News

What if we find nothing in our search for life beyond Earth?

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Illustration of a hypothetical planet covered in water. Credit: NASA/JPL-Caltech.

April 7, 2025, Mountain View, CA -- What if we spend decades building advanced telescopes to search for life on other planets and come up empty-handed? A recent study led by ETH Zurich researchers including corresponding author and SETI Institute affiliate, Dr. Daniel Angerhausen, tackled this question, exploring what we can learn about life in the universe—even if we don't detect signs of life or habitability. Using advanced statistical modeling, the research team sought to explore how many exoplanets scientists should observe and understand before declaring that life beyond Earth is either common or rare.

"Even a single positive detection would change everything—but until then, we need to make sure we're learning as much as possible from what we don't find," said Angerhausen.

The Challenge of Null Results

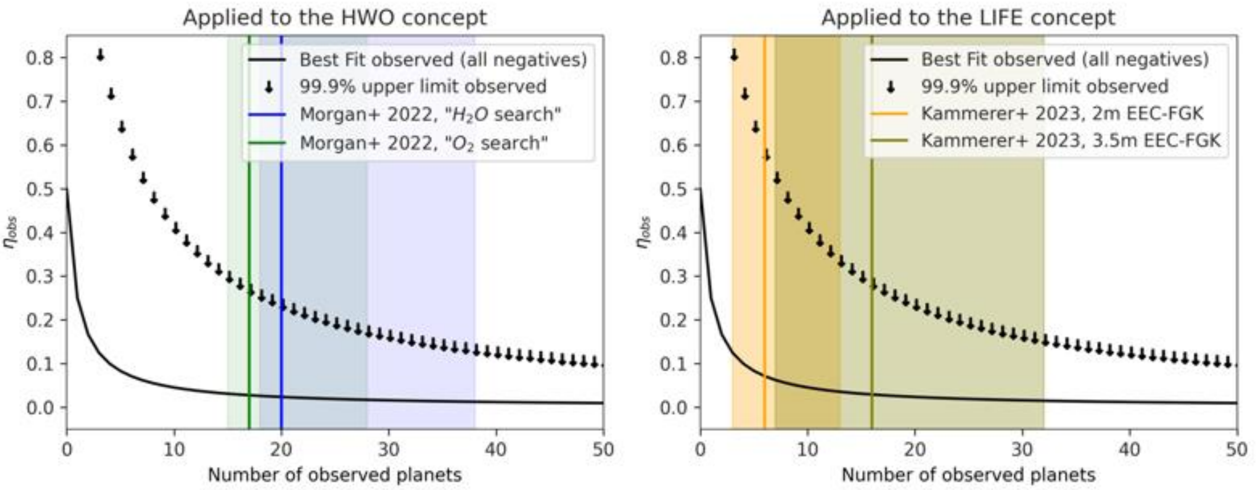
In science, sometimes, even not finding something can yield important insights. When scientists search for life on exoplanets, they often focus on specific features, such as signs of water or gases like oxygen and methane, that might indicate biological activity. But what happens if scientists don't find any of these features? Can we still learn something meaningful about how common life might be in the universe?

This study shows that if scientists examine 40–80 planets and find no signs of life, they can confidently conclude that fewer than 10–20% of similar planets harbor life. However, this depends heavily on how certain we are about each observation.

Such a finding would enable scientists to put a meaningful upper limit on the prevalence of life in the universe, which hasn't been possible to date. Further, if even only 10% of planets in the Milky Way alone have some form of life, that could still be 10 billion planets or more.
“This kind of result would be a turning point,” said lead author Angerhausen. “Even if we don’t find life, we’ll finally be able to quantify how rare - or common - planets with detectable biosignatures really might be.”

Implications for Future Missions

The findings have direct implications for upcoming missions like NASA’s Habitable Worlds Observatory (HWO) and the European-led Large Interferometer for Exoplanets (LIFE). These missions will study dozens of Earth-like planets by studying the planets’ atmospheres for signs of water, oxygen, and even more complex biosignatures. According to this study, the number of planets observed will be large enough to draw significant conclusions about the prevalence of habitability and life in our galactic neighborhood. However, the study also points out that even with advanced instruments, these surveys will need to carefully account for uncertainties and biases and derive frameworks to quantify them to ensure their results are statistically meaningful.



