What other planets can teach us about Earth

March 5 2020, by Josie Garthwaite

A composite image shows Earth from the vantage point of a spacecraft in orbit around our planet's moon in October 2015. Credit: NASA/Goddard/Arizona State University

Sometimes, you need to leave home to understand it. For Stanford planetary geologist Mathieu Lapôtre, "home" encompasses the entire Earth.

"We don't only look at other planets to know what's out there. It's also a way for us to learn things about the planet that's under our own feet," said Lapôtre, an assistant professor of geological sciences in the School of Earth, Energy, & Environmental Sciences (Stanford Earth).

Scientists since Galileo have sought to understand other planetary bodies through an earthly lens. More recently, researchers have recognized planetary exploration as a two-way street. Studies of space have helped to explain aspects of climate and the physics of nuclear winter, for example. Yet revelations have not permeated all geoscience fields equally. Efforts to explain processes closer to the ground—at Earth's surface and deep in its belly—are only beginning to benefit from knowledge gathered in space.

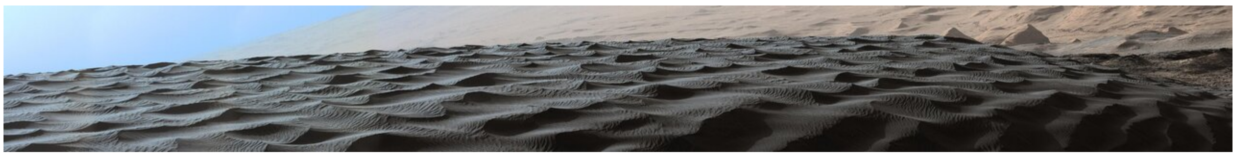
Now, as telescopes acquire more power, exoplanet studies grow more sophisticated and planetary missions produce new data, there's potential for much broader impacts across Earth sciences, as Lapôtre and co-authors from Arizona State University, Harvard University, Rice University, Stanford and Yale University argue in the journal *Nature Reviews Earth & Environment*.

"The multitude and variety of planetary bodies within and beyond our solar system," they write in a paper published March 2, "might be key to resolving fundamental mysteries about the Earth."

In the coming years, studies of these bodies may well alter the way we think about our place in the universe.

Alien forms

Observations from Mars have already changed the way scientists think about the physics of sedimentary processes on Earth. One example got underway when NASA's Curiosity Rover crossed a dune field on the red planet in 2015.



Ripples formed by wind atop a sand dune in Gale Crater on Mars offer an analog for understanding the conditions that created ancient ripples and dunes on Earth. Credit: NASA/JPL-Caltech/MSSS

"We saw that there were big sand dunes and small, decimeter-scale ripples like the ones we see on Earth," said Lapôtre, who worked on the mission as a Ph.D. student at Caltech in Pasadena, Calif. "But there was also a third type of bedform, or ripple, that does not exist on Earth. We couldn't explain how or why this shape existed on Mars."

The strange patterns prompted scientists to revise their models and invent new ones, which ultimately led to the discovery of a relationship between the size of a ripple and the density of the water or other fluid that created it. "Using these models developed for the environment of Mars, we can now look at an old rock on Earth, measure ripples in it and then draw conclusions about how cold or salty the water was at the time the rock formed," Lapôtre said, "because both temperature and salt affect fluid density."

This approach is applicable across the geosciences. "Sometimes when exploring another planet, you make an observation that challenges your understanding of geological processes, and that leads you to revise your models," Lapôtre explained.

