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Do Super-Earths Have Convective Cores?

M.W. Gold (1,2), J.J. Leitner (2), M.G. Firneis (1,2)

(1) Institute of Astronomy, University of Vienna, Vienna, Austria (manfred.gold@univie.ac.at), (2) Research Platform: ExoLife, University of Vienna, Vienna, Austria (manfred.gold@univie.ac.at)

The processes within the Earth responsible for the generation of the magnetic field are known fairly well by now and highly sophisticated 3D dynamo models are already capable of simulating magnetic field reversals (Glatzmaier and Roberts, 1995). But do the assumptions about the Earth's interior, like vigorous convection in the outer core, also hold for Super-Earths, terrestrial exoplanets more massive than the Earth? To shed light on this matter, as a first step an interior structure model (e.g., Wagner et al., 2011) has to be applied in order to determine density, pressure and temperature gradients of the planetary structure under consideration, in conjunction with an adequate equation of state that accounts for high-pressure conditions in the deeper regions of the planet. By coupling a structure model with a parameterized convection approach for the mantle (e.g., Nimmo et al., 2004), the heat flow across the core-mantle boundary can be determined. This heat flow is crucial in assessing the ability of the planet's core for vigorous convection, one prerequisite for dynamo action. If the heat flow is lower than the heat conducted down the adiabat, conduction will dominate, and thus convection will be restrained. By using the model curves calculated by Wagner et al. (2011), and employing the parameterized approach demonstrated by Nimmo et al. (2004), the CMB heat flow has been estimated for the case of 5 M_E and 10 M_E planets, assuming 205 ppm ^{40}K in the core . It turns out that the heat conducted down the adiabat Q_k exceeds the heat flow across the core-mantle boundary Q_C in both cases: Q_k=33.37 TW and 93.6 TW for 5 M_E and 10 M_E planets, respectively, using the results for the Keane-EOS from Wagner et al. (2011), while Q_C=5.61 TW and 12.13 TW, respectively.
The difficulties involved with the parameterized approach (Labrosse, 2003) and the poorly constrained values of core quantities, like the thermal expansivity, or thermal conductivity at the base of the mantle, can lead to substantial inaccuracies in the estimated heat flows, but it seems to be very likely that the qualitative trend is correct: the increasing dominance of conduction in planetary cores and mantles with increasing planetary mass. Although radiogenic heat has been included in the energy budget of the core in this preliminary model, its influence on viscosity hasn't been scrutinized so far. Moreover, the possibility of compositional convection at pressures prevalent in massive terrestrial exoplanets should be subject of further studies.

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