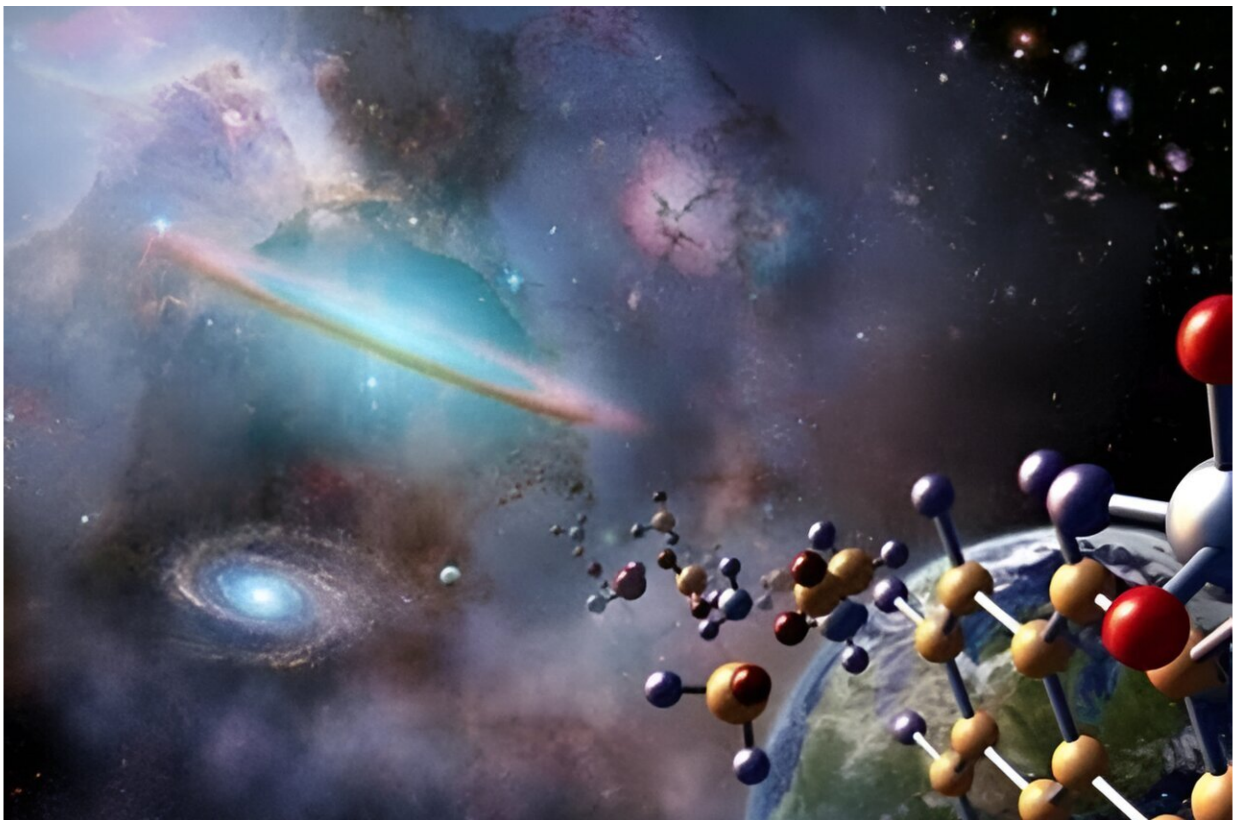
Life might be difficult to find on a single planet but may be obvious across many worlds

March 27 2024, by Evan Gough



Panspermia is the idea that life is spread throughout the galaxy, or even the Universe, by asteroids, comets, and even minor planets. Credit: NASA/Jenny Mottor

If we could detect a clear, unambiguous biosignature on just one of the thousands of exoplanets we know of, it would be a huge, game-changing moment for humanity. But it's extremely difficult. We simply aren't in a place where we can be certain that what we're detecting means what we think or even hope it does.

But what if we looked at many potential worlds at once?

