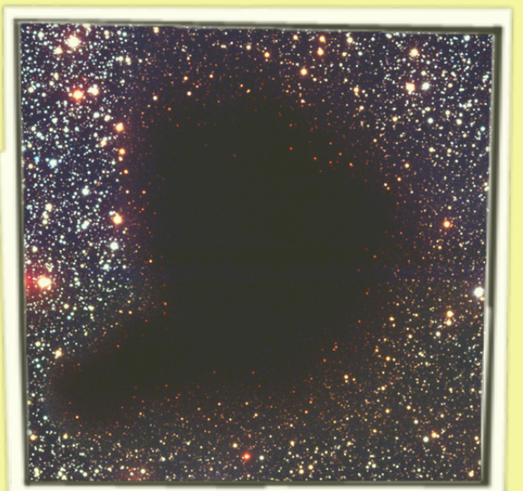
What is a First Hydrostatic Core?



Simulations predict the formation of a molecular hydrogen object in hydrostatic equilibrium, that appears right after the core collapses and before the beginning of the Class 0 phase (Larson et al. 1969). This evolutionary state in between a starless core and a protostar is called the First Hydrostatic Core (FHSC).

On the observational side the starless and protostar phases have been extensively studied, however the transition between them is not that well understood. Therefore, the detection and confirmation of the existence of the FHSC is of prime importance in our understanding of the evolution of dense cores and star formation.

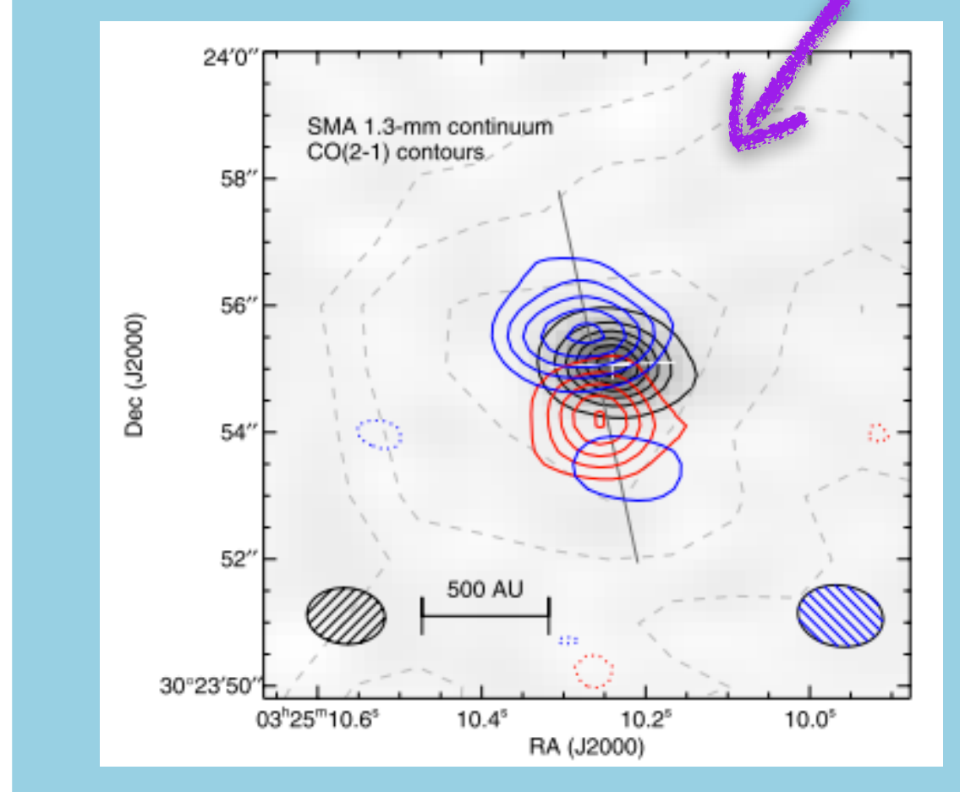
This Work

Here we present CARMA multi-line rotational transitions maps of dense gas tracers (**N$_2$H$^+$, CS, HCO$^+$, HCN and NH$_2$D)** for **two** of the eight known FHSC candidates.

Why are they candidates?

