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Sulfur chemistry in the Horsehead PDR: deriving the S abundance from CS

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Abstract.

Sulfur is an abundant element in diffuse interstellar clouds where it remains mostly in the gas phase. However, it could deplete on dust grains at higher densities (it is still a mystery in which form sulfur can be depleted). Therefore, an accurate determination of the gas phase sulfur abundance in different environments is needed. In the case of photo–dissociation regions (PDRs), the sulfur abundance is also a key parameter for the chemistry because it heavily influences the electronic abundance. The fractional ionization itself determines the abundance of molecular ions playing a role in ion–molecule reactions and is also an important parameter to constrain the coupling of gas and magnetic field. Direct observation of S and S^+ in PDRs is often difficult because their relevant lines are either blocked from the ground or because the spatial resolution is not high enough to perform detailed studies. However, an appropriate S-bearing molecule may be used if its abundance scales with that of sulfur, which is the case of CS we have studied.

In this contribution we present high spatial resolution observations ($\sim 5''$) of the CS(2–1) line of the edge of the Horsehead nebula (e.g. Abergel et al. 2003) recently obtained with the IRAM Plateau de Bure interferometer (PdBI). These data complement our observational study of the source that includes previous PdBI maps of hydrocarbons (CCH, c–C_3H_2 and C_4H), ^{12}CO and $C^{18}O$ (Pety et al. 2005) and also CO(3–2), CS(3–2), CS(5–4) and 1.2 mm continuum emission observations with the IRAM-30m telescope (Teyssier et al. 2004). As expected, the CS emission has a different behavior compared to that observed for the small hydrocarbon species; it slowly increases from the cloud edge to the UV shielded regions. We have used the stationary PDR code of J. Le Bourlot et al. together with a non–LTE, non–local radiative transfer model including both gas and dust to constrain the sulfur abundance from that of CS. In particular, given a sulfur abundance, the PDR model provides the CS abundance profile that is used afterwards in the radiative transfer model. Then, synthetic spectra at different PDR positions are compared with our high resolution PdBI observations across the edge. The study of CS and CO excitation has also provided important constrains to the temperature and density structure of the Horsehead PDR. In particular, we confirm that a steep density gradient ($n_H \sim r^4 \sim A_V^{0.8}$) is needed to reproduce the molecular line observations at the PDR edge (see Habart et al. 2005 for previous estimations from H_2 observations). We finally found that the CO excitation, specially the intensity of the CO(2–1) and CO(3–2) lines, is consistent with warm ($T_k \sim 100$ K) molecular gas in the PDR.

Keywords. ISM: abundances, ISM: individual (Horsehead), molecular processes.

References

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