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Thermal evolution and lifetime of intrinsic magnetic fields of Super Earths in habitable zones

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(Submitted on 26 Oct 2010)

We have numerically studied the thermal evolution of various-mass terrestrial planets in habitable zones, focusing on duration of dynamo activity to generate their intrinsic magnetic fields, which may be one of key factors in habitability on the planets. In particular, we are concerned with super-Earths, observations of which are rapidly developing. We calculated evolution of temperature distributions in planetary interior, using Vinet equations of state, Arrhenius-type formula for mantle viscosity, and the astrophysical mixing length theory for convective heat transfer modified for mantle convection. After calibrating the model with terrestrial planets in the Solar system, we apply it for 0.1--$10M_{\oplus}$ rocky planets with surface temperature of $300~\mbox{K}$ (in habitable zones) and the Earth-like compositions. With the criterion for heat flux at the CMB (core-mantle boundary), the lifetime of the magnetic fields is evaluated from the calculated thermal evolution. We found that the lifetime slowly increases with the planetary mass (M_p) independent of initial temperature gap at the core-mantle boundary ($\Delta T_{\rm CMB}$) but beyond a critical value $M_{c,p}$ ($\sim O(1)M_{\oplus}$) it abruptly declines by the mantle viscosity enhancement due to the pressure effect. We derived $M_{c,p}$ as a function of $\Delta T_{\rm CMB}$ and a rheological parameter (activation volume, V^*). Thus, the magnetic field lifetime of super-Earths with $M_p > M_{p,c}$ sensitively depends on $\Delta T_{\rm CMB}$, which reflects planetary accretion, and V^*, which has uncertainty at very high pressure. More advanced high-pressure experiments and first-principle simulation as well as planetary accretion simulation are needed to discuss habitability of super-Earths.

Comments: 19pages, 15 figures, accepted for publication in ApJ
Subjects: **Earth and Planetary Astrophysics (astro-ph.EP)**
Cite as: **arXiv:1010.5317v1 [astro-ph.EP]**

Submission history

From: Chihiro Tachinami [view email]
[v1] Tue, 26 Oct 2010 05:40:26 GMT (385kb)