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Modification of icy planetesimal interiors by early thermal evolution and collisions

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In the early solar system radiogenic heating by ^{26}Al and collisions are the two prominent ways expected to modify the internal composition of icy planetesimals, building blocks of comets, by removing highly volatile compounds like CO, CO_2 and NH_3. However, observations indicate that even large comets like Hale-Bopp (R ≈ 35 km) can be rich in these highly volatile compounds [1].
Here we constrain under which conditions icy planetesimals experiencing both internal heating and collisions can retain pristine interiors [2]. For this purpose, we employ both the state-of-the-art finite difference marker-in-cell code I2ELVIS [3] to model the thermal evolution in 2D infinite cylinder geometry and a 3D SPH code [4] to study the interior heating caused by collisions among icy planetesimals. For simplicity we assume circular porous icy planetesimals with a low density (≈ 470 kg/m^3) based on measurements for comet 67P/Churyumov-Gerasimenko [5].
For the parameter study of the thermal history we vary (i) icy planetesimal radii, (ii) formation time and the (iii) the silicate/ice ratio. For the latter we keep the mean density fixed and change the porosity of the icy planetesimal. For the impact models we use porous, low-strength objects and vary (i) target and (ii) projectile radii, (iii) impact velocity as well as (iv) impact angle. Potential losses of volatile compounds from their interiors are calculated based on their critical temperatures taken from literature [6]. Our combined results indicate that only small or late-formed icy planetesimals remain mostly pristine, while early formed objects can even reach temperatures high enough to melt the water ice.

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