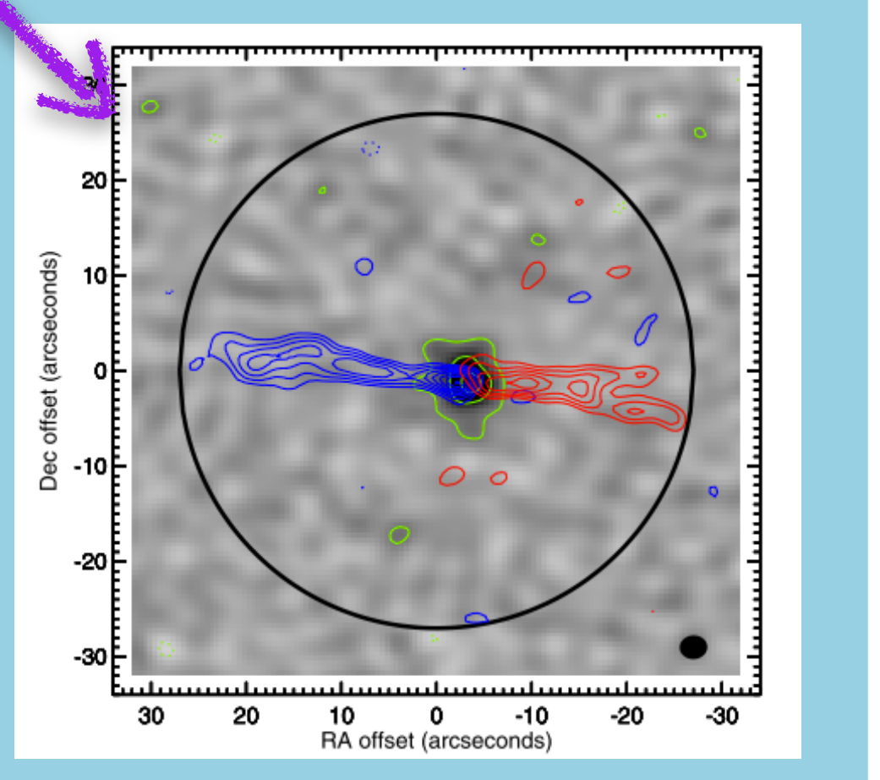
Outflows

L1451MM



Pineda et al. 2011

PerBolo 58



Dunham et al. 2011

Predictions

	PerBolo58	**L1451MM**
• Low velocity Outflow (< 5 km/s)	✓	✓
• No emission at < 24 um	✓	✓
• Very Low Luminosity	✓ (0.01 L$_{sun}$)	✓ (<0.03 L$_{sun}$)

