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Thermal Evolution of Early Solar System Planetesimals and the Possibility of Sustained Dynamos

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We present a study investigating the possibility of long-lived magnetic field dynamos in early solar system planetesimals. Earlier work [Weiss et al, 2008, 2009] has revealed strong magnetic field signatures in meteorites found on Earth. Their paleomagnetic analysis of the angrite class of meteorites revealed a recorded paleomagnetic field of at least 10 microTesla. It was suggested that these angrites came from a common angrite parent body which had a sufficiently strong and long-lived internal magnetic field yielding the aforementioned meteorite paleomagnetic signal. We investigate the possibility of dynamos and their duration through the use of a relatively straightforward thermal evolution model that is based on a parameterization of stagnant lid mantle convection. We also evaluate the possibility of surface recycling but are able to reasonably dismiss this.

Several reference scenarios are considered in which we investigate the sensitivity of parameters such as (reference) mantle viscosity, core radius, core density, melt constant and age of the planetesimal (i.e. the amount of radiogenic heating by short-lived nuclides) on the thermal evolution of the planetesimal. We also vary the planetesimal radius and, for different core radii, determine how long the dynamo in each thermal evolution is sustained based on positive core convective heat flux and exceedance of the critical magnetic Reynolds number of either 1,10 or 100.

A constraint is placed on the size of planetesimals that would have been able to support a sufficiently strong dynamo for any given length of time. We have also derived an approximate analytical solution that explicitly shows the dependence of dynamo life-time on certain parameters for scenarios whose thermal evolutions are dominated by secular cooling.