Detection of subsonic material outside dense cores : are cores truly isolated from their surrounding molecular cloud?

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Introduction

Star formation takes place in dense cores within molecular clouds. These cores are characterised by higher densities and lower temperatures compared to the parental cloud (Caselli et al., 2002). Observations using high-density (>10^4 cm^{-3}) tracers show the turbulence inside dense cores to be subsonic (Barranco & Goodman, 1998), in contrast to the supersonic turbulence in the large-scale ambient cloud (Larson, 1981).

Understanding the transition from the cloud to subsonic dense cores is imperative in the study of core formation, as the dissipation of turbulence is an essential step in the process. This transition region could also help understand the connection between the cores and the ambient molecular cloud. NH_3 inversion transitions are ideal tracers to observe the dense cores and surrounding cloud, which have inherently different densities (Choudhury et al., 2020).

The dense cores are usually thought to be well-separated from their natal cloud, and evolve as isolated units. However, recent results using stacking analysis (Choudhury et al., 2021) show significant amount of subsonic material outside the traditionally determined core boundaries. This challenges our understanding of a sharp core-cloud boundary, and possible accretion of this material onto the core, will change our understanding of the morphology and the dynamical evolution of dense cores. However, due to lack of sensitivity, we do not know the exact extent of this subsonic region, nor how it is spatially distributed.

Addressing these questions, here we present preliminary results from a recent high-sensitivity observation of a prestellar core, H-MM1, in the molecular cloud L1688 in Ophiuchus.

Observing dense core and ambient cloud using single tracer

- Prestellar core H-MM1 in L1688 (Ophiuchus)
- Tracer : NH_3 (1,1) and (2,2)
- Data : Green Bank Telescope (Beam ≈ 31″)
- rms noise level ≈ 22 mK

(Comparable to noise levels achieved with stacked spectra in Choudhury et al., 2021)

- Fit with *pyspeckit* (Ginsburg & Mirocha, 2011)
- **A second component with subsonic turbulence is detected throughout the core and its immediate neighbourhood** (Fig. 1)
- The detected components could be separated into two components, and the roughly uniform ambient cloud component. (Fig. 2)

