Science Fact

Astronautical Explanations for 'Oumuamua

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The object we now call 'Oumuamua ("Scout") traversed the inner Solar System in September and October 2017, leaving at 27 kilometers per second, well over Solar System escape velocity, in the direction of Pegasus.[1] First thought to be a comet,[2] it was redesignated as an asteroid when it was estimated to be four hundred meters long and only forty meters across.[3]

The light-curves made clear that 'Oumuamua was oddly shaped and rotating, possibly tumbling.[4] The European Southern Observatory issued an artist's impression, depicting it as dark and spindle-shaped (Fig. 1, Page 31). The shape recalled various fictional spaceships, including the one attached to Halley's Comet in the 1985 film *Lifeforce*, based on the novel *The Space Vampires* by Colin Wilson, and the hollow 'prison-world' of Rhaam in Harry Harrison's story "Out of Touch" for *Jeff Hawke*, the world's longest-running SF comic strip, drawn by Sydney Jordan.[5] My own most popular SF story, "The Comet, the Cairn and the Capsule," imagined an interstellar comet passing through the inner Solar System[6], and my first commercial sale, "Derelict," was about an unmanned starship entering the Solar System.[7] There was a certain irony in that both of them became topical, fifty years later, at the same time.

The spindle image on the opposite page has dominated media coverage, although it may be seriously misleading. To begin with, the object's albedo was roughly 70%, as bright as the clouds of Venus or polished metal. In 2018 a team led by Dr. Michael Belton, of Belton Space Exploration Initiatives, Tucson, found that 'Oumuamua could have biaxial or even triaxial rotation, with periods ranging between 6.58 and 54.48 hours.[8] Eight hours was the best fit, at least for the primary rotation. While the spindle shape was likely to be correct if the periods were long, the best fit to the light-curve was "an extremely oblate spheroid" if they were shorter. At Belton's request, Dr. William K. Hartmann of the Planetary Science Institute, Tucson, painted 'Oumuamua as a thick disc (Fig. 2), like the "saucer section" of the Kuiper Belt object Ultima Thule (now "Arrokoth") was found to be in the New Horizons flyby of January 2019.

Fig. 1. "'Oumuamua spindle shape," M. Kommesser, European Southern Observatory, NASA.

As 'Oumuamua left the Solar System, it was slowly accelerating, perhaps because of outgassing due to solar heat belatedly penetrating to the interior.[9] That heat should have been detected by the Spitzer infrared space telescope, but wasn't, confirming that 'Oumuamua is highly reflective. Furthermore no emissions were observed, not even by the SOHO or STEREO solar-orbiting spacecraft, both of which would have detected dust or water vapor, nor by Spitzer, which would have detected carbon dioxide. For that acceleration to be the rocket effect of expelled material, 10–40% of the total mass would be lost, and the spin rate would inevitably be altered. No such alteration was observed. If instead the acceleration was due to radiation pressure, then 'Oumuamua would be much less massive than believed. The acceleration was inversely proportional to the

Fig. 2. "'Oumuamua as a thick disc," painted by Dr. William K. Hartmann, March 2018.

square of the distance from the Sun, and remarkably, it was even and unbroken despite the evidence of rotation and possible tumbling.[10] If the acceleration was due to any form of outgassing, it could not remain steady if the body tumbled, especially with a period as long as eight hours.

Sergey Mashchenko's study of the light-curves in 2019 produced a still more remarkable result. While the spindle shape wasn't entirely ruled out, the best fit appeared to be an extremely thin sheet (less than 1 mm thick) about 40 meters in diameter. Mashchenko gave that a 91% probability of being correct, with the spindle's probability at only 9%.[11] Shmuel Bialy and Abraham (Avi) Loeb of Harvard had already argued that 'Oumuamua could be an extraterrestrial artifact, most likely a solar sail,[12] and in his book *Extraterrestrial*, Loeb is more than a little annoyed that the cigar-shape still dominates almost all the published artwork.[13] David A.

