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Formaldehyde formation pathways constrained by isotopic ratios in L1689B

Tracing the chemical heritage from the interstellar medium to forming stars and planets is a fundamental challenge in modern astrophysics. In this context, variations of isotopic ratios due to fractionation reactions across different environments provide important constraints on chemical evolution. Thus, monitoring isotopic ratio variations in carbon-bearing molecules along the star forming sequence allows us to trace the history of molecule formation and physical conditions.

Formaldehyde (H_2CO), one of the simplest organic molecules detected in dense cores, is a key tracer as it can form both in the gas phase and on the surfaces of dust grains. Distinguishing between these formation routes relies on robust indicators such as the ortho-to-para ratio and the carbon isotopic ratio.

In this talk, I present an analysis of the ortho-to-para ratio and the $^{12}\text{C}/^{13}\text{C}$ ratio of formaldehyde in the prestellar core L1689B. We use observations of H_2CO , H^{13}CO , and $\text{H}_2\text{C}^{18}\text{O}$ obtained with the IRAM 30m telescope, and model the data with the non-LTE radiative transfer code Molpop-CEP. The physical and chemical parameters are inferred through Bayesian sampling, focusing on the core center and selected offsets along a horizontal cut.

At the core center, we find an ortho-to-para ratio close to 3 and a $^{12}\text{C}/^{13}\text{C}$ ratio of 56^{+14}_{-11} , consistent with a dominant grain-surface formation pathway and compatible with the elemental carbon ratio in the interstellar medium (~ 70). Along the horizontal cut, the $^{12}\text{C}/^{13}\text{C}$ ratio decreases with distance from the core, reaching values as low as ~ 25 . Such low values are not explained by current chemical models.

These results provide new constraints on the formation and evolution of formaldehyde in prestellar environments and highlight significant spatial variations in isotopic ratios. Future observations will aim to better constrain the low $^{12}\text{C}/^{13}\text{C}$ values and to probe their variation along the line of sight, while dedicated chemical modeling will be required to explain these discrepancies.