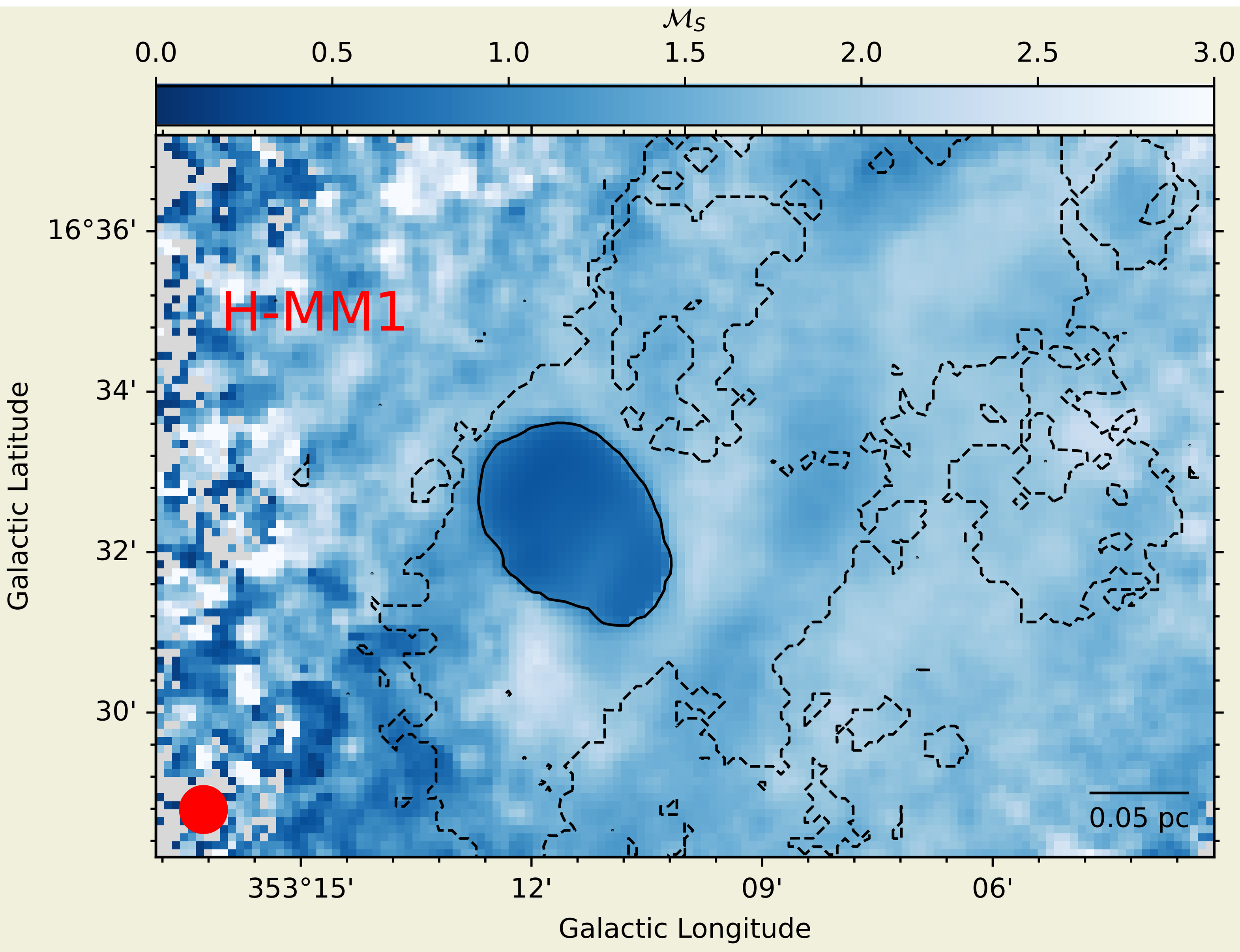


Figure 1 : *Sonic Mach number in the neighbourhood of H-MM1, derived from NH_3 observations. The black-solid contour shows the subsonic region of the prestellar core as seen with a traditional one-component fit (eg. Choudhury et al., 2020). The black-dashed contours show the extent of the additional subsonic material which could only be detected with a two-component fit. It is clearly visible that there is subsonic material present well beyond the prestellar core boundary. The beam and the scale bar are shown in the bottom left and bottom right corners, respectively.*

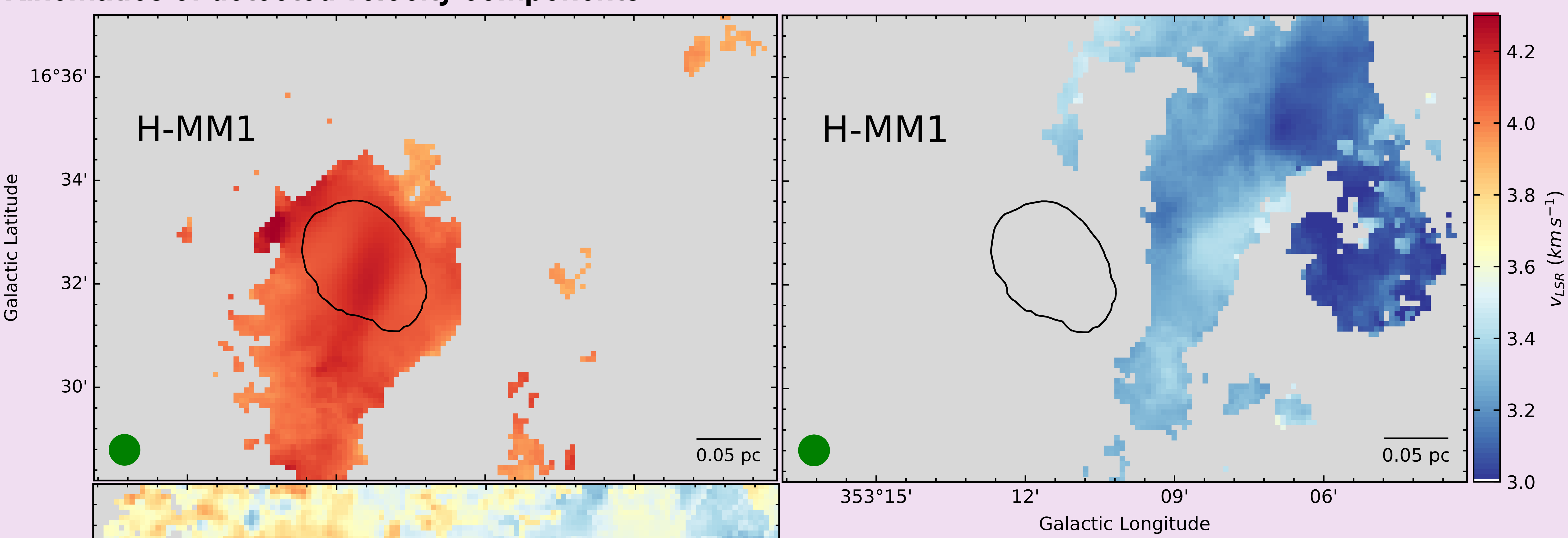
Primary results

- **Subsonic material is detected up to 0.2 pc outside the typically calculated coherent core boundary** (Fig. 1).
- This material is **not distributed homogeneously,** and has a **orientation nearly parallel to the minor axis of the core**.
- The subsonic material is present in **two kinematically separated components** with systematically different velocities (top panels of Fig. 2) and temperatures ($T_K \approx 10$ K and $T_K \approx 15$ K, for the red- and blue-shifted components, respectively).

Implications

- The material present in the **extended subsonic region** (top left panel in Fig. 2) **could be accreted by the core** without it disrupting the dynamical stability of the core.
- Possible core growth via further accretion would mean that **the cores do not evolve in isolation**, as previously thought, and the **core-cloud boundary is not sharp**.

