Our living planet shapes the search for life beyond Earth

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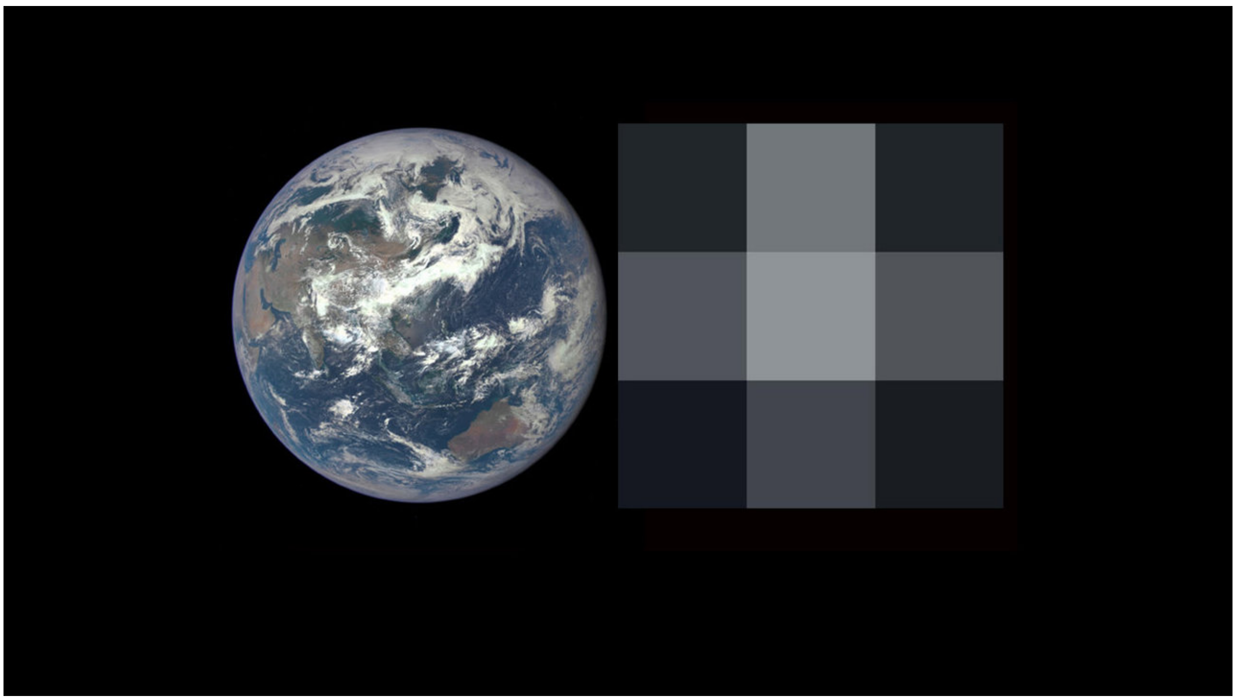

Left, an image of Earth from the DSCOVR-EPIC camera. Right, the same image degraded to a resolution of 3 x 3 pixels, similar to what researchers will see in future exoplanet observations. Credit: NOAA/NASA, Stephen Kane

As a young scientist, Tony del Genio of NASA's Goddard Institute for Space Studies in New York City met Clyde Tombaugh, the discoverer of Pluto.

"I thought, 'Wow, this is a one-time opportunity,'" del Genio said. "I'll never meet anyone else who found a planet."

That prediction was spectacularly wrong. In 1992, two scientists discovered the first planet around another star, or exoplanet, and since then more people have found planets than throughout all of Earth's preceding history. As of this month, scientists have confirmed more than 3,500 exoplanets in more than 2,700 star systems. Del Genio has met many of these new planet finders.

Del Genio is now co-lead of a NASA interdisciplinary initiative to search for life on other worlds. This new position as the lead of this project may seem odd to those who know him professionally. Why? He has dedicated decades to studying Earth, not searching for life elsewhere.

We know of only one living planet: our own. But we know it very well. As we move to the next stage in the search for alien life, the effort will require the expertise of planetary scientists, heliophysicists and astrophysicists. However, the knowledge and tools NASA has developed to study life on Earth will also be one of the greatest assets to the quest.

Habitable Worlds

There are two main questions in the search for life: With so many places to look, how can we focus in on the places most likely to harbor life? What are the unmistakable signs of life—even if it comes in a form we don't fully understand?

"Before we go looking for life, we're trying to figure out what kinds of planets could have a climate that's conducive to life," del Genio said. "We're using the same climate models that we use to project 21st century climate change on Earth to do simulations of specific exoplanets that have been discovered, and hypothetical ones."

Del Genio recognizes that life may well exist in forms and places so bizarre that it might be substantially different from Earth. But in this early phase of the search, "We have to go with the kind of life we know," he said.

Further, we should make sure we use the detailed knowledge of Earth. In particular, we should make sure of our discoveries on life in various environments on Earth, our knowledge of how our planet and its life have affected each other over Earth history, and our satellite observations of Earth's climate.

Above all else, that means liquid water. Every cell we know of—even bacteria around deep-sea vents that exist without sunlight—requires water.

