Origins of life researchers develop a new ecological biosignature

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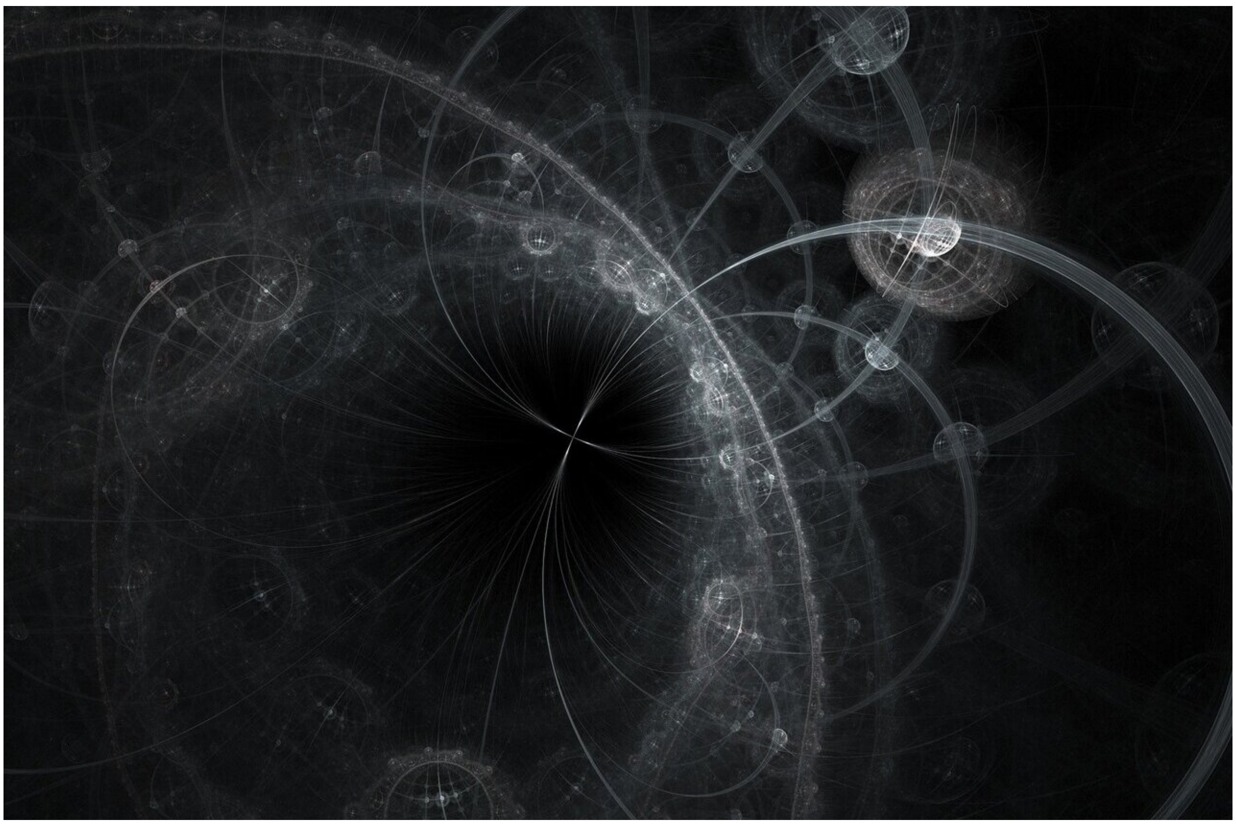

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When scientists hunt for life, they often look for biosignatures, chemicals or phenomena that indicate the existence of present or past life. Yet it isn't necessarily the case that the signs of life on Earth are signs of life in other planetary environments. How do we find life in systems that do not resemble ours?

In groundbreaking new work, a team led by Santa Fe Institute Professor Chris Kempes has developed a new ecological biosignature that could help scientists detect life in vastly different environments. Their work appears as part of a special issue of the*Bulletin of Mathematical Biology* collected in honor of renowned mathematical biologist James D. Murray.

The new research takes its starting point from the idea that stoichiometry, or chemical ratios, can serve as biosignatures. Since "living systems display strikingly consistent ratios in their chemical make-up," Kempes explains, "we can use stoichiometry to help us detect life." Yet, as SFI Science Board member and contributor, Simon Levin, explains, "the particular elemental ratios we see on Earth are the result of the particular conditions here, and a particular set of macromolecules like proteins and ribosomes, which have their own stoichiometry." How can these elemental ratios be generalized beyond the life that we observe on our own planet?

The group solved this problem by building on two lawlike patterns, two scaling laws, that are entangled in elemental ratios we have observed on Earth. The first of these is that in individual cells, stoichiometry varies with cell size. In bacteria, for example, as cell size increases, protein concentrations decrease, and RNA concentrations increase. The second is that the abundance of cells in a given environment follows a power-law distribution. The third, which follows from integrating the first and second into a simple ecological model, is that the elemental abundance of particles to the elemental abundance in the environmental fluid is a function of particle size.

While the first of these (that elemental ratios shift with particle size) makes for a chemical biosignature, it is the third finding that makes for the new ecological biosignature. If we think of biosignatures not simply in terms of single chemicals or particles, and instead take account of the fluids in which particles appear, we see that the chemical abundances of living systems manifest themselves in mathematical ratios between the particle and environment. These general mathematical patterns may show up in coupled systems that differ significantly from Earth.

Ultimately, the theoretical framework is designed for application in future planetary missions. "If we go to an ocean world and look at particles in context with their fluid, we can start to ask whether these particles are exhibiting a power-law that tells us that there is an intentional process, like life, making them," explains Heather Graham, Deputy Principal Investigator at NASA's Lab for Agnostic Biosignatures, of which she and Kempes are a part. To take this applied step, however, we need technology to size-sort particles, which, at the moment, we don't have for spaceflight. Yet the theory is ready, and when the technology lands on Earth, we can send it to icy oceans beyond our solar system with a promising new biosignature in hand.

More information: Christopher P. Kempes et al, Generalized Stoichiometry and Biogeochemistry for Astrobiological Applications, *Bulletin of Mathematical Biology* (2021). DOI: 10.1007/s11538-021-00877-5

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