OCTOBER 2021

SCIENTIFICAMERICAN.COM

SCIENTIFIC AMERICAN

Unprecedented Arctic Wildfires

Competitive Birding

A Map of All Mathematics

A NEW FORCE OF NATURE?

An intriguing experiment may reveal a hidden world of physics

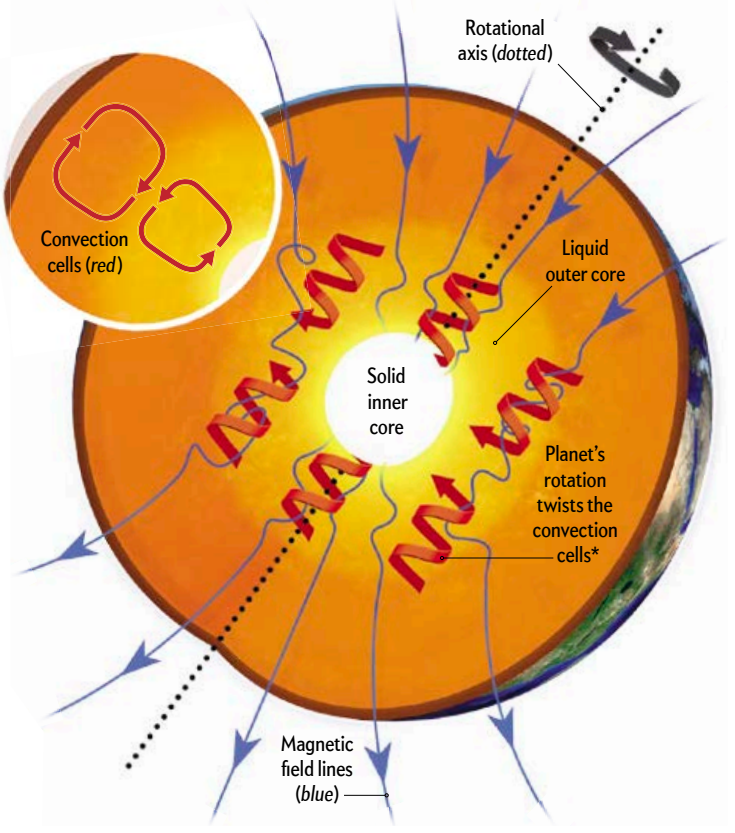
Text by Clara Moskowitz | Graphic by Mark Belan

Seeking Dynamos

Most of our neighboring planets have magnetic fields, but scientists do not fully understand how they arise

The magnetic fields in our solar system are surprisingly diverse—Jupiter's and Saturn's are extremely strong, but Mercury's is puny. Uranus's and Neptune's are out of whack with the direction of their rotation, although others are closely aligned. And each has a unique set of conditions that gives rise to a dynamo—the engine thought to activate a magnetic field.

Several upcoming space missions seek to study planetary magnetic fields, which offer a window into planets' internal makeup as well as their history and formation. NASA's Juno mission, for instance, is orbiting Jupiter with two sensor experiments to make the first global map of its magnetic field, the strongest in the solar system. And the European Space Agency has a mission in orbit now called Swarm, focused on monitoring how Earth's magnetic field changes over time.



Dynamo Basics

Dynamos form inside planets when moving electric charges give rise to magnetic fields. Earth's magnetic field, for instance, originates in its outer core, which is mostly made of molten iron. This iron, a metal, is essentially a river of electrically charged particles. These particles churn and flow because of convection—the tendency of denser material to sink and hotter, less dense stuff to rise—as well as our planet's rotation. The result is a constantly moving electric current, which produces a continuous magnetic field.

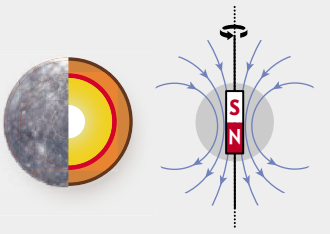
**Helices are likely smaller and more turbulent than shown here.*

Planets with Magnetic Fields

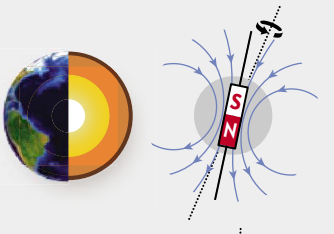
Each planet's magnetic field arises from its own unique composition and rotational properties. Venus and Mars seem to lack enough convection in their interiors to produce fields.

Solid iron | Liquid iron | Iron sulfide
Silicate mantle | Silicate crust | Liquid metallic hydrogen and helium
Liquid hydrogen | Water, methane, and ammonia | Hydrogen and helium

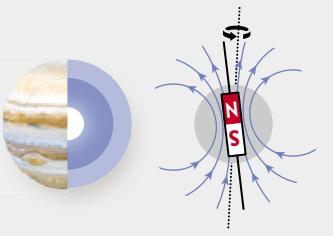
Mercury
The smallest of the planets also has the weakest magnetic field. Its internal dynamo is counteracted by the solar wind of particles streaming off the sun.



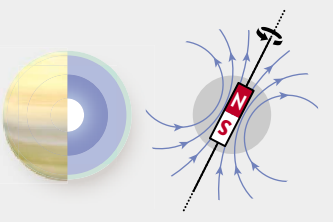
Earth
Our planet's magnetic north pole happens to point toward its geographic south pole, as do Mercury's and Uranus's.



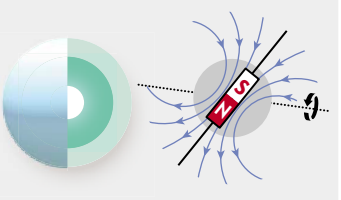
Jupiter
The solar system's strongest magnetic field is much more intense and complex than Earth's because of the gas giant's rapid rotation and larger metallic interior.



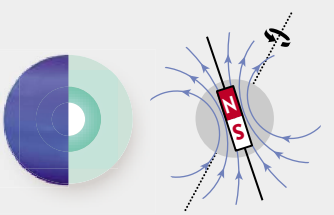
Saturn
Saturn's magnetic field is weaker than Jupiter's and symmetric around its axis of rotation, possibly because of helium rain that dampens convection in the atmosphere.



Uranus
The magnetic field here is tilted 60 degrees from the planet's rotational axis, causing the field's strength and orientation to fluctuate as Uranus spins.



Neptune
The farthest planet's magnetic axis is also misaligned from its rotational axis, giving it a lopsided shape that interacts with the solar wind in unbalanced ways.



Sources: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington (*Mercury's surface*); Reto Stöckli, NASA Earth Observatory (*Earth's surface*); NASA/JPL/Space Science Institute (*Jupiter's surface*)