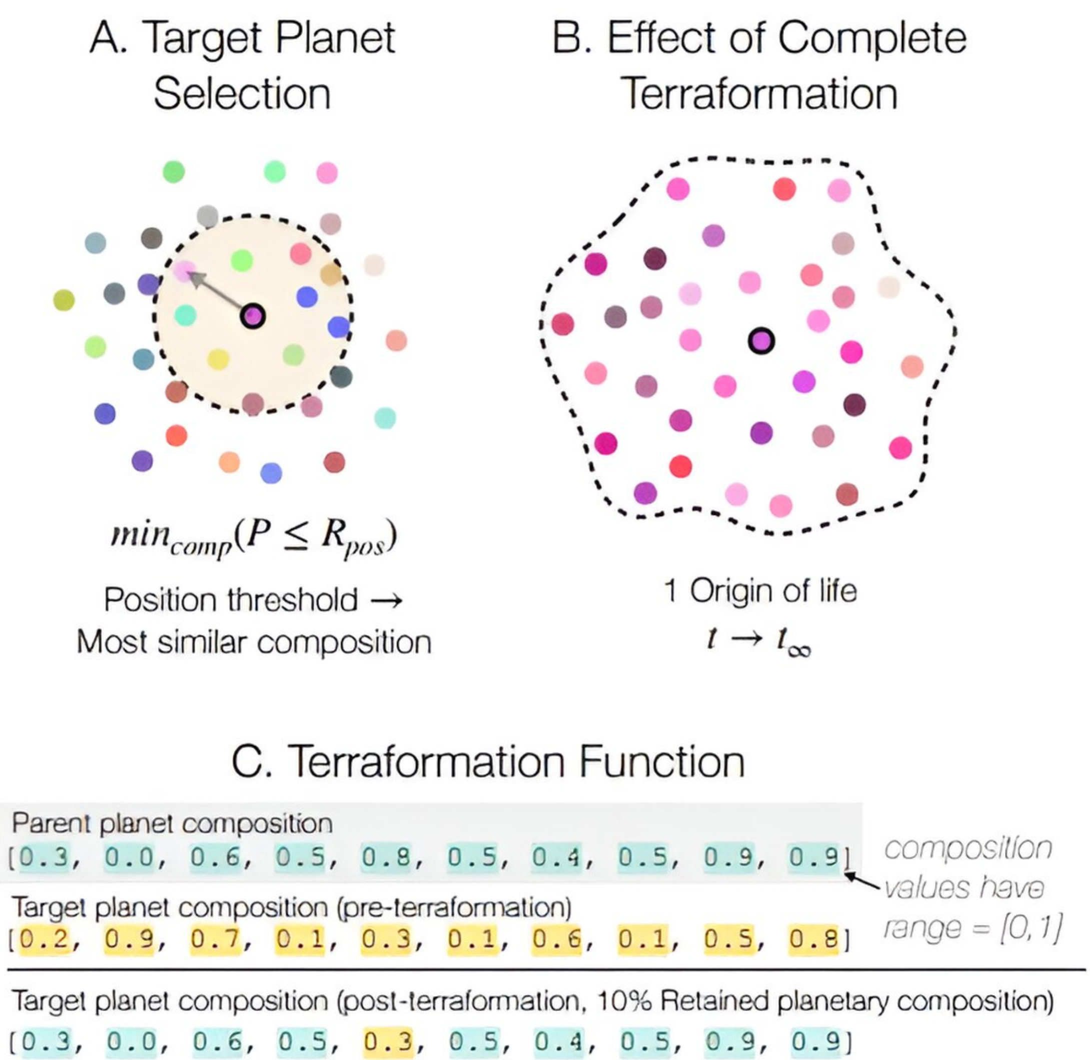
It's assumptions that plague us. Every chemical we detect in an exoplanet atmosphere, even with the powerful JWST, is accompanied by a set of assumptions. We simply don't know enough yet for it to be any other way. This puts us in a difficult place, considering the magnitude of the question we're trying to answer: is there life beyond Earth?

