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Ices in starless and starforming cores

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Icy grain mantles are commonly observed through infrared spectroscopy toward dense clouds, cloud cores, protostellar envelopes and protoplanetary disks. Up to 80% of the available oxygen, carbon and nitrogen are found in such ices; the most common ice constituents - H2O, CO2 and CO - are second in abundance only to H2 in many star forming regions. In addition to being a molecular reservoir, ice chemistry is responsible for much of the chemical evolution from H2O to complex, prebiotic molecules. Combining the existing ISO, Spitzer, VLT and Keck ice data results in a large sample of ice sources (\sime80) that span all stages of star formation and a large range of protostellar luminosities (<0.1-105 L\odot). Here we summarize the different techniques that have been applied to mine this ice data set on information on typical ice compositions in different environments and what this implies about how ices form and evolve during star and planet formation. The focus is on how to maximize the use of empirical constraints from ice observations, followed by the application of information from experiments and models. This strategy is used to identify ice bands and to constrain which ices form early during cloud formation, which form later in the prestellar core and which require protostellar heat and/or UV radiation to form. The utility of statistical tests, survival analysis and ice maps is highlighted; the latter directly reveals that the prestellar ice formation takes place in two phases, associated with H2O and CO ice formation, respectively, and that most protostellar ice variation can be explained by differences in the prestellar CO ice formation stage. Finally, special attention is paid to the difficulty of observing complex ices directly and how gas observations, experiments and models help in constraining this ice chemistry stage.

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