Could life exist in molecular clouds?

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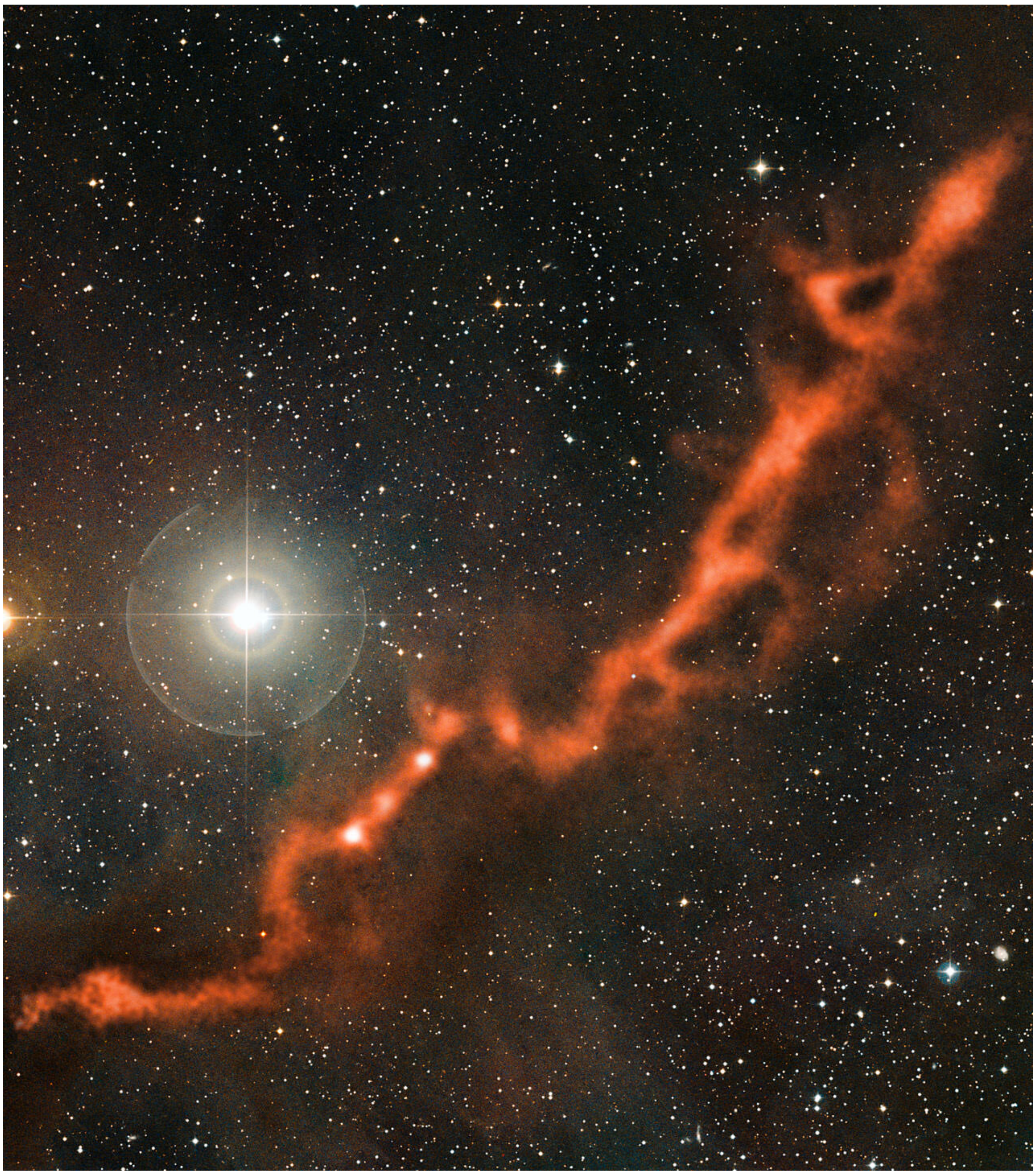

This image from the APEX telescope, of part of the Taurus Molecular Cloud, shows a sinuous filament of cosmic dust more than ten light-years long. Could life exist in molecular clouds like this one? Credit: ESO/APEX (MPIfR/ESO/OSO)/A. Hacar et al./Digitized Sky Survey 2. Credit: Davide De Marti

Our search for life beyond Earth is still in its infancy. We're focused on Mars and, to a lesser extent, ocean moons like Jupiter's Europa and Saturn's Enceladus. Should we extend our search to cover more unlikely places like molecular clouds?

The idea that life could survive on other worlds like Mars or Europa gained vigor in the last few decades. Scientists found Earth life persisting in some extreme environments: hydrothermal vents, Antarctic pack ice, alkaline lakes, and even inside nuclear reactors.

Parallel to these discoveries, astronomers found life's chemical building blocks in space. They've found amino acids inside meteorites, organic chemistry in the interstellar medium (ISM,) and polycyclic aromatic hydrocarbons (PAHs) in molecular clouds.