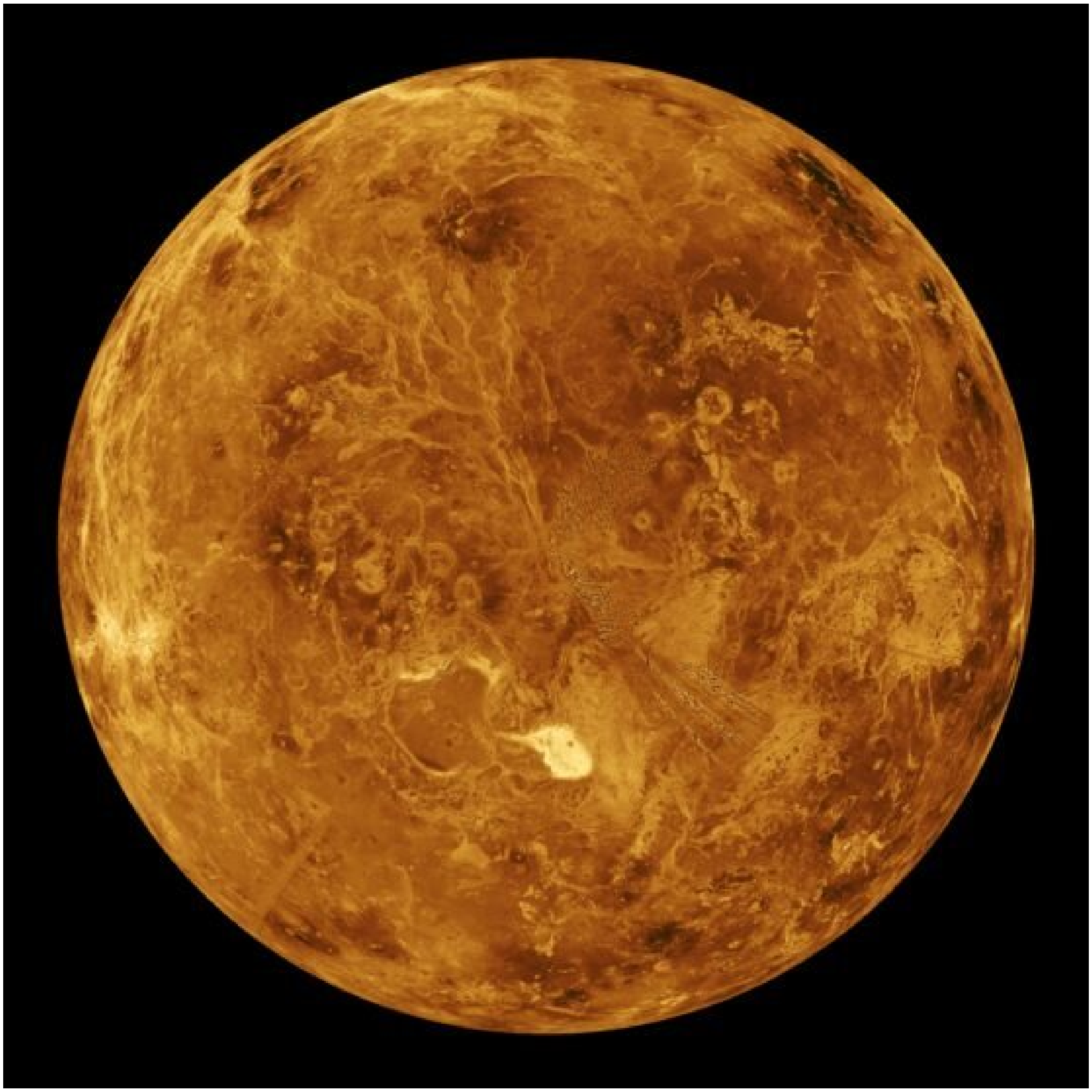
Planets as experiments

Other planetary bodies can also help to show how frequent Earth-like bodies are in the universe and what, exactly, makes Earth so different from the average planet.

"By studying the variety of outcomes that we see on other planetary bodies and understanding the variables that shape each planet, we can learn more about how things might have happened on Earth in the past," explained co-author Sonia Tikoo-Schantz, a geophysics professor at Stanford Earth whose research centers on paleomagnetism.

Consider, she suggested, how studies of Venus and Earth have helped scientists better understand plate tectonics. "Venus and Earth are about the same size, and they probably formed under fairly similar conditions," Tikoo-Schantz said. But while Earth has tectonic plates moving around and abundant water, Venus has a mostly solid lid, no water on its surface and a very dry atmosphere.

