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Towards combined modeling of planetary accretion and differentiation

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Results of current 1D models on planetesimal accretion yield an onion-like thermal structure with high internal temperatures due to powerful short-lived radiogenic heating in the planetesimals. These allow for silicate melting in the parent bodies [1] as suggested by meteorite samples. Yet, 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 [1]. Furthermore final radii of the modeled bodies are limited to a few hundred kilometers. This leaves the thermal evolution during the further growth from planetesimal to planetary mass uncertain. It was pointed out that impacts can not only deposit heat deep into the target body [2], which is later buried by ejecta of further impacts, but also that impacts expose in the crater region originally deep-seated layers, thus cooling the interior [3]. This combination of impact effects becomes even more important when we consider that planetesimals of all masses contribute to planetary accretion [4]. This leads occasionally to collisions between bodies with large ratios between impactor and target mass. Thus, impact processes can be expected to have a profound effect on the thermal evolution during the whole epoch of planetary accretion and may have implications for the onset of mantle convection. The described effects of an impact cannot be described properly in 1D geometry. Thus, to fill the gaps, we develop a combined numerical model, including both accretion and differentiation processes. Using the N-body code PKDGRAV we simulate the accretion of planetary embryos from an initial annulus of several thousand planetesimals. The accretion history of the largest resulting planetary embryo is used as an input for the thermomechanical 2D code I2ELVIS applying the so-called spherical-Cartesian geometry [5]. The thermomechanical model takes both short- and long-lived radiogenic heating and recent parametrizations of impact processes like impact heating [6] and impact excavation [7] into account. Results confirm that late-formed planetesimals do not experience silicate melting and avoid thermal alteration. However they also indicate that even for cool bodies a more complex thermal structure develops than the previously proposed onion-shell model. In early formed bodies accretion and iron core growth occur almost simultaneously and magma oceans develop in the interior of these bodies, which tend to form first close to the core-mantle boundary and migrate upwards with growing internal pressure.

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