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Intense velocity-shears and magnetic fields in diffuse molecular gas: from 10 pc to 5 mpc

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Abstract. Regions of intense velocity-shears are identified on statistical grounds in nearby diffuse molecular gas: they form conspicuous thin (~ 0.03 pc) and parsec-long structures that do not bear the signatures of shocked gas. Several straight substructures, ~ 3 mpc thick, have been detected at different position-angles within one of them. Two exhibit the largest velocity-shears ever measured far from star forming regions, up to 780 km s^{-1} pc^{-1}. Their position-angles are found to be also those of 10-parsec striations in the $I(100\mu\text{m})$ dust emission of the large scale environment. The **B** field projections, where available in these fields, are parallel both to the parsec- and to one of the milliparsec-scale shears. These findings put in relation the small-scale intermittent facet of the gas velocity field and the large scale structure of the magnetic fields.

Keywords. Turbulence, MHD, ISM:magnetic fields, ISM: kinematics and dynamics, ISM: structure, ISM: evolution

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Long thought to be featureless and of minor importance in molecular cloud dynamics, diffuse molecular gas is now recognized to be an important fraction of molecular clouds mass, and to harbor intense dynamical activity and still unexplored small-scale structure. These have been progressively revealed by large scale sensitive maps, see Goldsmith *et al.* 2008, Hily-Blant & Falgarone 2009, observations of its molecular richness (see references in Snow & McCall 2006), its ubiquitous small-scale structure (Falgarone *et al.* 1998) and its supersonic turbulence. We propose that turbulent dissipation is one of the missing clues in understanding the main features of diffuse gas, and the processes at the origin of its condensation. In this context, shocks are expected to be the main drivers of turbulent dissipation. What are the observations telling us?

Magnetic field intensity: A Bayesian analysis of a large sample of Zeeman measurements (Crutcher *et al.*, submitted) shows that the **B** intensity in the diffuse medium is likely not to increase with density, up to $n = 300$ cm^{-3}, suggesting that either the gas flows along the field lines (Hennebelle *et al.* 2008, Nakamura & Li 2008) or that shocks do not increase the **B** field intensity because they enhance ambipolar diffusion (Li & Nakamura 2004). Both scenarios predict shocks perpendicular to **B**.

Velocity-shears and **B** *orientation:* At the parsec-scale, intense velocity-shears of 15 to 30 km s^{-1} pc^{-1} have been disclosed on statistical grounds in two translucent regions of the Polaris Flare and the Taurus cloud: they are a manifestation of the intermittency of turbulence, traced by the non-Gaussian tails of probability distribution functions of CO line velocity centroid increments (CVI) (Hily-Blant *et al.* 2008, Hily-Blant & Falgarone 2009). Their locations form thin (< 0.05 pc) and coherent structures that extend over > 1 pc (Fig. 1). In the Taurus field, this locus is parallel to the **B** field projection, a finding possibly in line with the alignment of striations in the ^{12}CO(1-0) line velocity centroids with the local **B** field projection in one Taurus edge (Heyer *et al.* 2008). These intense velocity-shears do not bear shock signatures (e.g. density enhancement).

At the milliparsec-scale, the pc-scale coherent structure in the Polaris Flare splits into eight straight substructures (field observed with the IRAM interferometer: rectangle in Fig. 1, Falgarone, Pety and Hily-Blant 2009). They are the sharp edges of extended CO-layers and some exhibit the highest velocity-shears ever measured in non-star forming clouds, up to 780 km s^{-1} pc^{-1}. Their position angles, measured within $\pm 10\,^\circ$, are all different ($PA \sim 100^\circ$, 60°, 165°), while

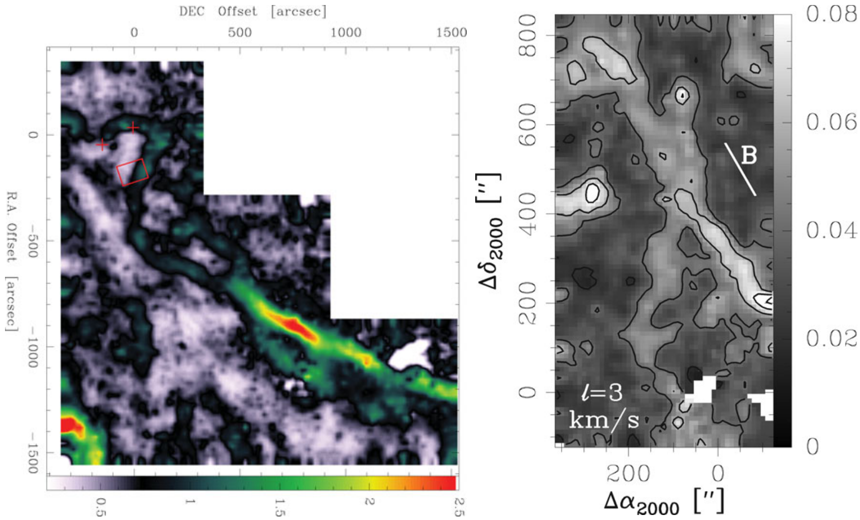

Figure 1. Extrema of ^{12}CO line CVI in the Polaris Flare *(left)* and the Taurus cloud *(right)* (from Hily-Blant *et al.* 2008, Hily-Blant & Falgarone 2009). 1 arcmin is 0.045 pc at the distance of both fields, $d = 150$ pc.

the **B** field projection measured 1° North has $PA = 108 \pm 19$ ° (Heiles 2000). Unexpectedly, the PAs of the small-scale velocity-shears are found among those of 10-parsec straight dust $I(100\mu\mathrm{m})$ streaks of the Polaris Flare.

The observations therefore suggest that there is a prevalence of velocity-shear and vorticity over compression in diffuse molecular gas, and that the most intense shear-layers appear to be parallel to the **B** field projections. It is remarkable that orientations of mpc-scale shears be recovered at the 10 pc-scale. These results warrant further observations both over large dynamic ranges to improve statistics and smaller scales with ALMA. They demand comparison with advanced numerical simulations.

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