"From time to time, Venus has some kind of catastrophic disruption and a resurfacing of much of the world," Tikoo-Schantz said, "but we don't see this continuous steady state tectonic environment that we have on Earth."



Unlike Earth, Venus has a mostly solid lid, no water on its surface and a very dry atmosphere. Credit: NASA/JPL

Scientists are increasingly convinced that water may explain much of the difference. "We know that subduction of tectonic plates brings water down into the Earth," Tikoo-Schantz said. "That water helps lubricate the upper mantle, and helps convection happen, which helps drive plate tectonics."

This approach—using planetary bodies as grand experiments—can be applied to answer more questions about how Earth works. "Imagine you want to see how gravity might affect certain processes," Lapôtre said. "Going to other planets can let you run an experiment where you can observe what happens with a lower or higher gravity—something that's impossible to do on Earth."

Core paradox

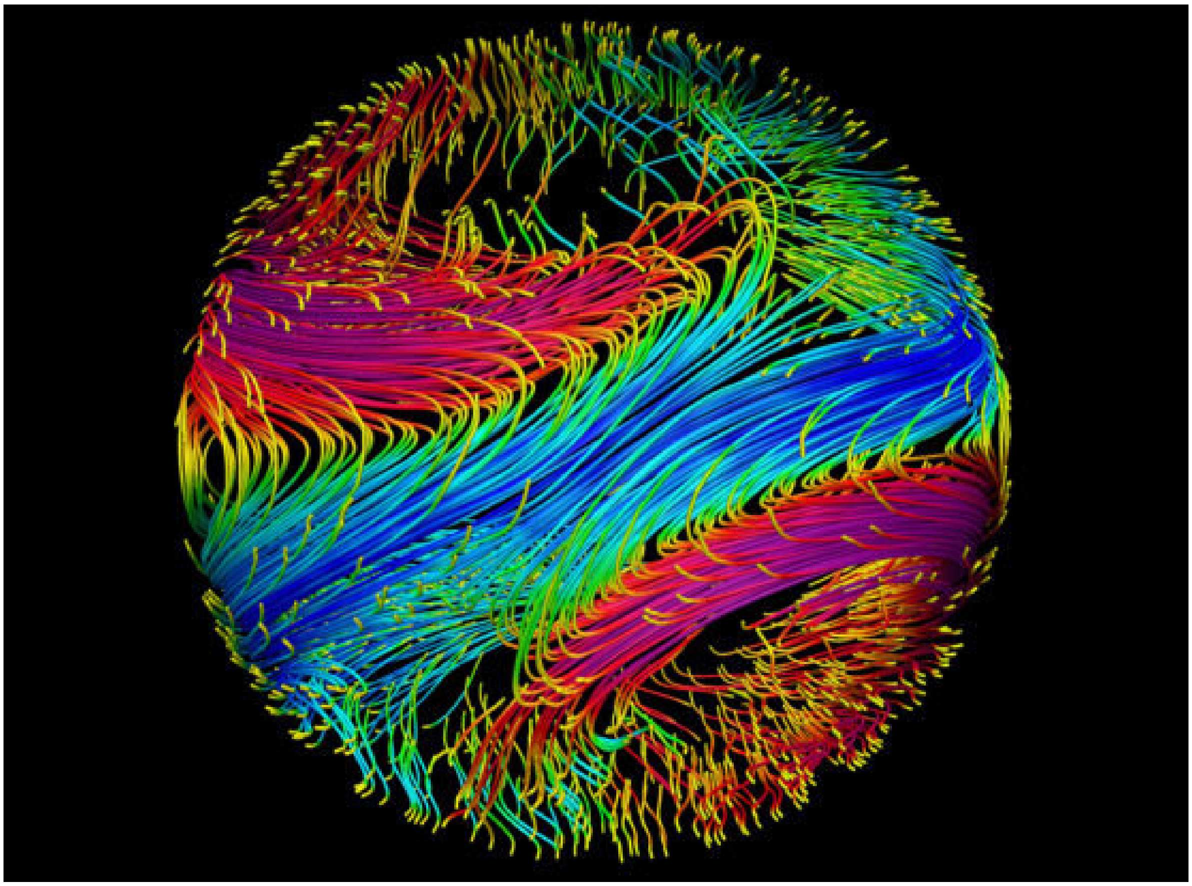
Studies measuring magnetism in ancient rocks suggest that Earth's magnetic field has been active for at least 3.5 billion years. But the cooling and crystallization of the inner core that scientists believe sustains Earth's magnetic field today started less than 1.5 billion years ago. This 2-billion-year gap, known as the new core paradox, has left researchers puzzling over how Earth's dynamo could have started so early, and persisted for so long.

