Modelling the thermo-chemical evolution of small bodies: From dust to magma ocean

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The early Solar system produced a vast variety of objects with different sizes, compositions, structures, and locations. Among those, the small bodies (asteroids, comets, dwarf planets) are of particular interest due to their importance as building blocks of the planets and as parent bodies of the meteorites. The properties and structures of small planetary bodies are greatly diverse, as are the compositions of meteorites. Meteorites provide strong evidence that partial melting and differentiation were ubiquitous in the planetesimals of the early Solar System. With respect to the degree of differentiation, two classes can be defined: chondrites, that originate from primitive, undifferentiated parent bodies and achondrites (iron, stony, and stony-iron meteorites), originating from bodies apparently fractionated into (at least) a silicate mantle and a metallic core. A large variety in the degree of differentiation has been identified: metal separated partially or completely from silicates and silicates fractionated from each other, causing the composition of rock to deviate moderately to strongly from a primitive chondritic composition.

To understand planetary evolution, in particular planetary differentiation, it is essential to know, by which mechanism, how, and when this diversity emerged. Numerical modelling of the structure, composition, and thermal history of meteorite parent bodies provides an effective theoretical tool that allows putting the information recovered into a more general context. The insights gained from the models of specific asteroids and of planetesimals in general bring planetary science closer to the understanding of the early evolution of the Solar System as a whole and of the planets in particular.

Here, we present a review of our numerical investigations on the modelling of rocky planetesimals. We use a spherically symmetric model of a planetesimal consisting of iron and silicates, which considers accretion as radial growth. Our model includes compaction, melting (along with the associated changes of the material properties and the partitioning of ^{26}Al), latent heat, differentiation by porous flow, advective heat transport, and convection along with the associated effective cooling in a potential magma ocean. We present implications for planetesimals in general as well as for some prominent asteroids.