Kinematics of detected velocity components



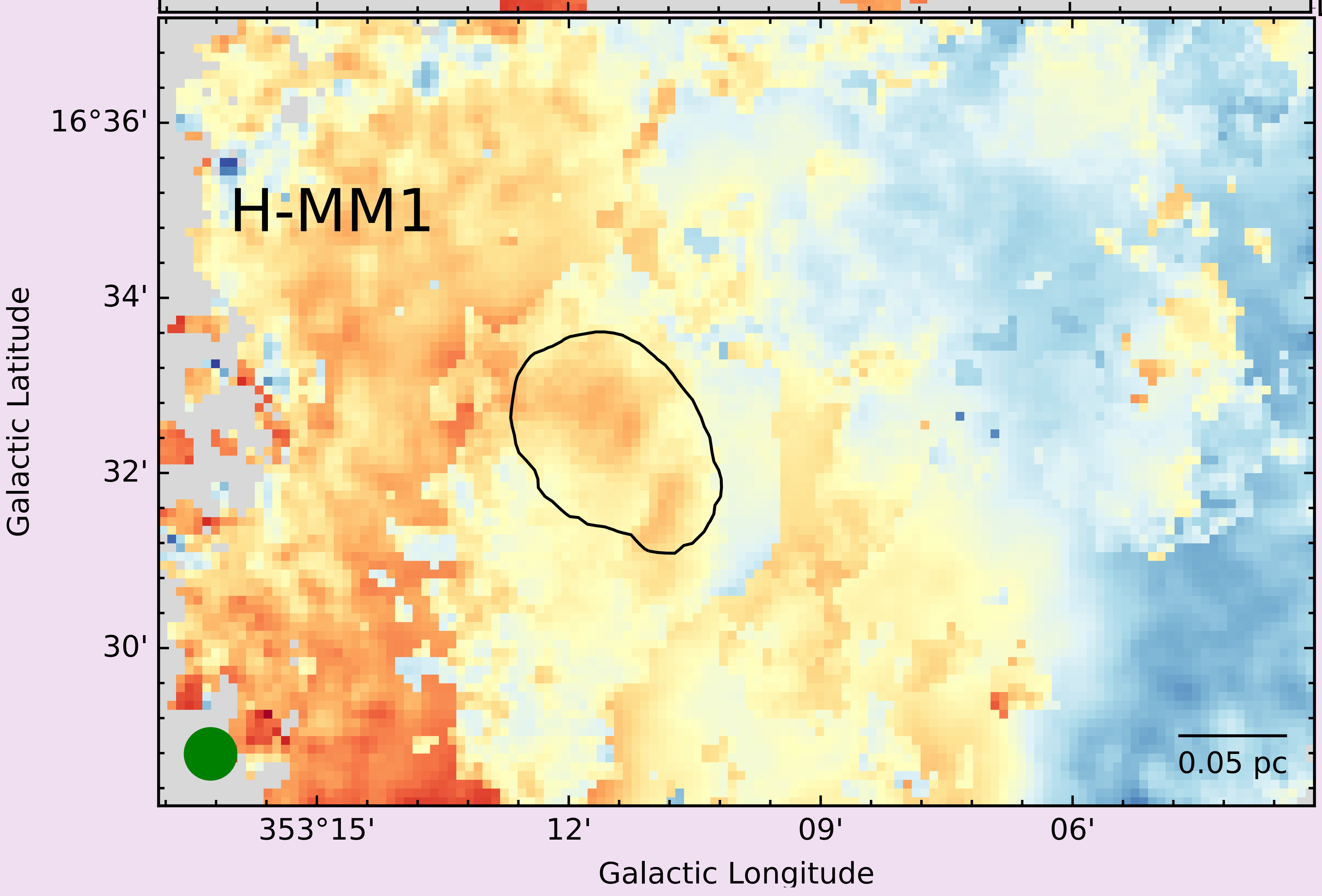


Figure 2 :
*Top : Centroid velocity maps of the red-shifted (left) and blue-shifted (right) components of the extended subsonic region (dashed contours in Fig. 1). The **red-shifted component** shows the prestellar core (black contour) and the **material closely connected to the core, both spatially and kinematically**. This material could be accreted by the core. The **blue-shifted component is spatially and kinematically well-separated from the core**, with velocities systematically lower (Δv~0.1 km/s) than the core and its neighbourhood. Though subsonic ($\mathcal{M}_S < 1$), this component is systematically warmer than the core material. **What is the origin and significance of this component?** Future observations with high-density tracers will help us shed light on this question.*
Bottom : Centroid velocity of the ambient cloud component. As expected for a molecular cloud, the velocity dispersion of this component is supersonic throughout, and there is no sharp changes in the velocity of this component. We see a general gradient in the velocity of the cloud from south-west to north-east (right to left in the map shown here), similar to previous observations of the region (Friesen et al., 2017, Choudhury et al., 2021)
The black contour shows the coherent region of the H-MM1 core, with a single-component fit.
The beam and scale bar are shown in the bottom left and bottom right corners, respectively.

References :

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