The Moon as a Fishing Net for Extraterrestrial Life

By Abraham Loeb on September 8, 2019

NASA announced recently the Artemis Program, consolidating its plan to establish a sustainable base on the Moon by 2024. This ambitious initiative revives an old question: will the unique qualities of the lunar surface enable new frontiers in astronomy?

Already a few decades ago, astronomers contemplated different ways to benefit from the absence of an atmosphere on the Moon. First, energetic particles, such as gamma-rays, X-rays, UV photons or cosmic-rays, would not be blocked by an atmospheric blanket as they are on Earth, and hence reach telescopes with large collecting areas that are mounted to the lunar surface. Second, observatories sensitive to optical, infrared, millimeter or radio waves could reach their diffraction limit without the blurring or absorption associated with passage through turbulent air. Arrays of detectors could therefore constitute giant interferometers with unprecedented angular resolution. Third, the lack of an ionosphere would allow radio observatories to receive signals at very low frequencies, below the terrestrial cutoff of 10 kHz. This would open a new spectral window into the Universe, allowing to map the three-dimensional distribution of hydrogen atoms from their first appearance 0.4 million years after the Big Bang and through the cosmic dawn, using the highly-redshifted 21-cm line. Although exciting and path-breaking in their own right, these traditional visions were all formulated well before the emergence of the frontier of astrobiology associated with the search for extraterrestrial life.

Can the Moon provide clues for extraterrestrial life? A new paper that we wrote with Manasvi Lingam answers this question in the affirmative. The idea is to consider the surface of the Moon as a fishing net for interstellar objects that are collected over time and potentially deliver building blocks of life from the habitable environments around other stars. The lack of a lunar atmosphere guarantees that these messengers will not burn up on their way but instead reach the lunar surface. In addition, the geological inactivity of the Moon implies that the record deposited on its surface will be preserved and not get mixed with the deep lunar interior. Serving as a natural mailbox, the lunar surface collected all impacting objects over the past few billions of years. Most of this "mail" originated from our neighborhood within the Solar system.

But the Solar system also intercepts external objects from interstellar space, ranging from dust particles to free-floating planets and stars. A detection of the first interstellar object, \`Oumuamua, with a size of order a hundred meters, was reported in 2017. This year, \`Oumuamua's cousin was tentatively discovered in the form of a meter-size meteor from outside the Solar system that burned up in the Earth's atmosphere in 2014. Given the search volume and duration of the surveys that made these detections, it is now possible for the first time to calibrate the flux of interstellar objects (assuming they enter the Solar system on random trajectories). With this calibration at hand, one can calculate the implied amount of interstellar material that collected on the surface of the Moon over its history. The assembly of interstellar matter can also be observed in real time; another new paper with my undergraduate student, Amir Siraj, showed that a two-meter telescope on a satellite in orbit around the Moon can identify interstellar impactors.

In case some interstellar impactors carry the building blocks of extraterrestrial life, one could extract these biomarkers by analyzing samples of the lunar surface. Moon rocks delivered to Earth by the Apollo mission were likely contaminated by terrestrial life and are not a viable alternative to a dedicated experimental base on the Moon .

Identifying biomarkers from debris of material that originated in the habitable zone around other stars would inform us about the nature of extraterrestrial life. The fundamental question is whether distant life resembles the biochemical structures we find on Earth. Similarities might imply that there exists a unique chemical path for life everywhere or that life was transferred between systems. Either way, a lunar study shortcuts the need to send spacecrafts on extremely long missions to visit other star systems. Getting similar information from a trip to the nearest star system: Alpha Centauri A, B or C, would take nearly nine years even if the spacecraft were to travel at the maximum speed allowed in nature, the speed of light; the first half of this period is required for reaching the target and the second half for the information to get back to us. With chemical rockets, this journey would take about a hundred thousand years, of order the time that elapsed since the first modern humans began migrating out of Africa. Excavating the lunar surface for physical evidence of extraterrestrial life is dramatically faster.

Based on the newly calibrated flux of interstellar objects, their debris should constitute up to thirty parts per million of the lunar surface material. Extrasolar organics might amount to a fraction of order parts per ten million. Amino acids – which serve as the building blocks of “life as we know it” – could amount to a few parts per hundred billion. Standard spectroscopic techniques can be employed to examine individual grains within the lunar regolith and search for signatures that would flag them as extrasolar, before unraveling the building blocks of extraterrestrial life within them.

How can the extrasolar origin be identified? The simplest flag would be a deviation from the unique Solar ratio for isotopes of oxygen, carbon or nitrogen. The feasibility of this method was already demonstrated in laboratories at the required levels of sensitivity.

But there is also the exciting opportunity for detecting biosignatures of extinct extraterrestrial life. On Earth, the oldest microfossils with unambiguous evidence for cells that lived 3.4 billion years ago, were discovered in the Strelley Pool Formation in Western Australia. It would be tantalizing to find microfossils of extraterrestrial forms of life on the Moon. And more outlandish - to find traces of technological equipment that crashed on the lunar surface a billion years ago with a letter from an alien civilization saying “we exist”. Without checking our mailbox, we would never know that such a message arrived.

The opportunity to discover signs of extraterrestrial life provides a new scientific incentive for a sustainable base on the lunar surface. The Moon is well known for its romantic appeal, but astrobiology offers a twist on this notion. Here’s hoping that the Moon will inform our civilization that we are not alone and that someone else is waiting for us out there.

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(Credit: Nick Higgins)