Astrobiologist explores likelihood of life originating on Earth

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Florida Tech astrobiologist Manasvi Lingam has asked life's biggest questions from a young age. Though he can't recall his exact queries, he says his interests were perfectly consistent with those of other children:

dinosaurs and aliens.

On bus rides with his family, he would pepper his parents with questions about the mysteries of the universe. On long walks with his grandfather, he would brainstorm how life could exist on different types of planets.

Lingam's fascination with early life and astrobiology never waned. Now an assistant professor of astrobiology, he has gone from asking his grandfather questions to creating his own models to explore complex topics such as the origin of life. He exchanged the pursuit of definitive answers for scholarly inferences, embracing the universe's uncertainties by exploring chance.

According to Lingam, models—or simplified representations of reality—accomplish two main tasks: they help researchers make predictions and they offer an alternative to experiments that may be too costly or impractical. That was the case with Lingam's recently published analysis regarding the potential origin of life on Earth.

"A Bayesian Analysis of the Probability of the Origin of Life per Site Conducive to Abiogenesis," published Aug. 19 in the journal *Astrobiology* by Lingam, recent Florida Tech graduate Ruth Nichols and University of Rome astrobiologist Amedeo Balbi, models the relationship between hypotheses predicting varying numbers of potential sites for abiogenesis—the emergence of life from non-life—on Earth and the likelihood of life's emergence at those sites.

A Bayesian analysis is one in which prior knowledge is used to estimate subsequent probability. For the sake of this model, the researchers focused on the possibility of life originating on Earth itself. So, since it's established that there is life on Earth, this model assumes that life originated on Earth at least once.

Lingam says this is one of his first times specifically studying the origin of life. However, he's modeled several adjacent questions, such as the evolution of technology-based intelligence.

The researchers compiled potentially urable sites—those viable for life to start—identified in previous research, each with different levels of conduciveness for the genesis of life. They included several different environments, ranging from underwater volcanoes to soap bubbles and tar to natural nuclear reactors akin to one that formed in Gabon two billion years ago.

Two main questions shaped their models: from how many sites on Earth could life have emerged; and what is the probability of life actually emerging from one of those sites? The goal of the study was not to directly answer the questions but to find the most accurate way of interpreting the data the models generate.

The researchers modeled three different scenarios: one with 10 urable sites, one with 10^{31} urable sites, and one close to the middle with 10^{16} urable sites.

Lingam initially anticipated that access to larger pools of urable sites would create a higher likelihood of life emerging on Earth. Think when you buy more lottery tickets, your chances of winning will go up.

Instead, the results were the complete opposite in this agnostic scenario. Lingam found that when comparing the larger number of sites to the smaller number, the probability of life per pool was almost inversely related to the number of pools.

"That's the two situations that are here. One where there are lots of sites, but there's very low probability [of life] per site. And the second where there are very few sites, but there's a very high probability per site," Lingam says.

Yes, this outcome is counterintuitive, he says. That's why it's important.

"Normally, 'the more, the better' is the attitude for many things in life," Lingam says. "But more is not always better. If it's fewer, but it's the right kind of fewer, then that can actually be better."

In other words, in the model where Earth had fewer urable sites overall, the researchers inferred that the probability of life emerging on a given site is enhanced. They established that a greater chance of generation of life could be more likely when urable sites are rare, and plentiful urable sites might lessen the likelihood of life from a given site.

From there, they drew the inference that the smaller sample of sites, which revealed a higher probability of life at a given site, likely contained more conducive environments.

Their findings suggest that within the Bayesian framework, placing constraints on the availability of suitable environments for the origin(s) of life on Earth may offer valuable insights into the probability of abiogenesis and the frequency of life elsewhere in the universe.

How could these findings be used?

Since researchers have different opinions on the most likely environments for life to emerge, Lingam says they can use this model in the context of understanding their preferred environments.

"Then they can do laboratory experiments, try to get a feel for how many trials might be needed to actually move to something like life," Lingam says.

Lingam would also like to continue building an understanding of early life by exploring the origins of intelligence.

Although he may not be able to directly answer his childhood questions, Lingam embraces the limitations and uncertainty that accompany his models.

"We can't peer back in time," Lingam says. "Sometimes you can arrive at answers just through very clever use of limited data… but there is a part that you'll never know."

From his upbringing marked by curiosity to his flourishing career in astrobiology, Lingam is committed to his dedication to the wonders that have always captivated him.

"I think this was something every kid goes through, but I took it very seriously," Lingam says. "It feels like, after a long winding voyage, [I'm] coming back to this childhood road."

More information: Manasvi Lingam et al, A Bayesian Analysis of the Probability of the Origin of Life Per Site Conducive to Abiogenesis, *Astrobiology* (2024). DOI: 10.1089/ast.2024.0037

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