Maps of dense tracers

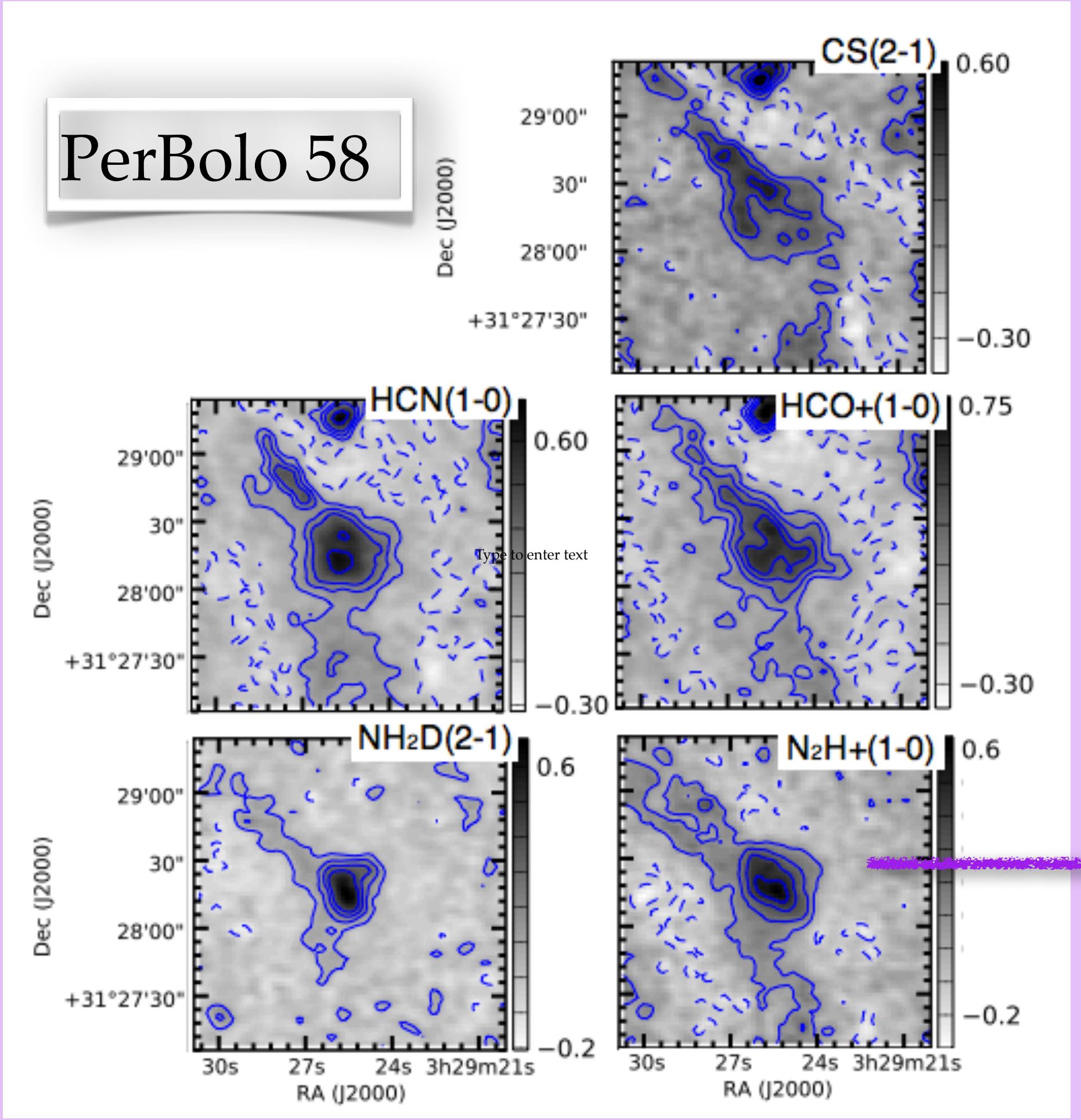


Figure 1. Integrated intensity maps for PerBolo58 using N$_2$H$^+$(1-0), NH$_2$D (1-0), HCO$^+$ (1-0), HCN (1-0) and CS (2-1). The core is detected in all the lines shown here. However, the CS(2-1) map shows signs of missing flux presumably because this line probes lower density, larger scale structure than the rest. Interestingly, a filamentary structure is detected in all the tracers.

