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The spatial distribution of optically thin $^{12}CO(1-0)$ in diffuse molecular clouds

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Abstract. We present 1 pc × 1 pc maps of two diffuse clouds in ^{12}CO and $^{13}CO(1-0)$, with a resolution of 20″ (0.015 pc at 150 pc), done with the IRAM-30m telescope. They reveal two types of thin (diameter$\approx$ 0.05 pc) filaments with aspect ratio $\approx 5-20$, of quite different densities: *(i)* dense and cold ones ($n_{\rm H} \approx 3000\,{\rm cm}^{-3}$ and $T_{\rm kin} \approx 15\,{\rm K}$), bright in both tracers, and *(ii)* warm and tenuous ones ($n_{\rm H} \approx 500\,{\rm cm}^{-3}$ and $T_{\rm kin} \approx 25\,{\rm K}$), only detected in $^{12}CO(1-0)$, *i.e.* below the detection limit of $^{13}CO(1-0)$.

Using a photodissociation code (Le Bourlot *et al*), we show that these latter structures, characterized by a temperature ratio $T_{\rm mb}[^{12}{\rm CO}(1-0)]/T_{\rm mb}[^{13}{\rm CO}(1-0)] \geqslant 15-20$ are optically thin in $^{12}CO(1-0)$. These results reveal for the first time that optically thin $^{12}CO(1-0)$ towards diffuse molecular clouds is highly structured rather than uniformly distributed, as previously thought. Moreover, as shown in figure 1, these structures do not coincide with the gas bright in ^{13}CO, and are distributed in the whole field.

In parallel, the statistical analysis of the line centroid velocity increments (see **?**,for a description of the method) shows *(1)* non-Gaussian signatures tracing large velocity shears (like in **?**) and *(2)* that the warm filaments, optically thin in $^{12}CO(1-0)$, coincide spatially with the locus of vorticity extrema. We try to model the filaments as two-fluid magnetized continuous shocks (C-shock), at low velocities (3-6 $\rm km\,s^{-1}$), by solving the steady-state chemistry, consistently with the thermodynamics of the shock wave. The pre-shock proton density ranges between 100 and $1000\,{\rm cm}^{-3}$. The resulting post-shocked regions have widths ($\approx 0.01-0.05$ pc) and line-of-sight velocity dispersions ($\approx 0.5\,{\rm km\,s}^{-1}$) consistent with those of the observed filaments.

The warm tenuous filaments may be similar to the structures responsible for the excess of high-J ($J_{\rm up} > 1$) emission of H_2, as reported by **?**), and presumably originating in tiny warm pockets of gas, scattered within the cold diffuse medium. Line intensities of species like HCO^+ and CH^+ further constrain the modelling of this gas (Falgarone *et al* submitted).

Modelling of the two types of filaments revealed by our observations require to couple photodissociation processes with out-of-equilibrium chemistry, and dynamical processes like magnetized shocks or vortices (*e.g.* **?**). The observed filaments may correspond to different stages in the evolution of these dissipative structures. They may be the seeds of more massive molecular filaments from which dense cores form.

Keywords. radio lines: ISM, turbulence, ISM: clouds, molecules, kinematics and dynamics, magnetic fields

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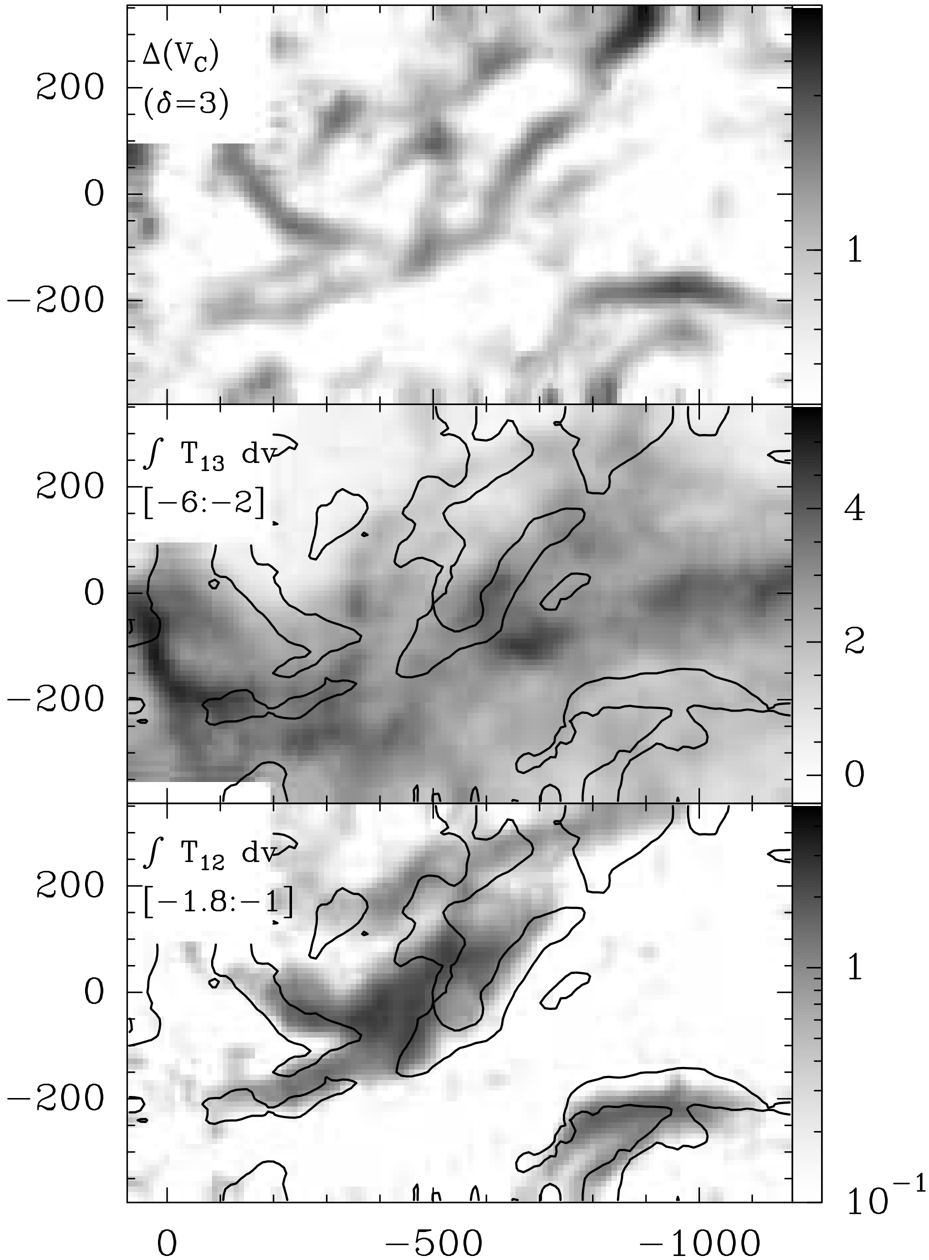

Figure 1. Optically thin ^{12}CO(1−0). *Top:* Line centroid velocity increment (CVI) between pair of points separated by 3 pixels. *Middle:* grey scale is the integrated emission of the ^{13}CO(1−0) in the whole velocity range, $[-6:-2]\,\mathrm{km\,s^{-1}}$. *Bottom:* grey scale is the integrated emission in the velocity range $[-1.8:-1]\,\mathrm{km\,s^{-1}}$ corresponding to the optically thin emission in ^{12}CO$(1-0)$. Contours are the CVIs from the top panel, above a 5σ threshold.