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Non-equilibrium chemistry in the diffuse interstellar medium: detection of large HCO^+ abundances

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Abstract. We report detections of weak HCO^+(1-0) lines (10mK < T_A^* < 0.5 K) emitted by molecular gas in the translucent environment of low mass dense cores. The observed positions belong to a new kind of small scale structures identified as the locus of non-Gaussian velocity shears in the statistics of the centroid velocity increments of the CO(1-0) lines (see Poster by Hily-Blant et al., this conference). The interpretation of 10 of the HCO^+ velocity components is conducted in conjunction with that of the associated optically thin ^{13}CO emission . The derived HCO^+ column densities span more than two orders of magnitude, $10^{11} < N(HCO^+)/\Delta v < 5 \times 10^{13}$ cm^{-2}/km s^{-1}. These results provide HCO^+ abundances significantly above those produced by steady-state chemistry in weakly shielded gas.

We confront our results with models of non-equilibrium chemistry triggered in bursts of dissipation in interstellar turbulence. The bursts are ascribed to the general property of intermittency of turbulence and are described as small scale magnetized Burgers vortices, following Moffat, Kida & Ohkitani (1994). According to these authors, the lifetime of the small scale vortices, called the "sinews of turbulence", is imposed by the velocity field of large scale eddies. In the conditions of translucent molecular gas, this lifetime is found to be short, a few 100 years only, and the neutrals and ions within the vortices are therefore weakly coupled. As a consequence, the standard chemistry is modified both by the intense ion-neutral drift within the vortex and the enhanced heating due to viscous dissipation in the layers of large velocity shear at the edge of the vortex (Joulain et al. 1998). We find that gas formerly heated and enriched chemically during these transient bursts of dissipation, may account for the large observed abundances during the isobaric cooling and condensation of the gas, once the vortex has died out. We also show that despite the ephemeral nature of the model vortices (a few 100 yr), the gas retains the "hot chemistry" signature acquired during the lifetime vortex (i.e. large abundances of OH, H_2O, HCO^+ and CH^+) over thousand years or more after its death. Quantitatively, the average amount of warm gas requested in translucent clouds to account for the above HCO^+ abundances is consistent with the column density of warm H_2 (i.e. H_2 in rotational levels $J > 3$) observed in the diffuse ISM across the inner Galaxy by ISO-SWS (Falgarone et al. 2005).

Keywords. Astrochemistry, ISM: molecules, ISM: magnetic fields, turbulence

References

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