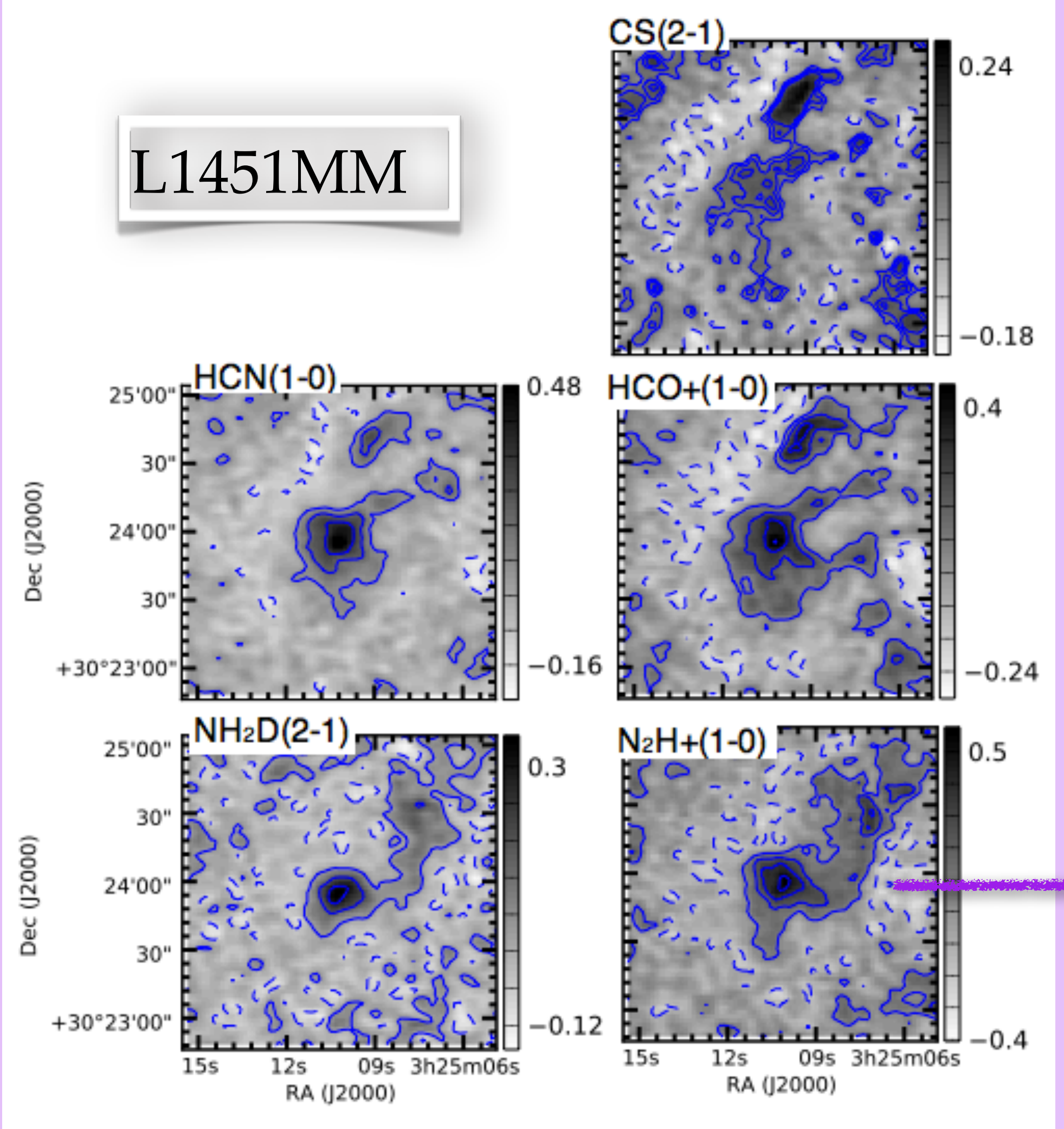


Figure 2. Integrated intensity maps for L1451MM for N$_2$H$^+$ (1-0), NH$_2$D (1-0), HCO$^+$ (1-0) , HCN (1-0) and CS (2-1). The core is detected in all the tracers. HCO$^+$ and CS show signs of missing flux, consistent with these molecules tracing a more extended structure from less dense gas. In this source a filamentary structure also shows up towards the northwest in all the molecules.

References:

- Larson 1969 MNRAS, 145, 271
- Dunham et al. 2011, ApJ, 741, 1
- Pineda et al. 2011, ApJ, 743, 201

Acknowledgements:

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Preliminary Results

PerBolo 58 N$_2$H$^+$

Two velocity Components within 7500 AU: Colliding Flows help form core?

