Ice deuteration: models and observations to interpret the protostar history

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Extremely large deuteration of several molecules has been observed around low-mass protostars for a decade. Among them, formaldehyde and methanol present particularly high deuteration, with observations of abundant doubly and triply deuterated isotopologues seen with ground-based millimetric telescopes [1]. The Herschel Space Telescope, launched in 2009, is now providing measures of the deuterium fractionation of water. First results towards the protostellar prototype, IRAS 16293, revealed that water shows HDO/H_2O and D_2O/H_2O ratios of ~3 and ~0.1 \% respectively [2]. Athough water shows a higher deuteration than the cosmic deuterium reservoir (10^{-5} relative to H nuclei), these values remain lower than the deuteration seen in formaldehyde and methanol. Water, formaldehyde, and methanol are believed to be mainly produced on interstellar ices in cold dark clouds. In this presentation, I will discuss 1) a theoretical model and 2) new interferometric observations of the water deuteration.

1) We have developed a macroscopic time-dependent gas-grain model, called GRAINOBLE [3], to study the formation and the deuteration of interstellar ices. The model follows the multilayer formation of ices distinguishing the chemical processes that occur in the mantle inert bulk and on the reactive surface. For this purpose, a comprehensive chemical network producing deuterated water, formaldehyde, and methanol has been considered following recent experiments and theoretical calculations [4] [5]. A grid of several thousands of models has been run and compared to observations toward low-mass protostars. The low deuteration of water compared to formaldehyde and methanol, can be explained by their different chemical history. Water is mainly formed during a translucent phase at low density while formaldehyde and methanol are rather formed in denser and colder prestellar cores, where the CO depletion is high [4] [5].

2) Interferometric mapping of HDO has been carried out with the PdB interferometer toward two low-mass protostars, IRAS2A and IRAS4A [6]. In both sources, the HDO emission is compact and unresolved in the PdB 2 arcsec synthesized beam. LVG analysis of the integrated line emission as well as other HDO lines from single dish observations [7] and $H_2{}^{18}O$ line from PdB observations [8] allows us to estimate the most reliable HDO/H_2O ratio in low-mass protostars. We found a deuterium fractionation of water in IRAS2A and IRAS4A higher to that found in IRAS 16293 [2], suggesting a water formation at high densities.

References

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