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Modelling of Ceres: Predictions for Dawn

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Introduction: The asteroid Ceres is the largest body in the asteroid belt. It can be seen as one of the remaining examples of the intermediate stages of planetary accretion, which additionally is substantially different from most asteroids. Studies of such protoplanetary objects like Ceres and Vesta provide insight into the history of the formation of Earth and other rocky planets. One of Ceres' remarkable properties is the relatively low average bulk density of 2077±36 kg m^{-3} (see [1]). Assuming a nearly chondritic composition, this low value can be explained either by a relatively high average porosity[2], or by the presence of a low density phase[3,4]. Based on numerical modelling[3,4], it has been proposed that this low density phase, which may have been represented initially by water ice or by hydrated silicates, differentiated from the silicates forming an icy mantle overlying a rocky core. However, the shape and the moment of inertia of Ceres seem to be consistent with both a porous and a differentiated structure. In the first case Ceres would be just a large version of a common asteroid. In the second case, however, this body could exhibit properties characteristic for a planet rather than an asteroid: presence of a core, mantle and crust, as well as a liquid ocean in the past and maybe still a thin basal ocean today. This issue is still under debate, but will be resolved (at least partially), once Dawn orbits Ceres. We study the thermal evolution of a Ceres-like body via numerical modeling in order to draw conclusions about the thermal metamorphism of the interior and its present-day state. In particular, we investigate the evolution of the interior assuming an initially porous structure. We adopted the numerical code from [5], which computes the thermal and structural evolution of planetesimals, including compaction of the initially porous primordial material, which is modeled using a creep law. Our model is suited to prioritise between the two possible structures mentioned above and to constrain the present-day state of Ceres' interior. Different formation times of Ceres of up to 60 Ma relative to the CAIs have been considered. Thereby, even for a late-forming model with t_0 = 60 Ma, the final average porosity after compaction falls far below 10 %. Our results imply that even for a high initial porosity of 50 % and late formation times of up to 60 Ma after the CAIs, Ceres ultimately compacts due to hot pressing down to an average porosity of approximately 6 %. This argues against the suggestion that the low density of Ceres can be explained by a porous structure[2]. A preliminary study by [6] confirms this result. However, a more systematic study which would consider the variation of the bulk density within the error bar of ±36 kg and additionally continuous accretion is needed (similar to the one performed in [7]) to exclude this case completely. The final confirmation will probably be provided by Dawn.

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