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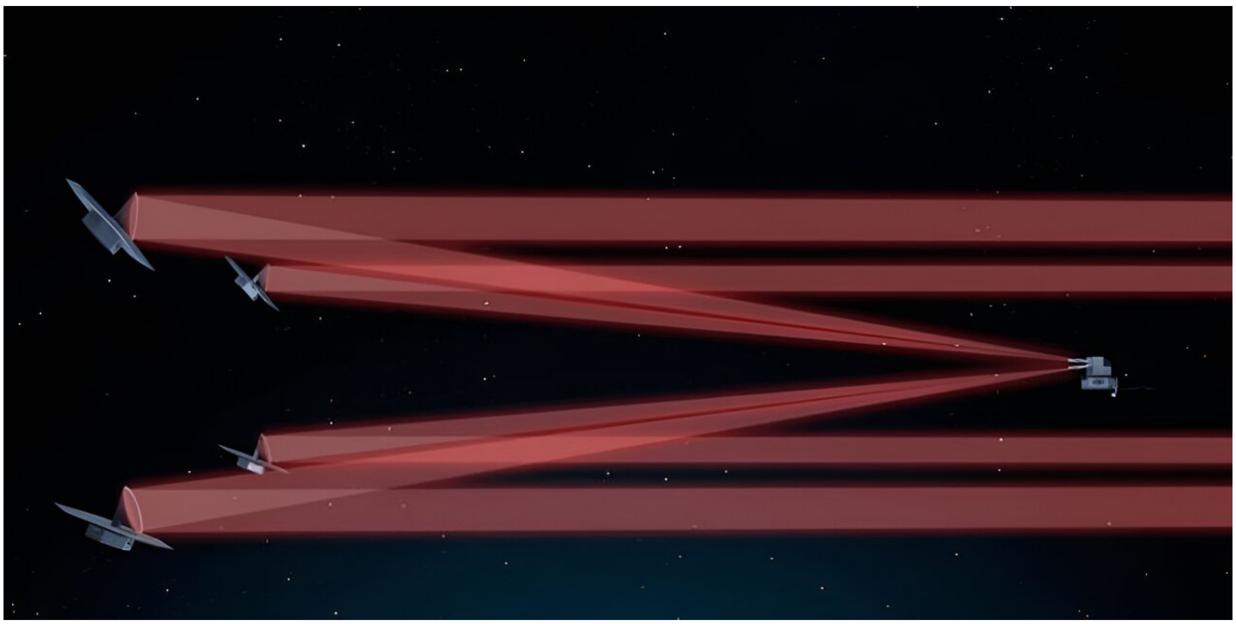
The LIFE telescope passed its first test, detecting biosignatures on Earth

March 12 2024, by Evan Gough



LIFE will have five separate space telescopes that fly in formation and work together to detect biosignatures in exoplanet atmospheres. Credit: LIFE, ETH Zurich

We know that there are thousands of exoplanets out there, with many millions more waiting to be discovered. But the vast majority of exoplanets are simply uninhabitable. For the few that may be habitable, we can only determine if they are by examining their atmospheres. LIFE, the Large Interferometer for Exoplanets, can help.

The search for biosignatures on potentially habitable exoplanets is heating up. The JWST has successfully gathered some atmospheric spectra from exoplanet atmospheres, but it has a lot of other jobs to do and observing time is in high demand. A planned space telescope named LIFE is dedicated to finding exoplanet biosignatures, and recently, researchers gave it a test: can it detect Earth's biosignatures?

As an interferometer, LIFE is made up of five separate telescopes that will work in unison to expand the telescope's working size. LIFE is being developed by ETH Zurich (Federal Institute of Technology Zurich) in Switzerland. LIFE will observe in mid-infrared, where the spectral lines from the important bioindicative chemicals ozone, methane, and nitrous oxide can be found.

