'Bouncing' comets could deliver building blocks for life to exoplanets

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A composite image of the Western hemisphere of the Earth. Credit: NASA

How did the molecular building blocks for life end up on Earth? One long-standing theory is that they could have been delivered by comets. Now, researchers from the University of Cambridge have shown how comets could deposit similar building blocks to other planets in the galaxy.

In order to deliver organic material, comets need to be traveling relatively slowly—at speeds below 15 kilometers per second. At higher speeds, the essential molecules would not survive—the speed and temperature of impact would cause them to break apart.

The most likely place where comets can travel at the right speed are 'peas in a pod' systems, where a group of planets orbit closely together. In such a system, the comet could essentially be passed or 'bounced' from the orbit of one planet to another, slowing it down.

At slow enough speeds, the comet would crash on a planet's surface, delivering the intact molecules that researchers believe are the precursors for life. The results, reported in the *Proceedings of the Royal Society A*, suggest that such systems would be promising places to search for life outside our solar system if cometary delivery is important for the origins of life.

Comets are known to contain a range of the building blocks for life, known as prebiotic molecules. For example, samples from the Ryugu asteroid, analyzed in 2022, showed that it carried intact amino acids and vitamin B3. Comets also contain large amounts of hydrogen cyanide (HCN), another important prebiotic molecule. The strong carbon-nitrogen bonds of HCN make it more durable to high temperatures, meaning it could potentially survive atmospheric entry and remain intact.

"We're learning more about the atmospheres of exoplanets all the time, so we wanted to see if there are planets where complex molecules could

also be delivered by comets," said first author Richard Anslow from Cambridge's Institute of Astronomy. "It's possible that the molecules that led to life on Earth came from comets, so the same could be true for planets elsewhere in the galaxy."

The researchers do not claim that comets are necessary to the origin of life on Earth or any other planet, but instead they wanted to place some limits on the types of planets where complex molecules, such as HCN, could be successfully delivered by comets.

Most of the comets in our solar system sit beyond the orbit of Neptune, in what is known as the Kuiper Belt. When comets or other Kuiper Belt objects (KBOs) collide, they can be pushed by Neptune's gravity toward the sun, eventually getting pulled in by Jupiter's gravity. Some of these comets make their way past the Asteroid Belt and into the inner solar system.

"We wanted to test our theories on planets that are similar to our own, as Earth is currently our only example of a planet that supports life," said Anslow. "What kinds of comets, traveling at what kinds of speed, could deliver intact prebiotic molecules?"

Using a variety of mathematical modeling techniques, the researchers determined that it is possible for comets to deliver the precursor molecules for life, but only in certain scenarios. For planets orbiting a star similar to our own sun, the planet needs to be low mass and it is helpful for the planet to be in close orbit to other planets in the system.

The researchers found that nearby planets on close orbits are much more important for planets around lower-mass stars, where the typical speeds are much higher.

In such a system, a comet could be pulled in by the gravitational pull of

one planet, then passed to another planet before impact. If this 'comet-passing' happened enough times, the comet would slow down enough so that some prebiotic molecules could survive atmospheric entry.

"In these tightly-packed systems, each planet has a chance to interact with and trap a comet," said Anslow. "It's possible that this mechanism could be how prebiotic molecules end up on planets."

For planets in orbit around lower-mass stars, such as M-dwarfs, it would be more difficult for complex molecules to be delivered by comets, especially if the planets are loosely packed. Rocky planets in these systems also suffer significantly more high-velocity impacts, potentially posing unique challenges for life on these planets.

The researchers say their results could be useful when determining where to look for life outside the solar system.

"It's exciting that we can start identifying the type of systems we can use to test different origin scenarios," said Anslow.

"It's a different way to look at the great work that's already been done on Earth. What molecular pathways led to the enormous variety of life we see around us? Are there other planets where the same pathways exist? It's an exciting time, being able to combine advances in astronomy and chemistry to study some of the most fundamental questions of all."

More information: Can comets deliver prebiotic molecules to rocky exoplanets?, *Proceedings of the Royal Society A: Mathematical and Physical Sciences* (2023). DOI: 10.1098/rspa.2023.0434. royalsocietypublishing.org/doi … .1098/rspa.2023.0434

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