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A Step Closer to Solving the Fermi Paradox

"Don't you ever wonder where everybody is?" That question, famously posed in the mid-20th century by physicist Enrico Fermi, spotlights that precisely zero extraterrestrial civilizations have been found in the Milky Way, although by some calculations, our galaxy ought to be teeming with communicative life.

Researchers have now suggested that the lack of evidence of complex extraterrestrial life—the so-called Fermi paradox—is due to the scarcity of planets hosting long-lived plate tectonics and an amalgam of watery and dry environments. These results were published in *Scientific Reports* (bit.ly/finding-ET-factors).

Intelligent life elsewhere in the Milky Way might require plate tectonics, oceans, and landmasses. Credit: iStock.com/Darryl Fonseka

A Framework for Intelligent Life

In 1961, Frank Drake, an American astronomer then at the National Radio Astronomy Observatory in Green Bank, W.Va., proposed an equation to estimate the number of extraterrestrial civilizations in the Milky Way capable of transmitting electromagnetic signals such as radio waves. That equation consisted of seven terms, including the fraction of stars with planetary systems and the average length of time that a civilization broadcasts its presence out into space. This expression, which is still in use today, has come to be known as the Drake equation. (Drake died in 2022.)

"It gives us a framework for understanding all the planetary and astrophysical processes that might lead to a civilization," said Michael Wong, a planetary scientist at the Carnegie Institution for Science in Washington, D.C., who was not involved in the research.

Drake himself estimated that perhaps 10,000 communicative extraterrestrial civilizations might exist in the Milky Way. But other people's estimates using the same equation have been wildly different. Some scientists have proposed that there's just one communicative civilization in the Milky Way: ours. But others have postulated that millions might be out there.

Those discrepancies are expected, Wong said, because scientists haven't pinned down the values of all of the terms that go into the Drake equation. "Some of the terms we know, thanks to advances in astronomy and astrophysics. Some of the terms, we have literally no idea what their numerical value should be," he said.

Bring in the Earth Science

A pair of researchers has now suggested replacing one of the terms of the Drake equation with two Earth science–related terms. Plate tectonics and the presence of both oceans and continents are critical to the development of complex life, the team argued, and the likelihood of a planet having those attributes should be incorporated into the Drake equation. Doing so reduces the number of predicted communicative life-forms in the Milky Way by several orders of magnitude, the team showed, which is a step toward reconciling the Fermi paradox.

> **"Some of the terms, we have literally no idea what their numerical value should be."**

In its original incarnation, the Drake equation included a term known as f_i, which pertains to the fraction of life-bearing planets on which intelligent life emerges. Drake originally assumed that f_i was 1—that is, 100% of planets that developed life also went on to host intelligent life.

But that's likely a gross overestimate, new work suggests. Robert Stern, an Earth scientist at the University of Texas at Dallas, and Taras Gerya, a geoscientist at ETH Zürich in Switzerland, have proposed that f_i is at least 500 times smaller. To arrive at that estimate, they assumed that intelligent life will develop only on planets that have long-lived plate tectonics and both continents and oceans.

Plate tectonics is critical for several reasons, according to the researchers. For starters, the process makes tall mountains. Those peaks undergo erosion, which moves sediment around. "That contributes huge amounts of nutrients to the oceans and stimulates life," Stern said. Plate tectonics also regularly sculpts new terrain, essentially creating unique niches for life, he said. "That allows for multiple evolutionary pathways."

More primitive forms of tectonics, such as so-called single-lid tectonics, occurred on early Earth. But it wasn't until roughly 1 billion years ago that plate tectonics likely started in earnest. At the same time, the planet witnessed a rise in complex life.

Wet or Dry? Take Both

The presence of continents and oceans is also critical to the emergence of intelligent life, Stern and Gerya proposed. On Earth, the earliest life-forms developed in the ocean. Gerya explained that a watery environment literally bathes organisms in nutrients and provides structural support for life-forms that lack skeletons. "For early life, the ocean seems to be necessary," he said.

But complex life capable of communicating across interstellar space also needs dry land. That's because advanced technologies such as those that control fire or harness electricity are most easily achievable on land, Stern said. "Technological civilizations aren't possible purely in the ocean."

Stern and Gerya estimated that the fraction of planets with plate tectonics lasting for more than 500 million years multiplied by the fraction of planets with a mixture of watery and dry environments is no larger than 0.002. "That number is very hard to pin down," however, Stern said, because quite a few assumptions are folded into that calculation.

"Technological civilizations aren't possible purely in the ocean."

It makes sense to incorporate Earth science–related terms into the Drake equation, Wong said. "It seems like, at least for the evolution of life on Earth, it was crucial for there to be oceans and continents as well as plate tectonics." But the fractions of planets hosting long-lived plate tectonics, oceans, and continents that Stern and Gerya proposed are highly uncertain, he said. "I don't know how, honestly, to try even to get at these numbers."

That might change in the future, however, Wong said. Astronomers are exploring the concept of a space telescope devoted to finding and characterizing habitable planets beyond our solar system. Such a telescope, currently known as the Habitable Worlds Observatory, could potentially identify oceans and landmasses on extrasolar planets. That would be game-changing for the field of planetary science, he said. "We're in a data-starved field."

By **Katherine Kornei** (@KatherineKornei), Science Writer

Carbon Offset Programs May Underestimate Hurricanes

A forest like this one in Maine could lose some carbon storage capacity to a hurricane. Credit: Chris Turgeon, Unsplash

New England is one of the most heavily forested areas in America: Roughly 15 million metric tons of carbon are stored there every year. Many carbon offset programs reforest in the region.

However, a new study published in *Global Change Biology* suggests that carbon offset programs may underestimate the destructive power of hurricanes (bit.ly/hurricanes-carbon-stocks). A single hurricane in New England could release at least 121 million metric tons of carbon from downed trees, the study showed, the equivalent of the energy use of almost 16 million homes in 1 year.

"I wanted to use this case study of New England and its risk from hurricanes to outline the broader issue," said Shersingh Joseph Tumber-Dávila, a forest ecologist at Dart-