Ph.D. Geophysics Public Lecture

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Thermal Energy Sources of the Magnetic Dynamos of Small Cold Terrestrial Planetary Bodies from Electrical Resistivity Measurements of Liquid Fe-S-Si Alloys at High Pressures

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Via ZOOM

Abstract

Formation of magnetic dynamos in terrestrial planets may be modeled from motion in the liquid outer core caused by convection, including thermal convection. To find thermal convective heat flux, adiabatic heat flux may be subtracted from total core-mantle boundary heat flux. Thermal conductivity can be determined from high-pressure thermal resistivity measurements of liquid iron alloyed with light elements. The cores of small terrestrial planetary bodies accreted at low temperatures are expected to contain high S (10-20 wt%). Previous research according to this methodology has focused on Fe, Fe-S, Fe-Si, and Fe-S-Si only where wt% S ≤ wt% Si. The measured thermal conductivity of liquid Fe-S-Si where wt% S ≥ wt% Si at high pressures is therefore needed for models of the energetics of the deep interiors of small terrestrial planetary bodies accreted at low temperatures.

With Fe-S-Si powder samples, a 1000 ton cubic press and 3000 ton multi-anvil press achieved static pressures 2-13 GPa. In each experiment, sample heating was performed into the liquid state. A thermocouple on each end of the sample measured temperature in situ. These thermocouples also functioned as electrodes, completing a circuit for measurement of voltage drop across the sample. Post-experimental analysis of a cross-section of each sample allowed for the calculation of resistivity and verification of composition and extent of melting using electron microprobe analysis. Thermal conductivity was calculated using the Wiedemann-Franz Law.

Resultant electrical resistivity values are 220-270 μΩ·cm for liquid Fe-8wt%S-4.5wt%Si at 2-5 GPa and 1700-1800 K and 350-500 μΩ·cm for liquid Fe-16wt%S-2wt%Si at 2-13 GPa and 1700-2000 K. These correspond to thermal conductivity values of 15-19 W/m/K and 8-12 W/m/K respectively. The core of Io is discussed in terms of a maximum core-mantle heat flow of 20-60 GW to match the observation of no magnetic dynamo. The early core of asteroid 4 Vesta with 16wt% S supports a longer duration relative to pure Fe. The core of exoplanet TRAPPIST-1h has an expected adiabatic core heat flux of 3.3-7 mW/m^2 and therefore likely sustains a magnetic dynamo with thermal convection as an energy source.

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