Observable tracers of the ionization fraction

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The ionization fraction controls several key physical and chemical processes of the ISM : fast ion neutral reactions allowing a rich interstellar chemistry, gas coupling to the magnetic field controlling the collapse of prestellar cores, collisional excitation of key molecular tracers (such as HCN). Determining the ionization fraction across the different regions of a giant molecular cloud, from its diffuse enveloppe to its densest core, is thus a mandatory step towards understanding the chemical and physical structure of a GMC, and their link to star formation. Our ORION-B IRAM-30m large program [1] (PIs : M. Gerin, J. Pety) provides an exhaustive map of a GMC (over ~20pc with a 50mpc resolution) in the full 100GHz band, allowing observations of ~20 molecular lines and thus an unbiased global survey of a GMC. However, classical observable tracers of the ionization fraction, such as the DCO+/HCO+ ratio [2], are only detectable in the densest cores.

We propose a statistical approach [3], exploiting large grids of astrochemical models to automatically find the best observable tracers of the ionization fraction among hundreds of species included in the model. The predictive power of each tracer is estimated using Random Forests, a flexible regression model, and we then provide simpler fit formulas to be used for the analysis of the observations. We find several new tracers of the ionization fraction, with strong predictive power despite large uncertainties in the other physical parameters (gas density, temperature, H_2 OPR, depletion...) and detectable in the extended enveloppe of the cloud, which we apply to our Orion-B dataset.

References

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