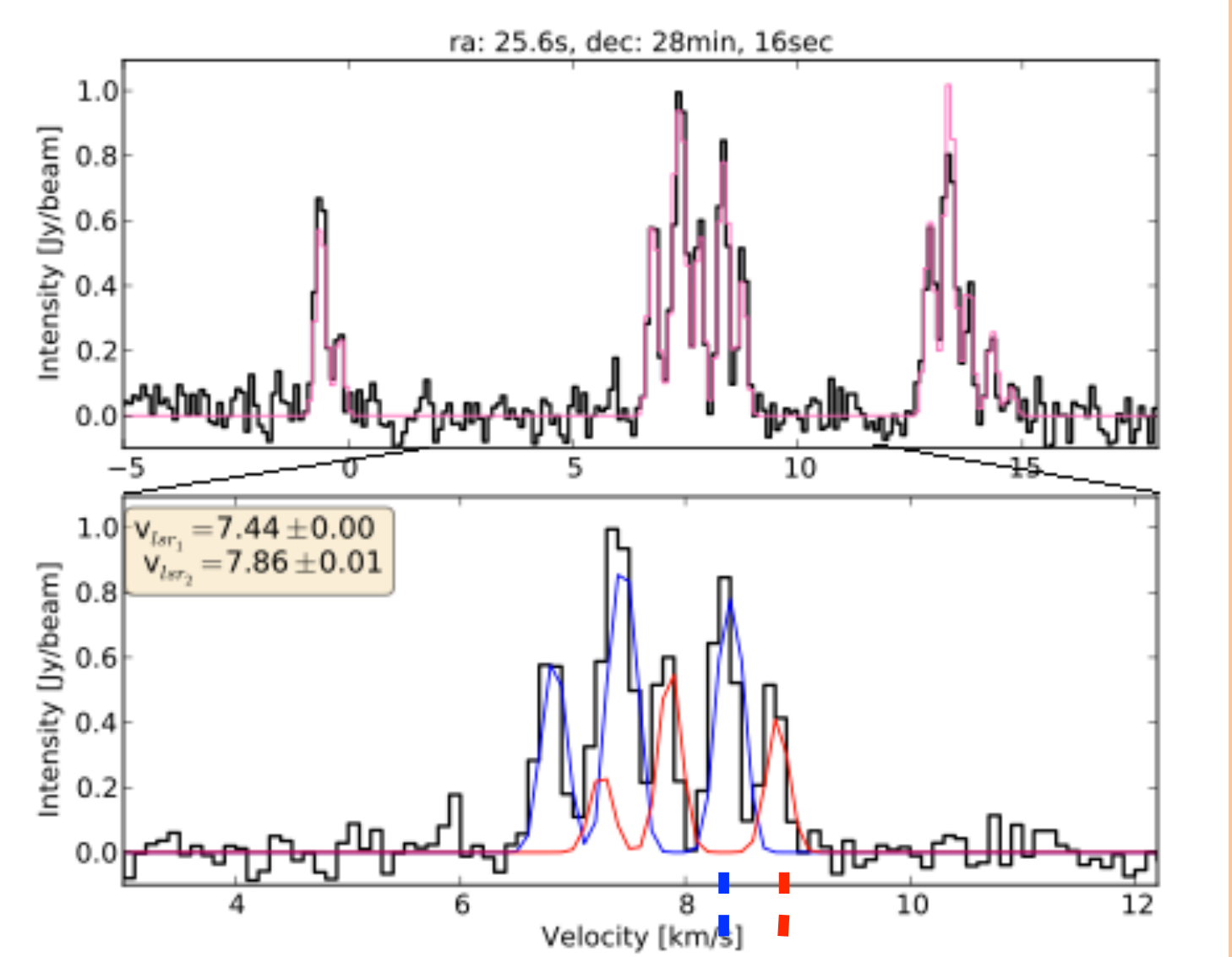


Figure 3a. Spectrum at the central position of the N$_2$H$^+$ data cube. The spectrum is composed of two different components at different velocities. The top panel shows the total fit to the entire spectrum. The bottom panel shows a blow up of the central part of the spectrum showing the fits to the two components.

