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Internal structure and thermal history of terrestrial planets

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In this decade, the condition for planets to occur and cultivate life, or habitability, has been discussed mainly from the aspect of the stability of liquid water. The planet should be some distance away from the central star not to let water vapor in the upper atmosphere be dissosiated and blown off by UV irradiation. At the same time, the planet should be close enough to the central star to achieve surface temperature higher than the freezing point of water.

In addition to them an existence of intrinsic magnetic field should be considered as one of the most important factor in determining whether the planet is habitable or not. The magnetic field would prevent the atmopshere from being blown off and also would protect the surface environment from the irradiation of the solar wind and galactic cosmic ray. There might be several ways to create magnetic field, but among them the dynamo action is the most plausible way to form and sustain global and stable magnetic field.

The dynamo action requires sufficiently vigorous convection within the core while the cooling rate of the core is limited by the heat trasnfer capability of the mantle. In other words, whether or not a planet could form intrinsic magnetic field depends on the thermal state, or thermal evolution, of the planet. Thus, in this study we construct a numerical model on the thermal evolution of various-sized terrestrial planets to clarify the condition for terrestiral planets to form magnetic field via dynamo action.

Internal structure of terrestrial planets (density and pressure distribution within upper mantle, lower mantle and core) are calculated from Birch-Murnaghan equation assuming hydrostatic equilibrium. By using resulting internal structures as initial condition, we simulate the thermal evolution of various-sized terrestrial planets. In this model we adopt mixing length theory to solve the thermal evolution of the mantle taking into account the temperature- and pressure-dependence of viscosity. Thermal evolution of the core is also considered. An inner core starts growing when the temperature of the central part of the core becomes lower than liquidus temperature of Fe-FeS alloy. The growth of inner core releases gravitational energy and latent heat that work as heat source within the core.

In this presentation we are going to present the resulting thermal evolution of various-sized terrestiral planets and discus the condition for terrestial planets to possess intrinsic magnetic field via dynamo action, or the condition to be habitable.