

Researchers advocate statistical approach to search for Earth-like planets

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A team of astronomers at the University of Chicago and Grinnell College seeks to change the way scientists approach the search for Earth-like planets orbiting stars other than the sun. They favor taking a statistical comparative approach in seeking habitable planets and life beyond the solar system.

"The nature of proof should not be: 'Can we point at a planet and say, yes or no, that's the planet hosting alien life,'" said Jacob Bean, associate professor of astronomy and astrophysics at UChicago. "It's a statistical exercise. What can we say for an ensemble of planets about the frequency of the existence of habitable environments, or the frequency of the existence of life on those planets?"

The standard approach of researching exoplanets, or planets that orbit distant stars, has entailed studying small numbers of objects to determine if they have the right gases in the appropriate quantities and ratios to indicate the existence of life. But in a recent paper with co-authors Dorian Abbot and Eliza Kempton in the *Astrophysical Journal Letters*, Bean describes the need "to think about the techniques and approaches of astronomy in this game—not as planetary scientists studying exoplanets."

"Nature has provided us with huge numbers of planetary systems," said Kempton, an assistant professor of physics at Grinnell College in Iowa. "If we survey a large number of planets with less detailed measurements, we can still get a statistical sense for how prevalent [habitable](#)

[environments](#) are in our galaxy. This would give us a basis for future, more detailed surveys."

Kempton and Bean attest to the challenges of making detailed observations of a potentially Earth-like planet. Together they have previously studied the super-Earth known as GJ 1214b, an exoplanet with a mass greater than Earth's but less than gas giants such as Neptune and Uranus. GJ 1214b turned out to be quite cloudy, which prevented them from determining the composition of its atmosphere.

"A large statistical study will allow us to look at many planets," Kempton said. "If any single object proves to be particularly challenging to observe, like GJ 1214b, that won't be a major loss to the observing program on the whole."

Kepler observatory a game-changer

The inspiration for the paper stemmed from Bean's membership on the Science and Technology Definition Team that is assessing the potential for a new space telescope, NASA's proposed Large UV/Optical/Infrared Survey (LUVOIR).

One of LUVOIR's scientific priorities is the search for Earth-like planets. During one team meeting, Bean and his colleagues listed all the properties of a potentially habitable exoplanet that they need to measure and how they would go about obtaining the data. Given the current state of technology, Bean concluded that it's unlikely scientists will be able to confirm an individual exoplanet as suitable for life or whether life is actually there.

Nevertheless, astronomers have gathered an impressive haul of exoplanetary data from NASA's Kepler space observatory, which has operated since 2009.

"Kepler completely changed the game," Bean said. "Instead of talking about a few planets or a few tens of planets, all of a sudden we had a few thousand planet candidates. They were planet candidates because Kepler couldn't definitely prove that the signal it was seeing was due to planets."

The standard approach has been to take additional observations for each candidate to rule out possible false positive scenarios, or to detect the planet with a second technique.

"That's very slow going. One planet at a time, a lot of different observations," Bean noted. But an alternative is to make statistical calculations for the probability of false positives among these thousands of exoplanet candidates. That new approach led directly to a good understanding of the frequency of exoplanets of different sizes. For example, scientists now can say that the frequency of super-Earth-type planets is 15 percent, plus or minus 5 percent.

Role of spectroscopy

Spectroscopic studies play a key role in characterizing exoplanets. This involves determining the composition of a planetary atmosphere by measuring its spectra, the distinctive radiation that gases absorb at their own particular wavelengths. Bean and his co-authors suggest focusing on what can be learned from measuring the spectra of a large ensemble of terrestrial exoplanets.

Spectroscopy may, for example, help exoplanetary researchers verify a phenomenon called the silicate weathering feedback, which acts as a planetary thermostat. Through silicate weathering, the amount of [atmospheric carbon dioxide](#) varies according to geologic processes. Volcanoes emit carbon dioxide into the atmosphere, but rain and chemical reactions that occur in rocks and sediments also remove the gas from the atmosphere.

Rising temperatures would put more water vapor into the atmosphere, which then rains out, increasing the amount of dissolved carbon dioxide that chemically interacts with the rocks. This loss of carbon dioxide from the atmosphere has a cooling effect. But as a planet begins to cool, rock weathering slows and the amount of carbon dioxide gradually builds from its volcanic sources, which causes rising temperatures.

Global-scale observations suggest that Earth has experienced silicate-weathering feedback. But attempts to verify that the process is operating today on the scale of individual river basins has proven difficult.

"The results are very noisy. There's no clear signal," Abbot said. "It would be great to have another independent confirmation from exoplanets."

All three co-authors are interested in fleshing out the details of experiments they proposed in their paper. Abbot plans to calculate how much carbon dioxide would be necessary to keep a planet habitable at a range of stellar radiation intensities while changing various planetary parameters. He also will assess how well a future instrument would be able to measure the gas.

"Then we will put this together to see how many planets we would need to observe to detect the trend indicating a silicate-weathering feedback," Abbot explained.

Bean and Kempton, meanwhile, are interested in detailing what a statistical census of biologically significant gases such as oxygen, [carbon dioxide](#) and ozone could reveal about planetary habitability.

"I'd like to get a better understanding of how some of the next-generation telescopes will be able to distinguish statistical trends that indicate habitable—or inhabited—planets," Kempton said.

More information: Jacob L. Bean et al. A Statistical Comparative Planetology Approach to the Hunt for Habitable Exoplanets and Life Beyond the Solar System, *The Astrophysical Journal* (2017). [DOI: 10.3847/2041-8213/aa738a](https://doi.org/10.3847/2041-8213/aa738a)

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