Dealing with uncertainty in millimeter astronomy: towards more realistic noise model and Bayesian approach

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The new large hyper-spectral surveys in radio-astronomy are a game changer for the study of star formation processes, feedback mechanisms and chemistry of the interstellar gas. Thanks to wide field hyper-spectral observations it is now possible to observe full molecular clouds (10 pc size) at a dense core scale (<0.1 pc) spatial resolution. The IRAM-30m Large Program "Orion B" is one of these pilot projects [1], with ∼250 square parsecs of the Orion B molecular cloud on 1 million pixels and 200 000 spectral channels per pixel, allowing to map the emission of dozens of molecules over the whole giant molecular cloud.

The estimation of the physical conditions at each pixel (UV radiation field intensity, thermal pressure, visual extinction, etc.) on such large and rich datasets by comparing them to state-of-the-art astrochemistry models is challenging. First, the different regions of the cloud have variable signal-to-noise ratios. If the brightest regions are well constrained, the regions with low SNR lead to poorly defined physical parameters and degenerate solutions. Taking advantage of the wide field of view dataset requires new methods to extract the most out of the detected emission lines while providing accurate estimates of the uncertainties.

We propose a new estimation method, combining the incorporation of both additive (e.g. observational noise) and multiplicative (e.g. calibration errors) error sources, a Bayesian approach giving access to accurate confidence intervals, and a spatial-smoothness prior. This prior accounts for the fact that regions with lower brightness, more diffuse gas are expected to have larger spatial scales than the denser regions. It allows the estimation to make use of the information of neighbouring pixels in low SNR regions, thus improving the estimation of the physical parameters in these regions.

As a first test, we apply our method to both simulated and real observations of common PDR tracers in the IR (excited CO rotational lines, H2, CH+, etc.), comparing with previous published estimations of the physical parameters in the Carina cloud [2], the Orion Bar and NGC 7023 [3].

References

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