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FORMATION MODELS OF COMETARY ICES IN PROTOPLANETARY DISKS

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We set out to constrain the chemical conditions in the early Solar System by analyzing chemical evolution models of protoplanetary disks and comparing them to our current knowledge of Solar System bodies, such as comets. We propose that the region located at 10 AU$\leq r \leq$30 AU is ideal for the formation of ice mantles that match observed cometary abundances. The growth of an ice mantle contributes to increase significantly the size of dust grains, which will impact the midplane temperature and the efficiency of dust coagulation.

With the use of a ProDiMo (Woitke et al. 2009) simulated T Tauri disk model, we obtain a 2D radiative disk model in vertical hydrostatic equilibrium which sets the conditions in which the chemistry evolves in the disk midplane. Due to the low temperatures and low ionization rates in the disk midplane, the relaxation timescale for obtaining a steady-state solution for the chemistry in this region is of the order of 10^8 yr (Woitke et al. 2009). For this reason we run a time-dependent chemical model for the disk midplane (Chaparro Molano & Kamp 2012a). At a radial distance of 10 AU from the central star, we are able to obtain ratios and formation timescales for ice-phase CO, CO_2, and CH_4 relative to H_2O that agree with cometary ice measurements and estimates (Bockelée-Morvan 2010). The main assumption used here is the prevalence of a low-level ionization source throughout the midplane, which we propose to be a cosmic-ray induced UV field (Chaparro Molano & Kamp 2013).

For an Early Solar Nebula model we find that the thermal conditions at 30 AU ($T \simeq 20$ K) make this a plausible region for the formation of the icy dust grain precursors to cometary bodies. Throughout the midplane, the mantle of ices that forms on the surface of dust grains can be of the order of a few hundred monolayers thick (Chaparro Molano 2013). We show that in the disk midplane the ice mantle increases the size of dust grains by up to 76%, almost doubling the mean size of the original dust grains (Fig. 1). We observe that the effects of grain growth by ice mantle formation are significant enough to change the dust size distribution and the extinction coefficients. This in turn affects the thermal structure of the disk midplane. In the future, the ice information should be used to recalculate the dust opacities in a way that is consistent with the chemistry.

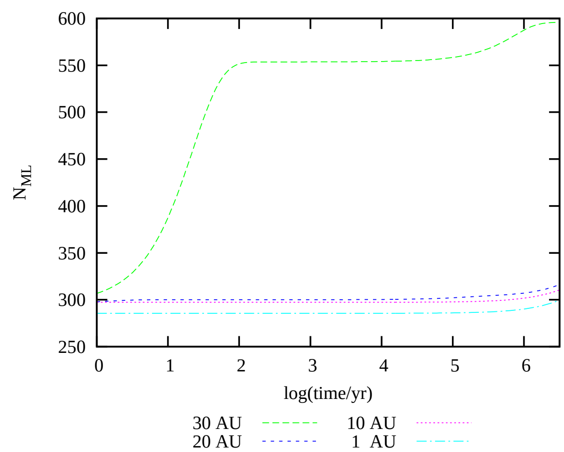

Fig. 1. Monolayer growth of the ice mantle forming on dust grains in the midplane of an Early Solar Nebula model, at different radii from the central star.

In addition, we obtain an ice/solid fraction of 30% at 30 AU, which is closer to the cometary ratio of 1:1 for the nucleus (Prialnik 1997) than for our previously mentioned T Tauri model (25%). This means that small dust grains may be further processed along the path to grow into cometary bodies.

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