Not saying it was aliens, but 'Oumuamua probably wasn't a nitrogen iceberg

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Artist's concept of Oumuamua. Credit: William Hartmann

On October 19, 2017, astronomers made the first-ever detection of an

interstellar object (ISO) passing through our solar system. Designated 1I/2017 U1 ′Oumuamua, this object confounded astronomers who could not determine if it was an interstellar comet or an asteroid. After four years and many theories (including the controversial "ET solar sail" hypothesis), the astronomical community appeared to land on an explanation that satisfied all the observations.

The "nitrogen iceberg" theory stated that "Oumuamua was likely debris from a Pluto-like planet in another stellar system. In their latest study, titled "The Mass Budget Necessary to Explain "Oumuamua as a Nitrogen Iceberg," Amir Siraj and Prof. Avi Loeb (who proposed the ET solar sail hypothesis) offered an official counter-argument to this theory. According to their new paper, there is an extreme shortage of exo-Plutos in the galaxy to explain the detection of a nitrogen iceberg.

In the paper where he broached the possibility, Loeb indicated that "Oumuamua's unusual character and behavior were consistent with a solar sail. This included the highly-reflective nature of the object and its profile, which appeared to be either cigar-shaped or pancake-like. More importantly, its sudden acceleration and deviation from its expected orbit appeared to be the result of radiation pressure, which is precisely how solar sails achieve propulsion.

There was also the way it entered our solar system, which allowed it to make a flyby of Earth after passing closest to our sun (perihelion). In other words, its orbital dynamics allowed it to get a close look at the only habitable planet in our solar system, which is precisely what one might expect of an interstellar probe. These arguments were detailed further in Loeb's book, "Extraterrestrial: The First Sign of Intelligent Life Beyond Earth."

At the time of the book's writing, all attempts to explain "Oumuamua in terms of natural phenomena fell short. Basically, there was no single

explanation that could account for its brightness, profile and acceleration while acknowledging that there was no evidence of outgassing. In addition, the sudden acceleration could not be attributed to gravitational forces since these should have been slowing "Oumuamua down at the time.

In March of 2021, two researchers from the School of Earth and Space Exploration (SESE) at Arizona State University (ASU) offered a new hypothesis. In two published studies, SESE Exploration Fellow Alan Jackson and Professor Steven Desch argued that "Oumuamua may have been a nitrogen ice fragment ejected from a young star system (possibly in the Perseus Arm of our galaxy) ca. 400 to 500 million years ago.

In their first paper, Jackson and Desch addressed the size and compositional constraints of "Oumuamua and showed that "Oumuamua's albedo was similar to the nitrogen ices on the surfaces of Triton and Pluto. In their second paper, they showed how these types of nitrogen ice fragments could be generated by the collision of extrasolar objects similar in composition to Pluto and Kuiper Belt Object (KBOs).

By their estimates, these collisions would generate and eject around 100 trillion (~10^{14}) objects into interstellar space, half of which would be composed of water ice and the other half of nitrogen (N_2). This population would be enough to satisfy the statistical significance of ISOs necessary to explain the detection of "Oumaumua. Equally important was the fact that an object composed of N_2 would not form a tail as it neared our sun, as there would be no water vapor or CO/CO_2 to sublimate. As Siraj explained to Universe Today via email:

"The attraction of the nitrogen iceberg hypothesis is primarily in explaining "Oumuamua's non-gravitational acceleration. Just like for a hypothetical hydrogen iceberg, a nitrogen iceberg's outgassing activity would not have been detectable in the measurements that were taken of

"Oumuamua by the Spitzer Space Telescope, which simply limited the abundance of carbon-based molecules around "Oumuamua. As a result, the sublimation of material could conceivably power the object's observed non-gravitational acceleration."

One of the main points made by Loeb in his proposal paper was that regardless of "Oumuamua's true nature, its detection implied a massive population of similar objects in our galaxy. In their rebuttal paper, which was recently accepted for publication in the journal New Astronomy, Siraj and Loeb addressed whether there is enough material in the Milky Way galaxy to create such a population of nitrogen icebergs.

A consequence of Jackson and Desch's assessment was that there must be a robust population of "exo-Plutos" in our galaxy. For that to be the case, stars in the Milky Way would need to have enough material left over from star formation (i.e., a mass budget) to accommodate the formation of these planets. To test this, Siraj and Loeb took the nitrogen iceberg model and examined what amount of stellar material is required to make it work.

