Astrophysics meets data science in the Orion B Giant Molecular Cloud

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Atoms and molecules have long been thought to be versatile tracers of cold neutral medium in the universe, from high-redshift galaxies to star forming regions and proto-planetary disks, because their internal degrees of freedom bear the signature of the physical conditions in their environments. However, the promise that molecular emission has a strong predictive power of the underlying physical and chemical state is still hampered by the difficulty to combine sophisticated chemical codes with gas dynamics. It is therefore important 1) to acquire self-consistent data sets that can be used as templates for this theoretical work, and 2) to document the diagnostic capabilities of molecular lines accurately. The current developments of sensitive wideband spectrometers in the (sub)-millimeter domain (e.g., IRAM-30m/EMIR, NOEMA, ...) open new avenues to fulfill this goal.

The ORION-B project (Outstanding Radio-Imaging of OrioN-B, co-PIs: J. Pety and M. Gerin) is a Large Program of the IRAM 30m telescope that aims to improve the understanding of physical and chemical processes of the interstellar medium by mapping a large fraction of the Orion B molecular cloud (5 square degrees) with a typical resolution of 27'' (50 mpc at a distance of 400 pc) and 200 kHz (or 0.6 km s^{-1}) over the full 3 mm atmospheric band. In a first study [1], we showed how tracers of different optical depths like the CO isotopologues allow one to fully trace the molecular medium, from the diffuse envelope to the dense cores, while various chemical tracers can be used to reveal different environments. A clustering algorithm was then applied to the intensities of selected molecular lines, and revealed spatially continuous regions with similar molecular emission properties, corresponding to different regimes of volume density or far-UV illumination [4]. In addition, a global Principal Component Analysis of the line integrated brightnesses revealed that some combination of lines are sensitive to the column density, the density, and the UV field [2]. In a recent study, we go one step further by checking whether/how it is possible to build a quantitative estimate of the H_2 column density, based on the molecular emissivity, and valid over a large range of conditions [6]. This is a prerequisite to accurately estimate the mass of the different (potentially velocity separated) components of a giant molecular cloud, in particular its filamentary nature [5]. To quantitatively interpret these results, we use the Cramer Rao Bound (CRB) technique to analyze and estimate the precision on the abundances, excitation temperatures, velocity field and velocity dispersions of the three main CO isotopologues [7].

References

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