Introduction: Early thermal and structural processes affect planetesimals and have strong implications for planet formation scenarios in protoplanetary disks. The evolution record of these "building blocks" is interwoven in the profiles of nowadays small icy-rocky bodies.

We present simulations of the early evolution of icy-rocky planetesimals formed beyond the so-called water snow line, before they are incorporated into giant planets, migrate inward or get ejected from the planetary system. The volatile composition and interior structure of these objects changes considerably prior to interaction with the giant planets. Some volatiles may survive throughout, but the varied thermal histories may impose an additional composition gradient to that inherent from the disk's physical-chemical evolution.

Modeling Issues: We regard a planetesimal as a cometary-like porous aggregate of various ices and refractory material [1], which is evolved under the influence of combined energy sources, such as crystallization (amorphous to crystalline water ice transition), radioactive decay, and reduced insolation. Composition includes refractory silicate-mineral solid grains and a mixture of volatiles, either in solid (ice) or gaseous (trapped) state. Equilibrium chemical compositions for these objects are taken from existing simulations of chemical and dynamical evolution of disk material [2], with H2O, CO, CO2, NH3 and CH4 and CH3OH as the key volatile species, as these are also the most commonly observed in comets [3]. The equations that govern thermal processing of ices and multi-phase gas flow in a porous medium are those of mass and energy balance, coupled with a hydrostatic scheme, for a 1-D spherical grid [4].

The early presence of organic species in the interior can affect the heat balance and phase transitions of water [5]. This is examined self-consistently, as the abundances and locations of all species evolve and we record mass ratios, temperatures, pressures and porosity variations [6]. Our parameter space addresses for some of the breadth of possible configurations: Formation region, orbital eccentricities (up to periastron just inside the snow line), orbital residence times (according to statistics of dynamical stability simulations), sizes (meter sized to 1000 km embryos) and radioactive sources (short and long lived isotopes, and varied initial concentrations).

Preliminary Results: We show, in Fig. 1, how an evolving temperature profile may look like, for smaller planetesimals that are negligibly affected by radioactive heating. The object has an orbit corresponding to the Jupiter-Saturn center of mass with high eccentricity, so that it ventures just within the snow line (~2.5 AU), where sublimation timescales are rapid. The 10 km object has a “bump” at ~30 Kyr, due to rapid onset of a crystallization front. However, from that point on, the temperature gradient changes and the interior below a few km is pristine.

We discuss the survival of species more volatile than water, as a function of their initial phases, sizes and densities and the timing of orbital and thermal evolution. For example, larger and denser objects, internally heated from the by radionuclides, can have volatiles surviving close to the surface, only to be lost almost as soon as the periastron distance decreases. The deeply buried processed material can be deposited later on. Mid-sized objects could retain some of their pristine volatile composition, to be deposited wherever they may go.

Fig. 1: Internal Temperature profile, as a function of time (x-axis, log scale) and distance from the surface (y-axis, log scale in m) for a 10 km object.


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