THERMAL EVOLUTION OF EARLY SOLAR SYSTEM PLANETESIMALS AND THE POSSIBILITY OF SUSTAINED DYNAMOS.

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We investigate the possibility of sustained dynamos in early solar system planetesimals. Paleomagnetic analyses of meteorites have revealed a record of past magnetic fields suggesting the presence of a stable, long lived, internally generated magnetic field at the time of their formation. Previous studies have suggested that early solar system planetesimals - meteorite parent bodies - are capable of supporting a magnetic field dynamo of sufficient strength and longevity over a very large range of planetesimal radii [1 - 3]. However, these studies allowed for conductive cooling only, across a `lid' with thickness held fixed throughout the thermal evolution.

We pursue the notion of a small-body dynamo powered by thermal convection and seek to determine which parameters are relevant for its occurrence and duration. A purely energetic argument provides a stringent envelope bounding planetesimal radii in order for a dynamo to meet paleomagnetic requirements. Figure 1 shows the change of temperature required to maintain a dynamo for 10 Myr with a magnetic field strength of 20 microTesla. We determine an upper bound of how much heat can be put into the core based on accretion age and using various scaling laws for core convective speeds and magnetic field strength we find lower bounds on how large the change of temperature in the core must be. This preliminary figure thus already illustrates the bounds within which any more advanced models must fall.

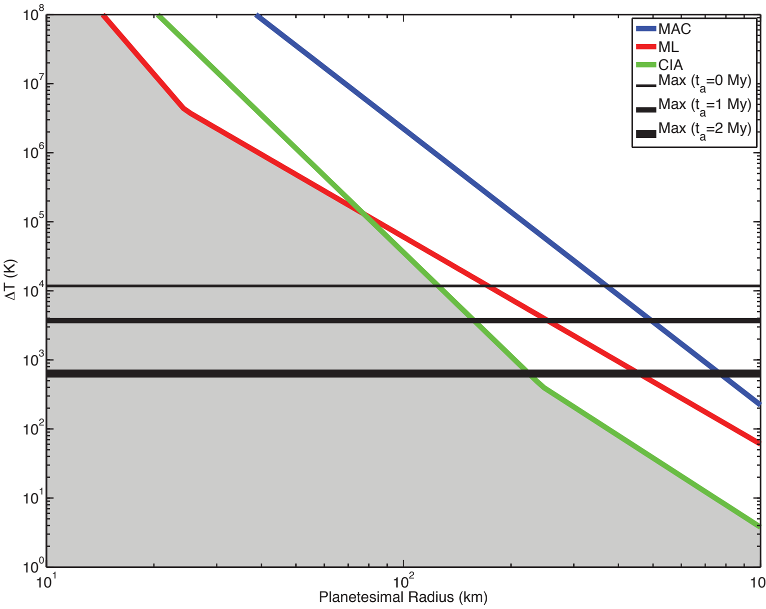

Figure 1: Colored lines - Minimum initial core temperature (above that of core melting temperature) required to maintain a dynamo for a duration of 10 Myr with a magnetic field strength of 20 microTesla using the MAC scaling (blue), the ML scaling (red), and the CIA scaling (green) for the core velocity and magnetic field strength. Black lines - maximum achievable core temperature assuming accretion age of 0 My (thin line), 1 My (medium line), and 2 My (thick line) after the formation of CIAs. Core radius is assumed to be 50% of planetesimal radius and the critical magnetic Reynolds number is 100. Grey area indicates that either a dynamo is not possible, or does not meet constraints.

To further refine this calculation we use a more sophisticated model for early planetesimal thermal evolutions in which the body begins cool, then warms due to radiogenic heating, and melts. Melting and thermal diffusion control the thickness of the lid during the initial phase of rapid heating. We incorporate continuous accretion, a low conductivity regolith surface layer, and boundary layer theory - assuming stagnant lid convection - to assess the body's thermal evolution. The evolution of planetesimal lid thickness is critical to this problem, where `lid' denotes the upper thermal boundary layer. The dynamical feedback between lid thickness, mantle temperature and viscosity determines the cooling rate of the body and the duration of any dynamo, if present. We derive an analytic solution which identifies the key parameters controlling this duration.

We place radius constraints on planetesimals with long-lived dynamos which, given a distribution of planetesimals, has implications for the prevalence of such bodies in the early solar system. The largest uncertainty involved is the choice of the critical magnetic Reynolds number and the scaling laws used for the core convective speed and magnetic field strength.

References: [1] Weiss B. P. et al. (2008) *Science, 322,* 713 – . [2] Weiss B. P. et al. (2010) *Space Science Rev., 152,* 341 - 390. [3] Elkins-Tanton L. T. et al. (2011) *EPSL, 305, 1 - 10.*