Thermal Evolution of Earth's Core during Accretion: A Primordial Solid Inner Core

Jafar Arkani-Hamed

Department of Physics, University of Toronto, Toronto, Canada

The formation of solid inner core has conventionally been explained in terms of secular core cooling. Accordingly, a solid inner core is initiated as the Earth cools and the temperature at the center of the core reduces below the melting temperature. A solid inner core may also form if the pressure in the core of a growing proto-Earth exceeds a threshold value and the existing core temperature becomes lower than the pressure-dependent melting temperature of core. Assuming a Mars-type initial proto-Earth, the lithostatic pressure at the center increases from ~60 GPa to ~300 GPa during the accretion, implying a high probability of an inner core growth. The formation of an inner core during the accretion of Earth is investigated assuming that Earth is formed by accreting a total of 25 or 50 Moon to Mars size planetary embryos, creating self-gravitating and compressible Earth models. The impact of an embryo heats the proto-Earth's interior differentially, more directly blow the impact site than elsewhere. The rotating low-viscosity impact-heated core stably stratifies shortly after each impact, with a spherically symmetric and radially increasing temperature distribution. Merging of an embryo to an existing proto-Earth increases the lithostatic pressure, hence the pressure-dependent melting temperature of core, resulting in core solidification. A total of 13 thermal evolution models of the proto-Earth's core are calculated to investigate effects of major physical parameters, such as the total number of impacting embryos, the partition coefficient of gravitational energy released during the descent of an embryo's iron core in the interior of existing proto-Earth model, thermal conductivity of the core and overlying silicate mantle, effects of core impunity on the solidus and liquidus of the core. No solidification is taken into account in the first 9 models. At the end of accretion, temperatures in the upper ~1000 km of the core are significantly different among the models. However, temperatures in the deeper part of the core of the models are very similar and well below the melting temperature of the core, indicating a possible solid inner core during accretion. The core solidification is considered in the remaining 4 models, which drastically changes the temperature distribution in the deeper parts of the core. All of the latter models show a large solid inner core of ~1600 km radius by the end of accretion.