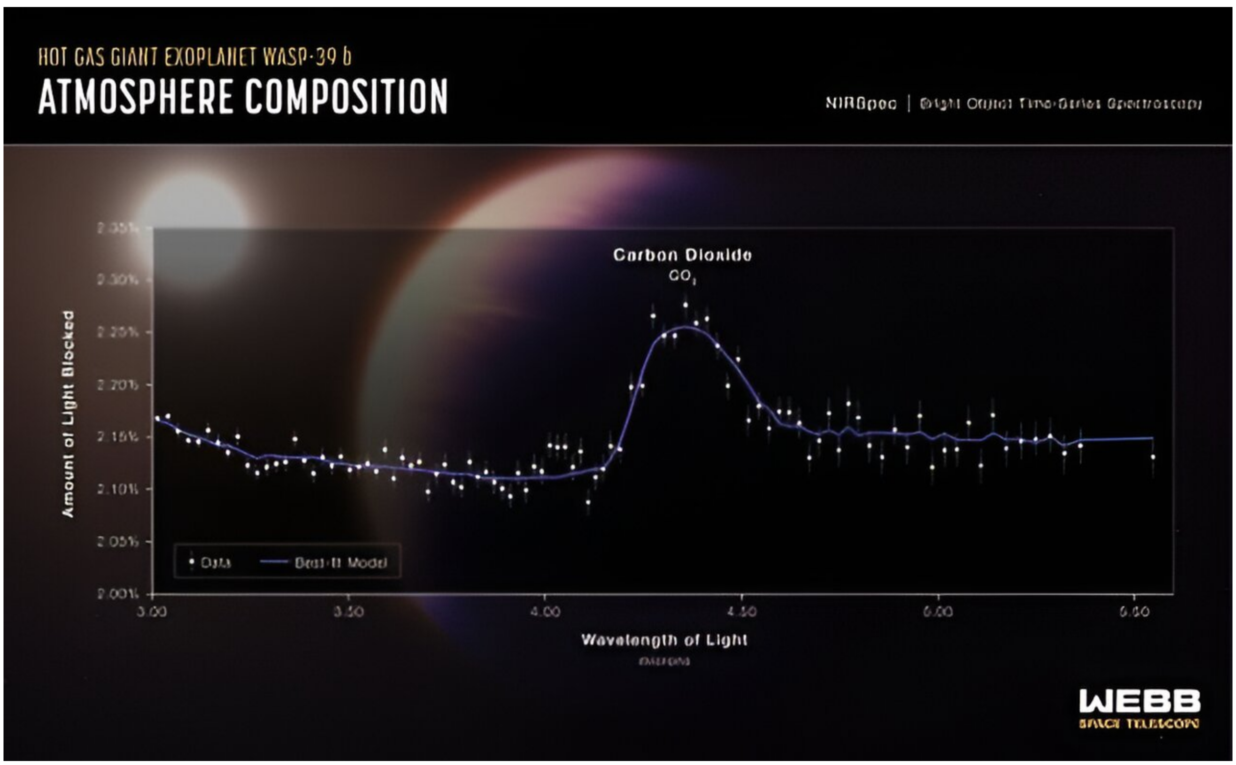
LIFE will be located at Lagrange Point 2, about 1.5 million km (1 million miles) away, where the JWST is also located. From that location, it'll observe a list of exoplanet targets in hopes of finding biosignatures. "Our goal is to detect chemical compounds in the light spectrum that hint at life on the exoplanets," explained Sascha Quanz, Professor for Exoplanets and Habitability at ETH Zurich, who is leading the LIFE initiative.

LIFE is still only a concept, and researchers wanted to test its performance. Since it hasn't been built yet, a team of researchers used Earth's atmosphere as a test case. They treated Earth as if it were an exoplanet and tested LIFE's methods against Earth's known atmospheric spectrum in different conditions. They used a tool called LIFEsim to work with the data. Researchers often use simulated data to test mission capabilities, but in this case, they used real data.

Their results are published in *The Astronomical Journal*. The research is titled "Large Interferometer For Exoplanets (LIFE). XII. The Detectability of Capstone Biosignatures in the Mid-infrared—Sniffing

Exoplanetary Laughing Gas and Methylated Halogens." The lead author is Dr. Daniel Angerhausen, an Astrophysicist and Astrobiologist at ETH in Zürich.

In a real-world scenario, Earth would be just a distant, nearly impossible to discern speck. All LIFE would see is the planet's atmospheric spectrum, which would change over time depending on what views the telescope captured and, critically, for how long it observed it.



A transmission spectrum of the hot gas giant exoplanet WASP-39 b, captured by JWST's Near-Infrared Spectrograph (NIRSpec) on July 10, 2022, reveals the first definitive evidence for carbon dioxide in the atmosphere of a planet outside the solar system. It was an exciting result, but only a taste of what we'll learn from LIFE. Credit: NASA, ESA, CSA, and L. Hustak (STScI). Science: The JWST Transiting Exoplanet Community Early Release Science Team

These spectra would be gathered over time, and that leads to an important question: how would the observational geometry and seasonal variations affect LIFE's observations?

Fortunately for the research team, we have ample observations of Earth for them to work with. The researchers worked with three different observational geometries: two views from the poles and one from the equatorial region. From those three viewpoints, they worked with atmospheric data from January and July, which accounts for the largest seasonal variations.