"A fundamental goal of astrobiology is to detect life outside of Earth," write the authors of a new paper. It's titled "An Agnostic Biosignature Based on Modeling Panspermia and Terraformation," and it's available on the preprint site *arXiv*. The authors are Harrison B. Smith and Lana Sinapayen. Smith is from the Earth-Life Science Institute at the Tokyo Institute of Technology in Japan, and Sinapayen is from the Sony Computer Science Laboratories in Kyoto, Japan.

The fundamental goal that the pair of authors give voice to is a difficult one to reach. "This proves to be an exceptional challenge outside of our solar system, where strong assumptions must be made about how life would manifest and interact with its planet," the authors explain.

We only know how Earth's biosphere works, and we're left to assume what similarities there might be with other planets. We don't have any consensus about how biospheres might be able to work. We're not completely ignorant, as chemistry and physics make some things possible and others impossible. But we're not an authority on biospheres.

Scientists are pretty good at modeling things and trying to generate useful answers, as well as generating relevant questions they might not have thought of without models. In this work, the pair of authors took a different approach to understanding life on other worlds and what effort we can make to detect it.



This figure from the study helps illustrate the authors' work. A shows a target planet selection, where an initial planet and its composition are randomly selected. This planet represents a terraformed parent planet. B shows the simulation run beginning with the initial parent planet, showing how nearby planets will be terraformed to more closely match the parent planet. C shows how each terraformed planet will retain some of its differences, about 10% in the researchers' model. Image Credit: Smith and Sinapayen, 2024

"Here we explore a model of life spreading between planetary systems via panspermia and terraformation," the authors write. "Our model shows that as life propagates across the galaxy, correlations emerge between planetary characteristics and location and can function as a population-scale agnostic biosignature."

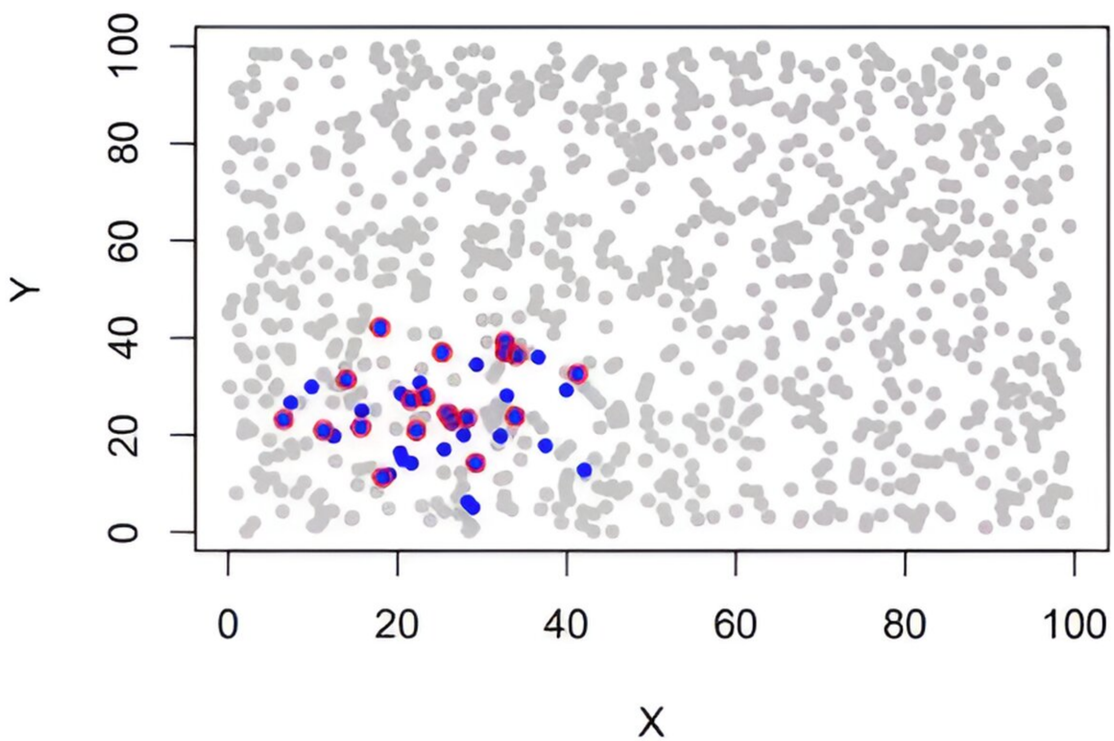
The word "agnostic" is key here. It means that they're aiming to detect a biosignature that's independent of the assumptions we're normally saddled with. "This biosignature is agnostic because it is independent of strong assumptions about any particular instantiation of life or planetary characteristic—by focusing on a specific hypothesis of what life may do rather than what life may be," the authors explain.

