Thermal and magnetic evolution of exoplanetary cores

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Most of the planets located within our solar system display evidence of past and/or current magnetic activity, with the potential exception of Venus. Magnetic fields of rocky bodies are thought to be driven by thermo-chemical convection taking place in an electrically conducting fluid in their deep interior, such as the liquid outer core for Earth. The existence of a magnetic field during the history of a planet is therefore considered as a constraint for past or present internal dynamics, as well as a strong evidence for the existence of a liquid core at depth. In addition, magnetism is thought to play an important role for the development of habitable surface conditions and for the long-term stability of a planet, as it shields the upper atmosphere from mass loss induced by stellar winds and extreme space weather events. This, as well as the discovery of a large number of extrasolar bodies, motivates the search and study of magnetic fields beyond the solar system. Such a goal requires knowledge of the cores of bodies other than Earth, while current observations are limited to their radius and minimum mass.

Here, we investigate the evolution of planets having different masses and compositions, defined by their iron content and the mantle iron number. Starting out from the temperature profile right after the solidification of a global magma ocean, we determine the size and structure of the core, and model its subsequent thermal and magnetic evolution history. We calculate the buoyancy fluxes resulting from compositional and thermal convection, as well as the generated magnetic field strength and lifetime. While the planetary mass does not seem to be a determining factor, we find that iron-rich planets start out with inner cores that are substantially larger than iron-poor bodies, and can maintain an active magnetic field for longer. Depending on the initial amount of impurities in the core, the strength of the generated magnetic fields is similar or stronger than Earth’s, although they are still too weak to be observed by current instrumentation.

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