Multi-line characterization of whole molecular clouds using stratified random sampling

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Characterizing the molecular emission from full molecular clouds is critical to identify the physical and chemical processes that act at different spatial scales and lead to the formation of stars. It is also important in order to connect spatially-resolved observations of galactic clouds with extragalactic observations that do not resolve the clouds.

Characterization clouds by multi-line mapping is however very time demanding, since it requires fully sampling the emission over many square degrees in the sky, and for this reason, it can only be carried out over a very limited sample of clouds. As an alternative to mapping, we have developed a new method of characterizing the multi-line emission from clouds based on statistical sampling. Our method uses available extinction maps to select a relatively small sample of cloud positions that cover the full range of column densities in the cloud, and that can be observed with only a modest investment of telescope time.

Here we present the first results of applying our sampling technique to the nearby Perseus molecular cloud, which has been observed with the IRAM 30m telescope over the whole 3mm wavelength band. Despite the complex structure of the cloud, its emission properties are well behaved over two orders of magnitude in column density, and can be well characterized using our sampling technique. With the help of a radiative transfer model, we have analyzed the behavior of the main molecular species over the full cloud, and we have determined their abundance profiles from the outermost cloud layers, where the molecules are photodissociated, to the densest parts of the cloud, where most species freeze out on the dust grains. Given the success of our sampling technique, we have recently extended its use to the Orion and California clouds, which present very different star-formation properties and therefore provide a valuable set for comparison