This approach is different. They analyze planets by their observed characteristics and then cluster them based on those observations. Then, they examine the spatial extent of the clusters themselves. That leads to a way to prioritize individual planets for their potential to harbor life.

Panspermia and terraforming play key roles. We know that rocks can travel between worlds, and that's called lithopanspermia. Powerful impacts on Mars lofted rocks into space, some of which eventually fell to Earth. If dormant organisms like spores could survive the journey, it's at least feasible that life could spread this way.

Terraforming is self-explanatory for the most part. It's the effort to engineer a world to be more habitable. If there are other technological, space-faring civilizations out there, one useful working assumption is that they'll eventually terraform other worlds if they last long enough. In any case, even non-technological life can purposefully alter its environment. (Sit and watch beavers sometime.)

The authors make an interesting point regarding panspermia and terraforming. They're both things that life already does, kind of. "Ultimately, our postulates of panspermia and terraformation are merely well-understood hallmarks of life (proliferation via replication and adaptation with bi-directional environmental feedback), escalated to the planetary scale, and executed on an interstellar scale," they write.



This figure from the research shows how simulated terraformed planets would appear clustered on a graph. This is a projection of 3D planet locations in the 2D X-Y plane and the earliest time step where the researchers detect a cluster of planets meeting their selection criteria. True terraformed planets have a blue fill, while planets detected by their selection method have a red outline. Image Credit: Smith and Sinapayen, 2024

The authors' model shows that the way planets are distributed around stars, along with their other characteristics, could be evidence of life without even attempting to detect chemical biosignatures. This is the agnostic part of their work. It's more powerful than a one-planet-at-a-time struggle to detect biosignatures, as plagued as that effort is by assumptions. Single planets with detected biosignatures can always be explained away by something anomalous. But that's harder to do in this agnostic method.

"Hypothesizing that life spreads via panspermia and terraformation allows us to search for biosignatures while forgoing any strong assumptions about not only the peculiarities of life (e.g., its metabolism) and planetary habitability (e.g., requiring surface liquid water) but even the potential breadth of structure and chemical complexity underpinning living systems," the authors explain.

We're accustomed to thinking about specific chemicals, and the types of atmospheres exoplanets have to determine the presence of biosignatures. But that's not how this works. This model is agnostic, so it's not really about specific chemical biosignatures. It's more about the patterns and clusters we could detect in populations of planets that could signal the presence of life via panspermia and terraforming.

Terraformed planets can be identified from their clustering, the authors claim. That's because when they're terraformed, the planets need to reflect the originating planet.

There are obstacles to this method that limit its usefulness and implementation. According to the authors, they need to identify "… specific ways in which better understanding astrophysical and planetary processes would improve our ability to detect life."

But even without more specifics, the method is thought-provoking and creative. In the end, the authors' model and method lead to a novel way to think about life's hierarchies and how these hierarchies might be replicated on other planets.

If this method is strengthened and more fully developed, who knows what it might lead to?

More information: Harrison B. Smith et al, An Agnostic Biosignature Based on Modeling Panspermia and Terraformation, *arXiv* (2024). DOI: 10.48550/arxiv.2403.14195

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