The discovery of extremophiles and life's building block in space suggests we should widen the scope of our search for life. Should molecular clouds be one of our targets?

Molecular clouds are massive clouds of gas and dust out of which stars form. They're called molecular clouds because they're mostly molecular hydrogen, though they can contain many different compounds. Though the clouds are filamentary in nature, they do form clumps of greater density that sometimes become stars.

Could life exist in such a tenuous environment? One researcher thinks the question is worth exploring. In a paper titled "Possibilities for Methanogenic and Acetogenic Life in a Molecular Cloud,," Chinese researcher Lei Feng examines the idea that life began in space as methanogens or acetogens, bacteria that produce methane and acetic acid as byproducts. These could be the precursors to Earth's life, according to Feng. The paper can be accessed on the pre-print server *arXiv*.

"If methanogenic life exists in the presolar nebula, then it may be the ancestor of Earth's life, and there [is] already some tentative [evidence] by several molecular biology studies," Feng writes. (English is not Feng's first language, but it's easy to see what he's getting at.)

Feng's exploration rests on the idea of panspermia. Panspermia is the idea that life exists throughout the universe and was spread around by asteroids, comets, even space dust and minor planets. The history of life on Earth suggests that panspermia could've played a role, but we just don't know. The idea was entirely speculative until scientists started finding life's building blocks in space.

The main problem with life in molecular clouds concerns the temperature. It can be as low as 10 Kelvin or -263 Celsius. That's extremely cold, even for Earth's extremophiles. There's also no solid surface, but that might not be enough to prohibit life.

A key factor in life, as far as we understand it, is that cells need liquid to go about their metabolic business. Without water, cell membranes would lack structure, so there'd be no way to keep the inside parts in and the outside stuff out. But does the liquid have to be water? Could it be liquid hydrogen? Methane? We don't know.

"Hydrogen molecules maintain a liquid state between 13.99 K and 20.27 K, and it happens to be the typical temperature of molecular clouds," Feng writes. "If we suppose that life in molecular clouds has a cell-like membrane structure and the hydrogen molecules (the main component of molecular clouds) enriched therein, the hydrogen pressure is also enlarged, and hydrogen could maintain a liquid state in molecular cloud life."

Feng explains that liquid hydrogen in molecular cloud life (MCL) could play the same role that water plays in Earth life. "A liquid hydrogen state is an ideal place for biochemical reactions similar to the water environment of cells on Earth," he states.

Life needs energy, too, and Earth life is almost entirely based on sunlight. Molecular clouds can be cold, dark places. How would Feng's MCL acquire energy?

"How does molecular cloud life obtain enough energy? Previously, the author proposed cosmic-ray-driven bioenergetics powered by the ionization of hydrogen molecules," Feng writes, referring to his previous paper on the same subject. There may be other possibilities.

Life and reproduction require energy transformation. Earth life relies on respiration. The respiration can be either aerobic or anaerobic, meaning it either uses oxygen or another electron acceptor.

Methanogenic bacteria were some of Earth's first life, and they produce methane as a byproduct in hypoxic (low oxygen) conditions. In the process, they generate free energy needed for life. Scientists have wondered if methanogens could live on Saturn's moon Titan. Could it be surviving in molecular clouds?

"Methanogens could live on Titan, then can they live in molecular clouds? Here we will discuss such probability and calculate the releases of free energy for methanogenic life in the environment of molecular clouds," Feng writes.

According to Feng, the calculations show that methanogenesis in molecular clouds can produce enough free energy to fuel life. "From the calculations, we found that the reaction of carbon monoxide, carbon dioxide or acetylene with hydrogen molecules releases sufficient Gibbs free energy to ensure the survival of molecular cloud life," Feng explains.

These activities could even produce biosignatures, according to the author. "The consumption of carbon compounds by life activities may affect the distribution of organic molecules. It might be a possible trace signal of molecular cloud life," he writes.

Feng's hypothesis is that life could've begun in molecular clouds and spread to Earth and elsewhere. He says that methanogenic and acetogenic life could be the ancestors of Earth's LUCA, the last universal common ancestor. LUCA is the common ancestral cell from which life's three domains, Bacteria, the Archaea, and the Eukarya, originated.

It never pays to discard an idea too hastily. There's a lot we don't know abouT life, the universe, and everything. Can we afford to rule Feng's idea out? Unfortunately for Feng, his work lacks the participation of other researchers, which can be a signal that something's not quite right. Some single-author papers have made important contributions to science, mostly in the past. But they're becoming increasingly rare.

Feng's hypothesis is an interesting, outside-the-box idea. Outside-the-box thinking doesn't always lead directly to a new understanding, but it can spur new pathways of thinking. However, Feng's work runs into some roadblocks. Molecular clouds only last about 100 million years. Is that enough time? Also, LUCA is still just a hypothetical organism.

More information: Lei Feng, Possibilities for methanogenic and acetogenic life in molecular cloud, *arXiv* (2023). DOI: 10.48550/arxiv.2311.14291

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