ICE INHERITANCE IN DYNAMICAL DISK MODELS

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Introduction: Comets and primitive meteorites exhibit isotopic and/or compositional similarities to volatile material in the interstellar medium, suggesting that some pristine interstellar material was incorporated intact into icy planetesimals in the Solar Nebula [e.g. 1,2]. The survival of interstellar material in icy bodies has important implications for the source of major isotopic anomalies of O, N, and H in planetesimals [e.g. 3], the physical conditions of the young Solar system [4], and the provenance of prebiotic building blocks found in meteorites and comets [5]. To date, the survival of interstellar volatiles within the protoplanetary disk stage has not been modeled using realistic disk physics.

Methodology: We developed a model to evaluate the prospects for interstellar icy material to survive passage through the disk and incorporation into icy bodies. Beginning with an interstellar ice structure and composition, we track ice destruction due to UV and heat as dust grains undergo diffusion, settling, and drift within a protoplanetary disk. We simulated thousands of particle trajectories spanning a range of grain sizes (1-1000um) and initial disk radii (20-150 au) in order to explore ice survival outcomes in different disk regimes.

Results & Implications: For our adopted disk model, we find ice loss is rapid for small (<10um) grains in the inner few tens of au, which are readily lofted into UV-exposed disk layers. It is therefore difficult to explain high degrees of inheritance through the local assembly of comets (~5-30 au; [6]). Instead, a plausible pathway to inheritance is to form pebbles at larger disk radii, which then drift inwards to the comet-forming zone with their ices mostly preserved. Our results therefore support that pebble drift + pebble accretion played a role in the formation of Solar System bodies ([e.g. 7,8]).

Icy pebbles drifting inwards from larger disk radii should mostly preserve their original interstellar isotopic signatures. In some cases, the ices are not processed at all and the molecular composition of the ice is not altered. This supports the idea that organics synthesized in the interstellar medium can be delivered to terrestrial planets by icy body impact and thus potentially participate in origins of life chemistry. In other cases, especially <10um grains beyond 100 au, there is significant ice photodissociation but minimal loss of ice from the grain. This is likely a robust site for ice-phase formation of more complex material. This scenario implies that interstellar-like isotopic signatures measured in meteoritic refractory organic material [9] could originate from heavy processing of simpler ice species within the disk, rather than reflecting synthesis in the ISM.

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