Comparison of the derived fraction of Earth-like planets with detectable biosignatures as a function of the number of observed planets for two mission concepts: the Habitable Worlds Observatory (HWO, left panel) and the Large Interferometer For Exoplanets (LIFE, right panel). The solid black curve indicates the best-fit observed fraction assuming all detections are negative, while the black arrows represent the 99.9% confidence/belief upper limit we would be able to derive. Vertical lines and shaded regions highlight predictions of the yields for these future concepts from recent studies: Morgan et al. 2022 for H2O and O2 searches with HWO (blue and green, left), and Kammerer et al. 2023 for LIFE biosignature searches (orange and yellow, right). If for example HWO cannot find water on any of 20 planets we could be 99.9% sure that the fraction of planets with water is less than 0.25, similarly if LIFE cannot detect life on any of the 18 planets in its average sample, we can be 99.9% sure that the fraction of planets with life is smaller than 0.3.

Accounting for Uncertainty

One key insight from the study is that uncertainties in individual observations—such as false negatives (when we miss a biosignature and mislabel it a dead planet)—can significantly affect the conclusions. For example, if there's a chance that a detection instrument might miss a biosignature, this uncertainty limits how much we can trust any conclusion based on null results. Similarly, if many planets in a survey turn out to be unsuitable for life but were mistakenly included, this skews the findings.

"It's not just about how many planets we observe—it's about how confident we can be in seeing or not seeing what we are searching for," said Angerhausen. "If we're not careful and are overconfident in our abilities to identify life, even a large survey could lead to misleading results."

Asking Better Questions

The study emphasizes that framing the right questions is crucial for meaningful results. Instead of broadly asking "How many planets have life?"—a question fraught with ambiguity—it might be better to ask more specific and measurable questions like "Which fraction of rocky planets in the conservative habitable zone show clear signs of water vapor, methane and oxygen?" This approach helps researchers design surveys that confidently detect or rule out specific features.

Why It Matters

Even if future surveys don't find evidence of extraterrestrial life, they will still provide valuable insights into how rare or common habitable conditions are in the universe. By carefully considering uncertainties and asking precise questions, scientists can turn null results into powerful tools for understanding our place in the cosmos.

This work serves as a reminder that science isn't just about finding answers—it's also about asking the right questions and embracing uncertainty as part of the journey.

"What if We Find Nothing? Bayesian Analysis of the Statistical Information of Null Results in Future Exoplanet Habitability and Biosignature Surveys " by Angerhausen et al is published in *The Astronomical Journal*: DOI: 10.3847/1538-3881/adb96d

Please click here for the ETH Zurich press release: https://www.phys.ethz.ch/news-and-events/d-phys-news/2025/04/in-the-search-for-life-on-exoplanets-finding-nothing-is-something-too.html

About the SETI Institute

Founded in 1984, the SETI Institute is a non-profit, multi-disciplinary research and education organization whose mission is to lead humanity's quest to understand the origins and prevalence of life and intelligence in the universe and share that knowledge with the world. Our research encompasses the physical and biological sciences and leverages data analytics, machine learning, and advanced signal detection technologies. The SETI Institute is a distinguished research partner for industry, academia, and government agencies, including NASA and the National Science Foundation.

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About ETH Zurich (the Swiss Federal Institute of Technology in Zurich, Switzerland)

Freedom, responsibility, and entrepreneurial spirit: ETH Zurich stands on a bedrock of true Swiss values. This university for science and technology dates back to the year 1855, when the founders of modern-day Switzerland created it as a center of innovation and knowledge. Consistently ranked as the top-ranked university in continental Europe, ETH Zurich currently ranks 7th in the world. *

Members of the Exoplanets and Habitability Group at ETH Zurich participate in several Swiss and international collaborations focused on large observational surveys, building new instrumentation, and interdisciplinary research projects and discussions surrounding particle physics and astrophysics.

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