Life in the Ocean

Research scientist Morgan Cable of NASA's Jet Propulsion Laboratory in Pasadena, California, is looking within the solar system for locations that have the potential to support liquid water. Some of the icy moons around Saturn and Jupiter have oceans below the ice crust. These oceans were formed by tidal heating, that is, warming of the ice caused by friction between the surface ice and the core as a result of the gravitational interaction between the planet and the moon.

"We thought Enceladus was just boring and cold until the Cassini mission discovered a liquid water subsurface ocean," said Cable. The water is spraying into space, and the Cassini mission found hints in the chemical composition of the spray that the ocean chemistry is affected by interactions between heated water and rocks at the seafloor. The Galileo and Voyager missions provided evidence that Europa also has a liquid water ocean under an icy crust. Observations revealed a jumbled terrain that could be the result of ice melting and reforming.

As missions to these moons are being developed, scientists are using Earth as a testbed. Just as prototypes for NASA's Mars rovers made their trial runs on Earth's deserts, researchers are testing both hypotheses and technology on our oceans and extreme environments.

Cable gave the example of satellite observations of Arctic and Antarctic ice fields, which are informing the planning for a Europa mission. The Earth observations help researchers find ways to date the origin of jumbled ice. "When we visit Europa, we want to go to very young places, where material from that ocean is being expressed on the surface," she said. "Anywhere like that, the chances of finding evidence of life goes up—if they're there."

Water in Space

For any star, it's possible to calculate the range of distances where orbiting planets could have liquid water on the surface. This is called the star's habitable zone.

Astronomers have already located some habitable-zone planets, and research scientist Andrew Rushby, of NASA Ames Research Center, in Moffett Field, California, is studying ways to refine the search. Location alone isn't enough. "An alien would spot three planets in our solar system in the habitable zone [Earth, Mars and Venus]," Rushby said, "but we know that 67 percent of those planets are not very habitable." He recently developed a simplified model of Earth's carbon cycle and combined it with other tools to study which planets in the habitable zone would be the best targets to look at for life, considering probable tectonic activity and water cycles. He found that larger rocky planets are more likely than smaller ones to have surface temperatures where liquid water could exist, given the same amount of light from the star.

Renyu Hu, of JPL, refined the search for habitable planets in a different way, looking for the signature of a rocky planet. Basic physics tells us that smaller planets must be rocky and larger ones gaseous, but for planets ranging from Earth-sized to about twice that radius, astronomers can't tell a large rocky planet from a small gaseous planet. Hu pioneered a method to detect surface minerals on bare-rock exoplanets and defined the atmospheric chemical signature of volcanic activity, which wouldn't occur on a gas planet.

Vital Signs

When scientists are evaluating a possible habitable planet, "life has to be the hypothesis of last resort," Cable said. "You must eliminate all other explanations." Identifying possible false positives for the signal of life is an ongoing area of research in the exoplanet community. For example, the oxygen in Earth's atmosphere comes from living things, but oxygen can also be produced by inorganic chemical reactions.

Shawn Domagal-Goldman, of NASA's Goddard Space Flight Center in Greenbelt, Maryland, looks for unmistakable, chemical signs of life, or biosignatures. One biosignature may be finding two or more molecules in an atmosphere that shouldn't be there at the same time. He uses this analogy: If you walked into a college dorm room and found three students and a pizza, you could conclude that the pizza had recently arrived, because college students quickly consume pizza. Oxygen "consumes" methane by breaking it down in various chemical reactions. Without inputs of methane from life on Earth's surface, our atmosphere would become totally depleted of methane within a few decades.

Earth as Exoplanet

When humans start collecting direct images of exoplanets, even the closest one will appear as a handful of pixels in the detector - something like the famous "blue dot" image of Earth from Saturn. What can we learn about planetary life from a single dot?

Stephen Kane of the University of California, Riverside, has come up with a way to answer that question using NASA's Earth Polychromatic Imaging camera on the National Oceanic and Atmospheric Administration's Deep Space Climate Observatory (DSCOVR). These high-resolution images—2,000 x 2,000 pixels - document Earth's global weather patterns and other climate-related phenomena. "I'm taking these glorious pictures and collapsing them down to a single pixel or handful of pixels," Kane explained. He runs the light through a noise filter that attempts to simulate the interference expected from an exoplanet mission.

DSCOVR takes a picture every half hour, and it's been in orbit for two years. Its more than 30,000 images are by far the longest continuous record of Earth from space in existence. By observing how the brightness of Earth changes when mostly land is in view compared with mostly water, Kane has been able to reverse-engineer Earth's rotation rate—something that has yet to be measured directly for exoplanets.

When Will We Find Life?

Every scientist involved in the search for life is convinced it's out there. Their opinions differ on when we'll find it.

"I think that in 20 years we will have found one candidate that might be it," says del Genio. Considering his experience with Tombaugh, he added, "But my track record for predicting the future is not so good."

Rushby, on the other hand, says, "It's been 20 years away for the last 50 years. I do think it's on the scale of decades. If I were a betting man, which I'm not, I'd go for Europa or Enceladus."

How soon we find a living exoplanet really depends on whether there's one relatively nearby, with the right orbit and size, and with biosignatures that we are able to recognize, Hu said. In other words, "There's always a factor of luck."

Provided by Jet Propulsion Laboratory