Answers may lie in other worlds.

"In our circle of close neighbors—the Moon, Mars, Venus—we're the only planet with a magnetic field that's been going strong since the beginning and remains active today," Lapôtre said. But Jupiter-sized exoplanets orbiting close to their star have been identified with magnetic fields, and it may soon be technically feasible to detect similar fields on smaller, rocky, Earth-like worlds. Such discoveries would help clarify whether Earth's long-lived dynamo is a statistical anomaly in the universe whose startup required some special circumstance.

Ultimately, the mystery around the origin and engine behind Earth's dynamo is a mystery about what creates and sustains the conditions for life. Earth's magnetic field is essential to its habitability, protecting it against dangerous solar winds that can strip a planet of water and atmosphere. "That's part of why Mars is such a dry desert compared to

Earth," Tikoo-Schantz said. "Mars started to dehydrate when its magnetic field died."



Night-side view of magnetic field lines in a simulation of a “hot Jupiter” exoplanet. Simulations like these help researchers better understand the interior dynamics of these planets and learn more about how they may have formed. Magenta indicates magnetic fields with positive polarity, and blue indicates fields with negative polarity. Credit: Tamara Rogers, Jess Vriesema, University of Arizona

Earth everchanging

Much of the impetus to look far beyond Earth when trying to decode its inner workings has to do with our planet's restless nature. At many points in its 4.5 billion-year existence, Earth looked nothing like the blue-green marble it is today.

"We're trying to get to the point where we can characterize planets that are like the Earth, and hopefully, someday find life on one of them," said co-author Laura Schaefer, a planetary scientist at Stanford Earth who studies exoplanets. Chances are it will be something more like bacteria than E.T., she said.

"Just having another example of life anywhere would be amazing," Schaefer said. It would also help to illuminate what happened on Earth during the billions of years before oxygen became abundant and, through processes and feedback loops that remain opaque, complex life burst forth.

"We're missing information from different environments that existed on the surface of the Earth during that time period," Schaefer explained. Plate tectonics constantly recycles rocks from the surface, plunging them into the planet's fiery innards, while water sloshing around oceans, pelting down from rainclouds, hanging in the air, and slipping in rivers and streams tends to alter the geochemistry of rocks and minerals that remain near the surface.

Earth's very liveliness makes it a poor archive for evidence of life and its impacts. Other planetary bodies—some of them dead still and bone dry, others somehow akin to the ancient Earth—may prove better suited to the task.

That's part of why scientists were so excited to find, in 2019, that a rock sample collected by the Apollo 14 astronauts in 1971 may in fact hold minerals that rocketed off of Earth as a meteorite billions of years ago. "On the Moon, there is no plate tectonics or aqueous weathering," Lapôtre said. "So this piece of rock has been sitting there intact for the last few billion years just waiting for us to find it."

To be sure, planetary scientists do not expect to find many ancient Earth time capsules preserved in space. But continued exploration of other worlds in our solar system and beyond could eventually yield a small statistical sample of planets with life on them—not carbon copies of Earth's systems, but systems nonetheless where interactions between life and atmosphere can come into sharper focus.

"They're not going to be at the same stage of life as we have today on Earth, and so we'll be able to learn about how planets and life evolve together," Schaefer said. "That would be pretty revolutionary."

More information: Mathieu G. A. Lapôtre et al. Probing space to understand Earth, *Nature Reviews Earth & Environment* (2020). DOI: 10.1038/s43017-020-0029-y

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