Central Velocity Maps

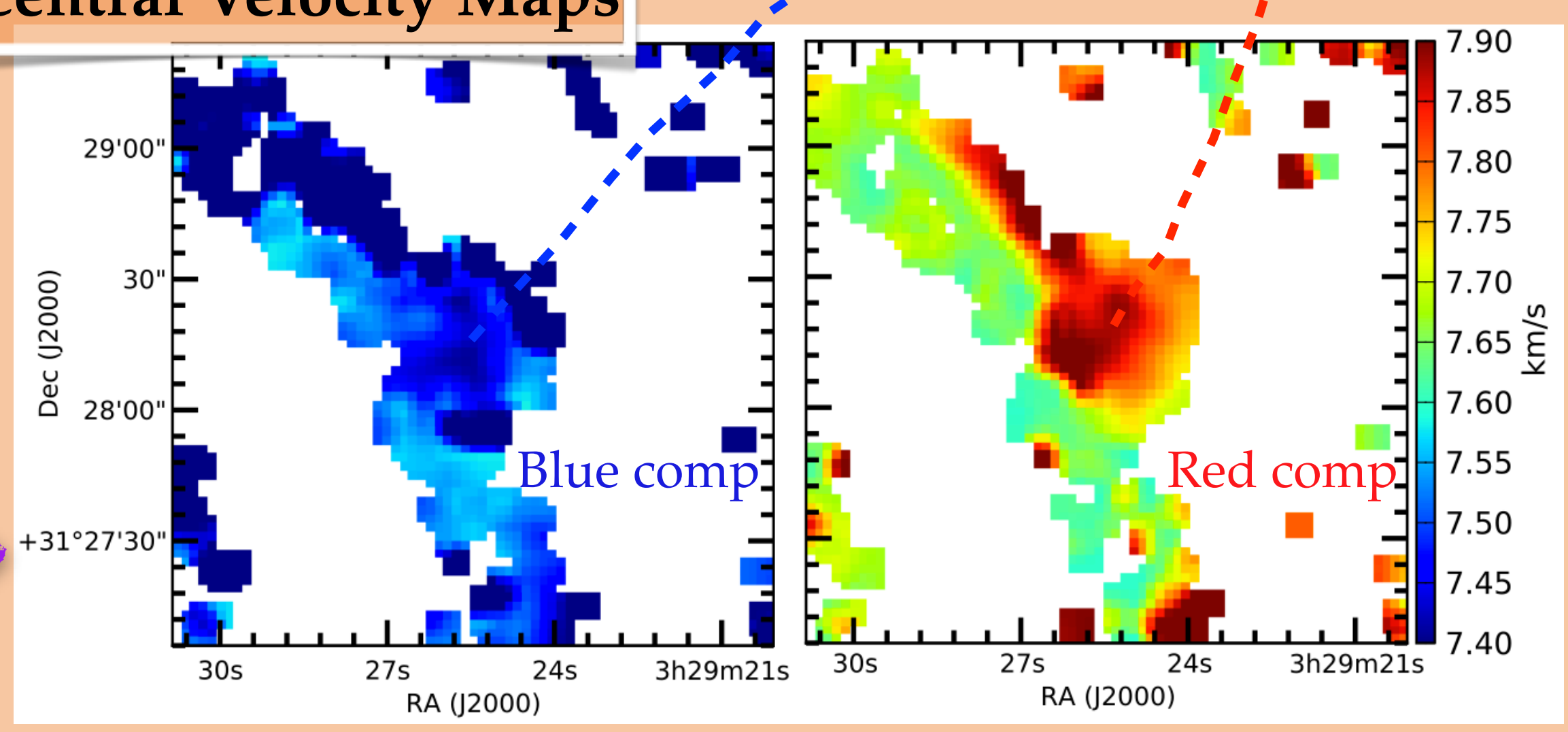


Figure 3b. Central velocity maps for N$_2$H$^+$. The spectrum on Figure 3b shows that this molecule present two components separated about 0.5 km/s at the center. The filamentary structure can be seen in the red and the blue component and they are close together at around 7.6 km/s.

