The evolving ice-gas interface during star- and planet-formation

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Complex organic molecules (>6 atoms) have been detected toward low- and high-mass protostars, galactic center clouds, protostellar outflows and comets, demonstrating the existence of efficient astrophysical pathways to chemical complexity. The detected molecules all reside in the gas. Yet many probably form on interstellar grains, in ices that evolve with their environment and finally evaporate as the grains are heated by new-born stars or by shocks. I will explore this ice evolution during star formation by combining Spitzer spectra of the first, simple ices with laboratory simulations of UV induced ice photochemistry and with millimeter observations tracing complex ice evaporation. The experiments show that UV irradiation of protostellar ices is efficient enough to explain the complex molecule observations in so called protostellar 'hot cores'. Moreover, the experiments predict that before the onset of thermal evaporation close to the protostar, small fractions of the complex ice will continuously evaporate non-thermally due to photodesorption, resulting in gas-phase fingerprints of the ice composition as it evolves. To test this prediction and thus the ice origins of complex molecules in space, we searched for a number of gas-phase complex organic molecules – $HCOOCH_3$, CH_3CHO, CH_3OCH_3, C_2H_5OH and $HCOCH_2OH$ – toward an ice-rich cloud core irradiated by a nearby protostar. The observations have resulted in a modified scenario for complex ice formation and desorption during star formation. A key unknown is what happens to these molecules during planet formation and I will end with showing some exciting results on the chemistry in protoplanetary disks, acquired within the ongoing SMA legacy program DISCS.