Artist's impression of the first interstellar object "Oumuamua," which was discovered on October 19th, 2017, by the Pan-STARRS 1 telescope in Hawaii. Credit: ESO/M. Kornmesser

"Our calculation is very straightforward," said Siraj. "We take all of the nitrogen iceberg model parameters, the required abundance of "Oumuamua-like objects to explain its detection by Pan-STARRS, and basic facts about stars in the galaxy, and derive from these values the total mass of solar metallicity material required to be converted into exo-Plutos, to make the nitrogen model plausible."

What they found was that even under the most optimistic assumptions possible, the model fails by several orders of magnitude. In short, a star system would not have enough nitrogen ice to allow for such a robust population of exo-Plutos, which means that statistically, there simply

cannot be enough ISOs composed of N_2 to account for the fortuitous detection of "Oumuamua.

The model becomes even more unlikely when one considers how cosmic rays naturally erode ISOs. According to other recently published research, this process imposes a much shorter lifespan on ISOs than previously thought. Siraj says, "The primary issue with a nitrogen iceberg model is that producing the required population of such objects would require more than ten times the entire mass of stars in the Milky Way galaxy to be converted directly into exo-Plutos—and when we properly account for inevitable cosmic ray erosion of nitrogen icebergs, we need a thousand times the galaxy's stellar mass. These numbers render the nitrogen model untenable, since only a small fraction of the stellar mass in the galaxy goes towards the production of exo-Plutos."

In addition, Siraj and Loeb cite research that appeared shortly after their study appeared on the arXiv that casts doubt on the prevalence of nitrogen icebergs in our galaxy. In a study titled "Constraints on the Occurrence of "Oumuamua-Like Objects," which appeared in the October issue of *Bulletin of the American Astronomical Society*, authors Levine et al. argue that both the hydrogen iceberg and nitrogen iceberg hypotheses suffer from critical flaws.

Whereas the temperature requirements for the former theory make it untenable, the necessary formation efficiency does the same for the latter. In the end, they also determined that the mechanism for producing N_2 ice fragments (impacts on extrasolar Kuiper Belt analogs) was insufficient to create objects as large as "Oumuamua, and several orders of magnitude too low to create a population of 10^{14} objects.

What does this mean for "Oumuamua and the more "exotic" explanation of its origin—i.e., that it might have been an ET solar sail? For starters, it does not mean "it was aliens," nor is anyone in the astronomical

community making that assertion. But it does mean that this latest attempt to explain "Oumuamua in terms of natural phenomena does not fit all of the requirements—contrary to what many suspected previously.

"The nitrogen model is now off the table," said Siraj. "This means that the "Oumuamua mystery remains wide open, motivating even more strongly the study of objects like "Oumuamua in the future. This is the goal of the interstellar object branch of the Galileo Project, which I have the privilege of leading—to discover and characterize objects like "Oumuamua, and ultimately to understand their nature."

The Galileo Project (described in a previous article) is a non-profit research initiative founded by Prof. Loeb and Frank H. Laukien, a visiting scholar to Harvard University and the Chairman, President, and CEO of the Bruker Corporation (a manufacturer of scientific instruments). This multi-national, multi-institutional project is made of volunteer experts, including Amir Siraj as its director of interstellar object studies.

Together, they are working to bring the search for extraterrestrial intelligence (SETI) and technosignatures into the mainstream. They are joined by astronomers and observatories worldwide that are looking forward to the next few years when next-generation observatories will become operational in the coming years. This includes the Vera C. Rubin Observatory (formerly the Large Synoptic Survey Telescope), which is finishing construction in Chile and is expected to commence operations sometime next year (or possibly 2023).

Using its 8.4-meter (27 foot) mirror and 3200-megapixel camera, this observatory will conduct a 10-year survey, during which time it will observe an estimated 37 billion stars and galaxies. The Rubin Observatory will also explore our solar system and provide regular alerts concerning newly-discovered objects, including an estimated 5 ISOs a

month. NASA and the ESA are also developing missions that will rendezvous with ISOs in the near future and study them up close.

Once again, the true nature and origins of "Oumuamua's have confounded explanation. In many ways, this is good news. If there is one thing the entire astronomical community can agree on, it's the fact that "Oumuamua represents a class of previously-unknown objects. The fact that such objects pass through our solar system regularly (and that some end up staying) presents immense opportunities for future study.

To put it in TL:DR terms, we're not saying it was aliens. But either way, we are sure to find out very soon.

More information: Amir Siraj, Abraham Loeb, The Mass Budget Necessary to Explain `Oumuamua as a Nitrogen Iceberg. arXiv:2103.14032v4 [astro-ph.EP], arxiv.org/abs/2103.14032

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