Velocity Channels

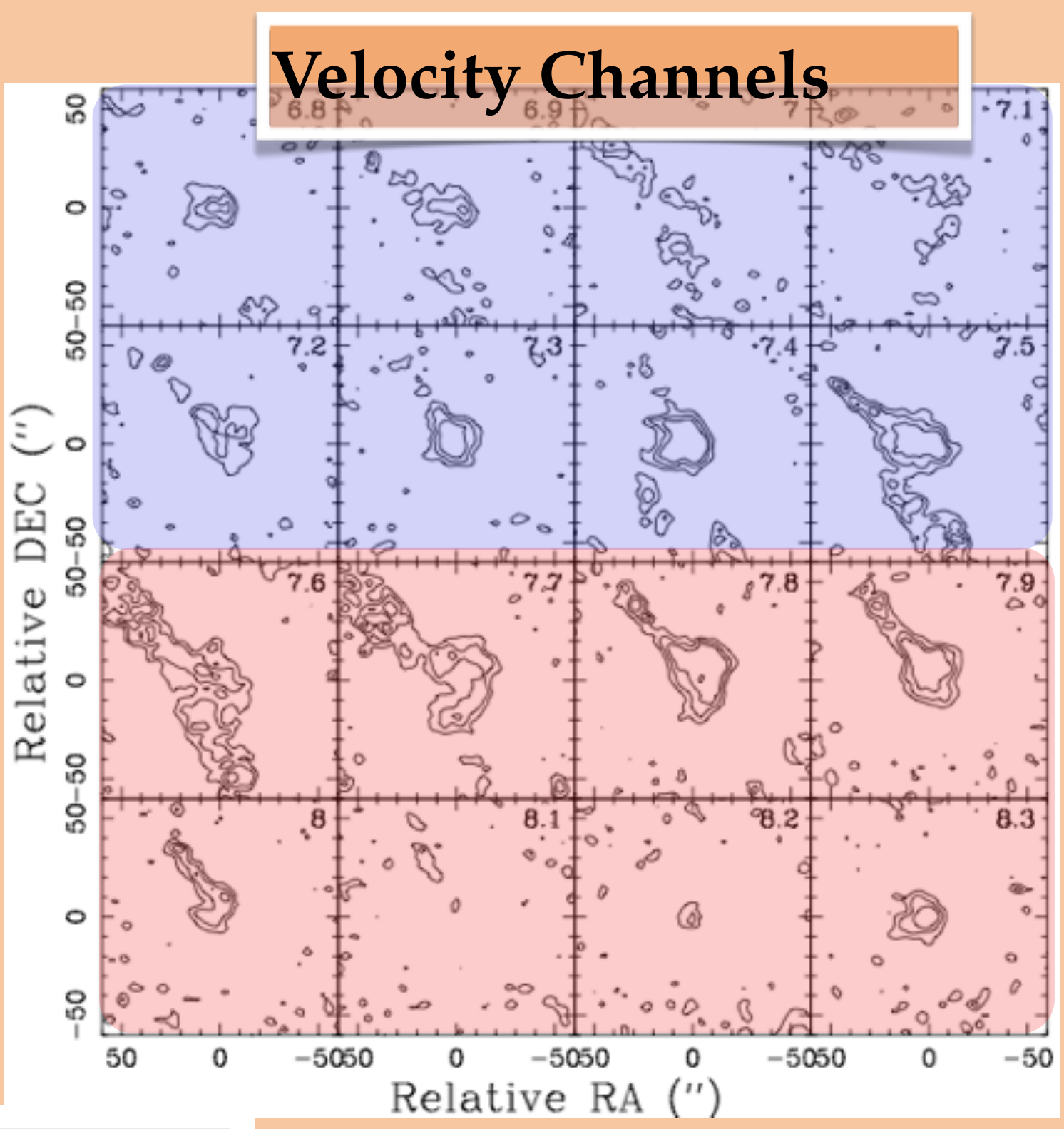
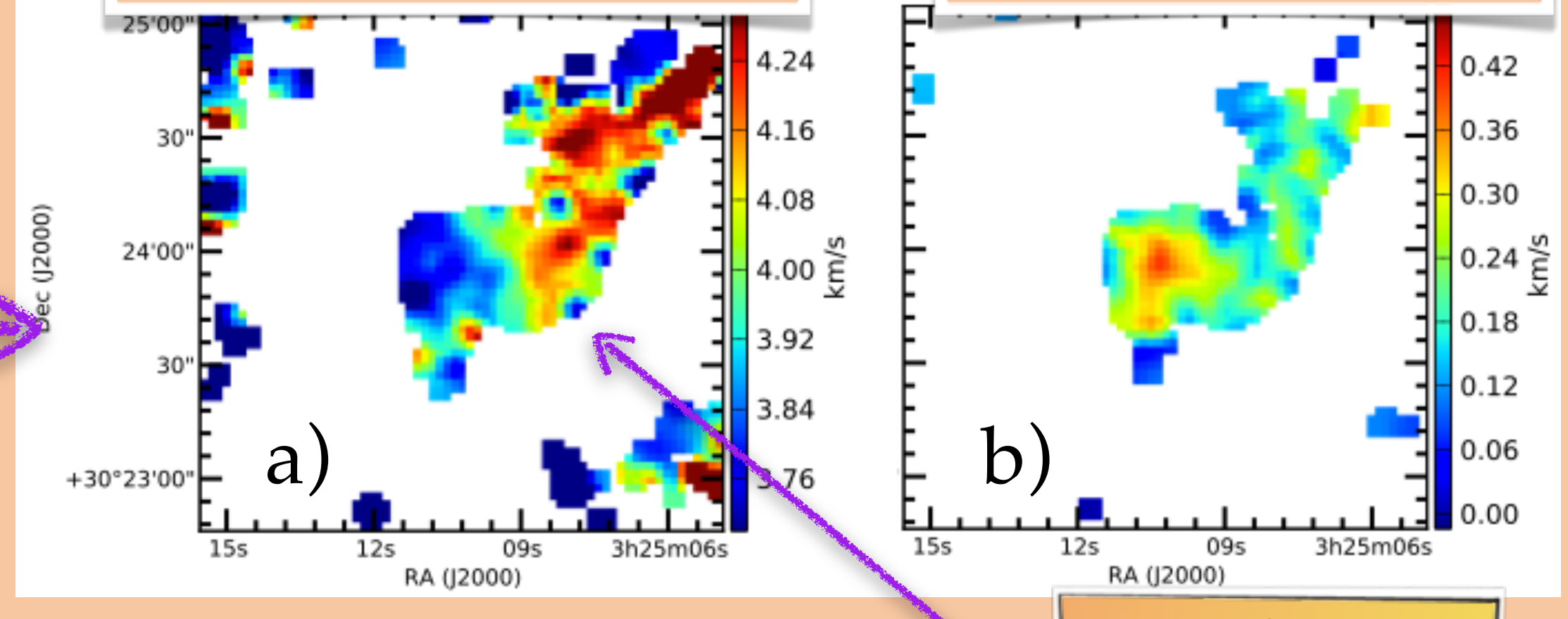