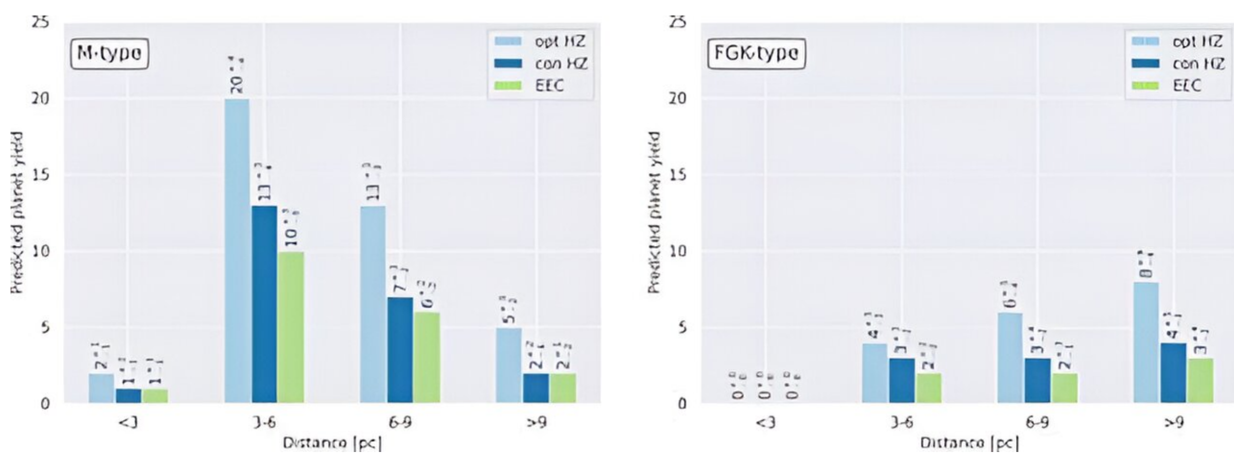
Though planetary atmospheres can be extremely complex, astrobiologists focus on certain aspects to reveal a planet's potential to host life. Of particular interest are the chemicals N_20, CH_3Cl, and CH_3Br (nitrous oxide, chloromethane, and bromomethane), all of which can be produced biogenically. "We use a set of scenarios derived from chemical kinetics models that simulate the atmospheric response of varied levels of biogenic production of N_2O, CH_3Cl, and CH_3Br in O_2-rich terrestrial planet atmospheres to produce forward models for our LIFEsim observation simulator software," the authors write.

In particular, the researchers wanted to know if LIFE will be able to detect CO_2, water, ozone and methane on planet Earth from about 30 light years away. These are signs of a temperate, life-supporting world—especially ozone and methane, which are produced by life on Earth—so if LIFE can detect biological chemistry on Earth in this way, it can detect it on other worlds.

LIFE was able to detect CO_2, water, ozone and methane on Earth. It also detected some surface conditions that indicate liquid water. Intriguingly, LIFE's results didn't depend on which angle Earth is viewed from. This is important since we don't know what angles LIFE will be observing exoplanets from.

Seasonal fluctuations are the other issue, and they weren't as easy to observe. But fortunately, it looks like that won't be a limiting factor. "Even if atmospheric seasonality is not easily observed, our study demonstrates that next-generation space missions can assess whether nearby temperate terrestrial exoplanets are habitable or even inhabited," said Quanz.

However, detecting the desired chemicals isn't enough. The critical piece is how long it takes. Building a space interferometer that detected these chemicals but took too much time to do it wouldn't be practical or effective. "We use the results to derive observation times needed for the detection of these scenarios and apply them to define science requirements for the mission," the research team writes in their paper.



This figure from the study illustrates the list of targets. The panel on the left shows planets around M-dwarf stars by distance. It shows the number of predicted planet targets for three different habitable zones: optimistic, conservative, and exo-Earth candidates. The panel on the right shows the same but for F, G, and K-type stars. Credit: *The Astronomical Journal* (2024). DOI: 10.3847/1538-3881/ad1f4b

To paint a larger picture of LIFE's observing times, the researchers developed a list of targets. They created a "… distance distribution of HZ planets with radii between 0.5 and 1.5 Earth radii around M and FGK-type stars within 20 pc of the sun that are detectable with LIFE." The data for these targets comes from NASA and from other previous research.

The results show that only a few days are needed for some targets, while for others, it could take up to 100 days to detect relevant abundances.

What the team calls "golden targets" are the easiest to observe. Planets in Proxima Centauri are an example of these types of targets. Only a few days of observation are needed for these planets. It'll take about ten days of observations with LIFE to observe "certain standard scenarios such as temperate, terrestrial planets around M star hosts at five pc," the researchers write. The most challenging cases that are still feasible are exoplanets that are Earth twins about 5 parsecs away. According to the results, LIFE needs between about 50–100 days of observing to detect the biosignatures.

LIFE is still just a potential mission at this point. It's not the first proposed mission that would be solely focused on exoplanet habitability. In 2023, NASA proposed the Habitable Worlds Observatory (HWO). Its goal is to directly image at least 25 potentially habitable worlds and then search for biosignatures in their atmospheres.

But according to the authors, their results show that LIFE is the best option.

"If there are late-type star exoplanetary systems in the solar neighborhood with planets that exhibit global biospheres producing N_2O and CH_3X signals, LIFE will be the best-suited future mission to systematically search for and eventually detect them," they conclude.

More information: Daniel Angerhausen et al, Large Interferometer For Exoplanets (LIFE). XII. The Detectability of Capstone Biosignatures in the Mid-infrared—Sniffing Exoplanetary Laughing Gas and Methylated Halogens, *The Astronomical Journal* (2024). DOI: 10.3847/1538-3881/ad1f4b

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