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The thermal evolution and dynamo generation of Mercury with an Fe-Si core

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The present day partially liquid (as opposed to fully solidified) Fe-rich core of Mercury is traditionally explained by assuming a substantial amount of S to be present in the core (e.g. Grott et al., 2011), because S lowers the core's melting temperature. However, this assumption has problematic implications: Mercury's large Fe-rich core and measured low FeO surface content are indicative of an oxygen poor bulk composition, which is consistent with the volatile-poor material that is expected to have condensed from the solar nebula close to the Sun. In contrast, S is a moderately volatile element. Combined with the high S content of Mercury's crust and (likely) mantle, as indicated by the measured high S/Si surface fraction, the resulting high planetary S abundance is difficult to reconcile with a volatile poor origin of the planet. Additionally, the observed low magnetic field strength is most easily explained if compositional buoyancy fluxes are absent [Manglik et al., 2010], yet such fluxes are produced upon solidifying a pure Fe inner core from Fe-S liquid.

Alternatively, both Mercury's high S/Si and Mg/Si surface ratios (Nittler et al., 2011) may indicate that a siderophile fractionation of Si and lithophile fractionation of S took place during Mercury's core-mantle differentiation. This fractionation behaviour of these elements is supported by metal/silicate partitioning experiments that have been performed at the low oxygen conditions inferred for Mercury [e.g. Chabot et al., 2014]. Mercury's bulk composition, in terms of S/Si and Fe/Si ratios, would also approach that of meteorites that are considered as potential building blocks of the planet if the core is Si-rich and S-poor.

Here we simulate the thermal evolution of Mercury with an Fe-Si core. Results show that an Fe-Si core can remain largely molten until present, without the need for S. An Fe-Si core also has interesting implications for Mercury's core-convection regime and magnetic field generation. The non-preferential Si fractionation between solid and liquid metal does not produce a compositional gradient, such that compositional buoyancy fluxes are negligible. Additionally, thermally driven core convection is more efficient as a result of a high latent heat release upon solidifying Si-rich metal. Implications of this scenario for Mercury's magnetic field strength and geometry need to be further examined.