Dynamo theory: How small planets can have self-sustaining magnetic fields

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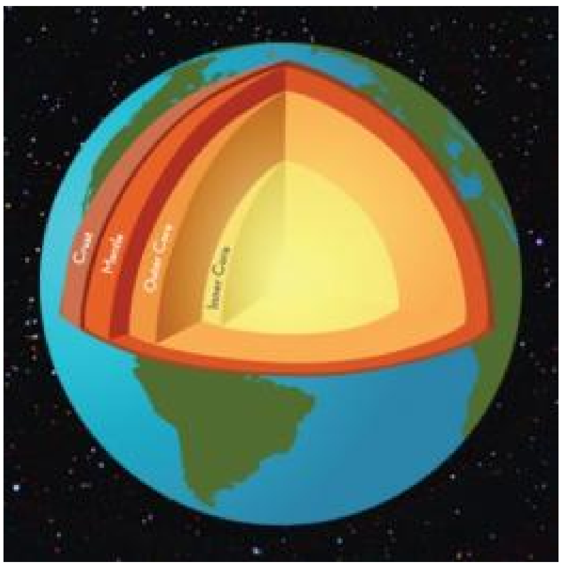

Earth’s magnetic field is generated from liquid iron located within the planet’s outer core that constantly moves as the planet cools. The outer core is located nearly 3,000 kilometers beneath Earth’s surface. Graphic: Christine Daniloff

The Earth's global magnetic field is generated in its metallic core, located nearly 3,000 kilometers beneath the planet’s surface. The field has existed on Earth for at least 3.5 billion years and offers clues about how other planets, stars and celestial bodies may have formed.

As scientists refine their understanding of how this field works in their ongoing probe of planetary history, one idea they use to explain this process is dynamo theory — the idea that a large dynamo, or magnetic field generator, exists within Earth's outer core, where liquid iron constantly moves as the planet cools. This continuous motion creates electric currents as electrons move through the liquid. Through this process, the energy of the moving fluid is converted into a magnetic field that can be sustained for billions of years.

Knowing that planetary bodies like Earth, the Moon, Mars, and even asteroids have, or once had, a magnetic field is crucial for understanding their history and internal structure. This is because the presence of a magnetic field inside a body reveals that it also likely formed a metallic core that generated that field, according to Benjamin Weiss, an associate professor in the Department of Earth, Atmospheric and Planetary Sciences. Such a field is one of the few ways to remotely sense a metallic core buried so deep beneath a body's surface.

If a fragment or rock from a planetary body is magnetized, this suggests that the body experienced large-scale melting in which heavier material sunk to the interior to form a metallic core and lighter material floated to the surface to create a rocky crust. This process gives a planet its history. "Otherwise, it would be a pile of space dust," Weiss said.

Determining whether a planet generated a magnetic field in the past is not only important for inferring the presence of a core, but also may be important for learning about the origin of the planetary body and even the history of climate change for that body.

For example, although Mars does not have a magnetic field generated by a core dynamo today, Weiss and his colleagues have identified magnetization in Martian rocks, which indicates that Mars did have a strong global field billions of years ago. It appears that the disappearance of this early dynamo roughly coincided with the loss of Mars' early thick atmosphere and the transition from an early warm, wet climate to the planet's current cold and inhospitable conditions.

But scientists' understanding of dynamo theory has been complicated by recent discoveries of magnetized rocks from the moon and ancient meteorites, as well as an active dynamo field on Mercury — places that were thought to have perhaps cooled too quickly or be too small to generate a self-sustaining magnetic field. It had been thought that smaller bodies couldn't have dynamos because they cool more rapidly and are therefore more likely to have metallic cores that do not stay in liquid form for very long.

In 2008, an MIT-led group that included Weiss discovered magnetic traces within chunks from small, rocky objects called planetesimals that are believed to have slammed together to form the rocky planets 4.5 billion years ago. Planetesimals had previously been thought to be too small to have formed core dynamos. According to Weiss, the finding suggests that sustaining a magnetic field like the one on Earth might not require a large, cooling core that constantly moves liquid and creates currents, but could also be somehow generated by the cores of smaller bodies like planetesimals — some of which are only 160 kilometers wide.

Scientists will soon have a chance to explore the relationship between a body's size and its ability to have a dynamo thanks to NASA's Dawn spacecraft, which was launched in September 2007 to study Ceres and Vesta, the two largest asteroids in the asteroid belt located between Mars and Jupiter. Dawn is slated to go in orbit around Vesta in 2011, and one of the main goals of the mission is to test whether Vesta, which has a mean diameter of 530 kilometers, has a core. A group of magnetized meteorites known as the HED meteorites are thought to be from Vesta and could be evidence of an early core dynamo on the asteroid.

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