Figure 3c.
Velocity channels for the spectrum in Figure 3a. The blue and red shading correspond to the blue and red component respectively.

L1451MM N$_2$H$^+$

Central Velocity Map **Linewidth Map**



Rotatig core?

Figure 4a. Central velocity map using N$_2$H$^+$. The map shows a velocity gradient in a direction perpendicular to the outflow axis detected in Pineda et al. (2011).

Figure 4b. Linewidth map using N$_2$H$^+$. The map shows that the linewidth peaks at the center of the core. This could be due to outflow-core interaction or thermal feedback from the central source.

Spectrum and line fit

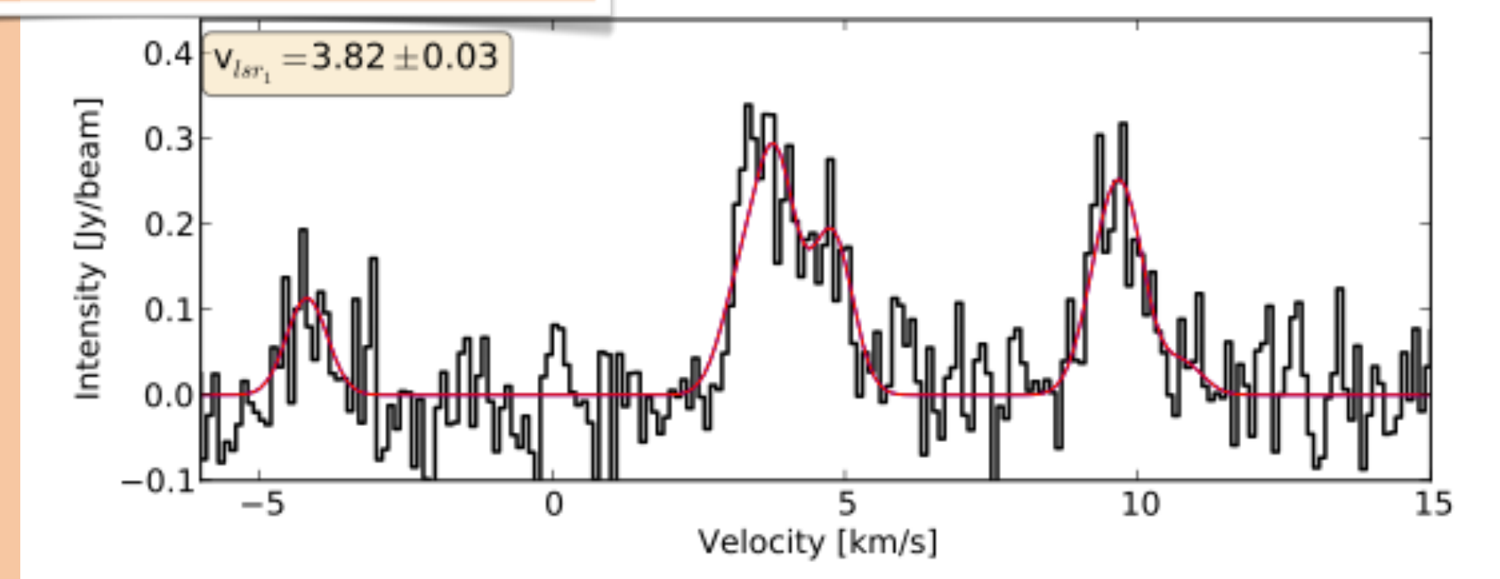


Figure 5. Spectrum at a central position of the N$_2$H$^+$ central velocity map in Figure 4. The maps above (Figure 4) were constructed by doing a similar fit as the one shown here, for each position (with similar S/N for all spectra).