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Probing the interstellar ice composition in the dense star forming cloud Chamaeleon I: first results of JWST program "Cheerio"

Knowledge of the initial chemical conditions of physical environments is vital for a better understanding and study of how these lead to astrophysical objects such as protostars and protoplanetary disks. More specifically, the starting point for the study of molecules is the cold and dense dust and gas clouds, known as molecular clouds, where the chemical composition is transformed from that of the diffuse atomic interstellar medium. These regions create the conditions for molecules to form; some of which are frozen out on dust grains as molecular solids or "ice". These icy grains develop both chemically and physically through the evolution into larger grains, with the latter contributing to the gravitational collapse of the cloud to a protostar. Here, we focus on characterizing the formation of the initial interstellar ices where the reservoirs of elements which will be delivered to planets at later stages of star formation are stored. We mainly focus on the carbon, oxygen and nitrogen budgets. The James Webb Space Telescope (JWST) is well suited to address such needs thanks to its high spectral and angular resolution and its multi-wavelength filter coverage. In this study we will focus on the near-infrared spectrum of the dust, rather than the mid- or far-infrared continuum, where it is usually observed by astronomers. In the near-infrared wavelength range, the dust does not emit and thus molecular clouds, which appear dark in the visible, can be traced along lines of sight towards field stars behind them through absorption features of the intermediary solid phase molecules and dust.

The main goal of the JWST Cheerio program (PID: 4358, PI Z. Smith) is to probe the ice composition of the molecular cloud Chamaeleon I. With the use of the NIRCam instrument in its slitless spectroscopy mode, the observations will be analyzed to determine the ice onset threshold at the cloud edges. The central dense core region of Chamaeleon I was mapped in H_2O, CO_2 and CO in the preceding program [1], Ice Age (PID: 1309, PI M. McClure). A more complete H_2O / CO_2 observational ice map will be constructed by adding the wider field Cheerio observations, tracing lower extinctions and ice formation thresholds. In this work we used the NIRCam images of the Chamaeleon I field across multiple filters to establish and analyze a master catalogue of field star positions. We reduced the images using the JWST pipeline along with a customized background correction, then derived fluxes for each source at all available wavelengths. We evaluated the performance of aperture vs. PSF photometry for flux derivation. The optimal methodology for the reduction steps was determined based on analysis of sources with varying signal-to-noise ratios, corresponding to different subcategories of the total sample. The desire to achieve reliable, high-accuracy flux values stems from the aim to categorize and classify these sources with high confidence. To do that, we used this extensive photometric dataset to combine and compare fluxes across all filters. This large statistical sampling of photometry across Chamaeleon I will also play an essential role in the wider aims of the Cheerio program, serving as a benchmark for comparison with the derived spectroscopic fluxes.

References

[1] Z. L. Smith et al. "Cospatial ice mapping of H_2O with CO_2 and CO across a molecular cloud with JWST/NIRCam". In: *Nature Astronomy* 9 (June 2025), pp. 883–894. DOI: 10.1038/s41550-025-02511-z.