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Towards combined modeling of planetary accretion and differentiation

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Abstract

Results of current 1D models on planetesimal accretion yield an onion-like thermal structure with very high internal temperatures due to powerful short-lived radiogenic heating in the planetesimals. These lead to extensive silicate melting in the parent bodies. Yet, magma ocean and impact processes are not considered in these models and core formation is, if taken into account, assumed to be instantaneous with no feedback on the mantle evolution.

It was pointed out that impacts can not only deposit heat deep into the target body, which is later buried by ejecta of further impacts [1], but also that impacts expose in the crater region originally deep-seated layers, thus cooling the interior [2]. This combination of impact effects becomes even more important when we consider that planetesimals of all masses contribute to planetary accretion. This leads occasionally to collisions between bodies with large ratios between impactor and target mass.

Thus, all these processes can be expected to have a profound effect on the thermal evolution during the epoch of planetary accretion and may have implications for the onset of mantle convection and cannot be described properly in 1D geometry.

Here we present a new methodology, which can be used to simulate the internal evolution of a planetary body during accretion and differentiation: Using the N-body code PKDGRAV[3] we simulate the accretion of planetary embryos from an initial annulus of several thousand planetesimals. The growth history of the largest resulting planetary embryo is used as an input for the thermomechanical 2D code I2ELVIS [4]. The thermomechanical model takes recent parametrizations of impact processes like impact heating and crater excavation [5] into account. The model also includes both long- and short-lived radiogenic isotopes and a more realistic treatment of largely molten silicates [6].

Results show that late-formed planetesimals do not experience silicate melting and avoid thermal alteration, whereas in early-formed bodies accretion and iron core growth occur almost simultaneously and magma oceans develop in the interior of these bodies. These tend to form first close to the core-mantle boundary and migrate upwards with growing internal pressure.

References

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