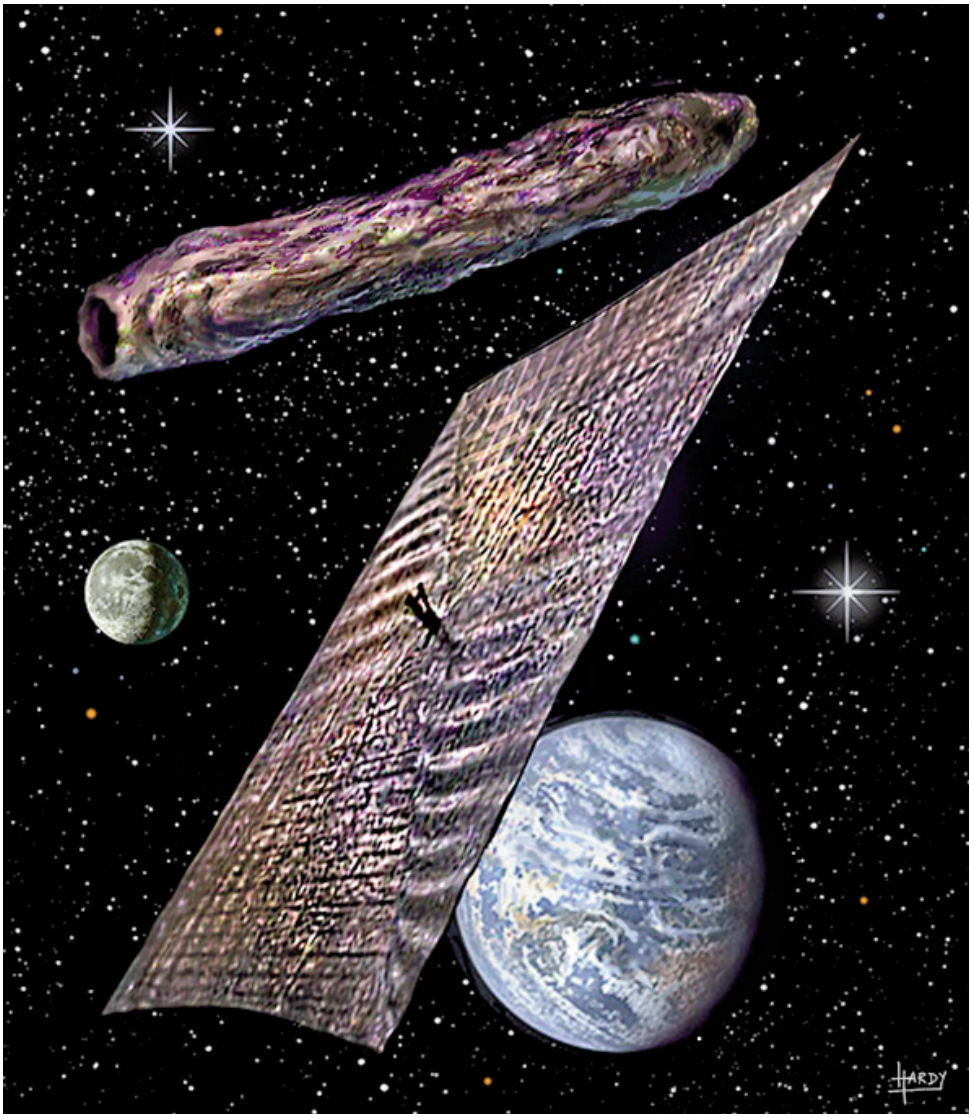

Fig. 3. "'Oumuamua—Spindle or Lightsail?" Painting by David A. Hardy, 2021

Hardy's illustration contrasts the two extremes (Fig. 3).

Because of his participation in Breakthrough Starshot, which proposes to send micro-lightsails to the nearer stars, Loeb is often dismissed with the German proverb, "To him who has a hammer, everything looks like a nail." He replies, "Not only do skilled carpenters most definitely *not* see nails everywhere, but they are trained to differentiate among those they do observe."[13] *Differentiate* is the key word: his point is that 'Oumuamua is not like anything we have seen before and needs a different kind of thinking, rather than trying to force it into familiar categories. It has no similarity to the two other interstellar objects detected since: one is an asteroid captured by the Solar System in its early history, [14] and the other is Comet Borisov, whose composition resembles comets of our Solar System, particularly Comet Hale-Bopp (1996).[15] Both Borisov and Hale-Bopp appear to have formed in the outer reaches of their planetary systems, but incorporating material originating from much further in, and have seldom if ever passed close to a star before.

Two "natural explanations" have tried to explain the non-detection of outgassing by STEREO, SOHO, and Spitzer. The first was that 'Oumuamua was composed of solid hydrogen, which would have been undetectable by the three spacecraft as it boiled off. Professor Loeb and his colleagues showed that such material would have been sputtered away by high-energy cosmic radiation during the timespan of an interstellar journey.[16] The second suggestion was that instead it was composed primarily of solid nitrogen, like parts of the crust of Pluto, and it had been expelled from a similar but much thicker surface, common in the formation of planetary systems.[17] On those suppositions, nitrogen icebergs would outnumber comets by 200 to 1 in interstellar space; yet only the second interstellar object was a conventional comet.

Professor Loeb quickly showed that if nitrogen icebergs were so common, the amount of nitrogen involved would be greater than is known to exist within stars.[18] Dr. Hartmann's painting of 'Oumuamua as a disc has been used in the media to illustrate the hypothesis, but when I asked him for permission to reproduce it, it turned out that he was unaware of that.[19] A nitrogen iceberg 'Oumuamua would be much thinner and shinier.

In any case, how likely it is that a crustal fragment of solid nitrogen would remain intact, while being blasted off a planetary surface at more than escape velocity? Water has been found in Martian meteorites—but not in solid form. Instead it's chemically bound into the rock, which nitrogen is not likely to be. Authors Jackson and Desch aren't proposing that the fragments are rock interspersed with solid nitrogen, but are actual nitrogen icebergs that survived ejection intact. They dismiss the extraterrestrial hypothesis, because we've never seen an ET solar sail, but we've never seen a nitrogen iceberg either, although there's enough nitrogen ice on Pluto and Triton for them to be generated by impacts today—if they can be. The nitrogen hypothesis requires 'Oumuamua to have shed 92% of its mass while passing through the Solar System, which makes the steady rotation still harder to explain. Jackson and Desch do recognize that in the configuration they envisage, 'Oumuamua's acceleration would have to be variable, but in another of their many assumptions they suppose that the effect would average out.[17] Obviously, it could, if the emission was from all over the sunlit surface (and only from there), or from small matching areas on both sides—but that doesn't mean that it would *even* out, giving a constant acceleration despite a rotation or tumbling period as long as eight hours.

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Astronautical Explanations

To explain the observed effects, 'Oumuamua has to maintain a constant surface area facing the Sun while also rotating as seen from Earth. Addressing that issue, Professor Loeb has recently noted that this requires "extreme geometry," suggesting that that the part visible from here may have been a solar collector for a solar-electric drive.[10] When I was asked to review the issue for the online journal *Concatenation*, a first idea that occurred to me was that 'Oumuamua might be a discarded hexagonal plate from a flexible Dyson sphere, an idea suggested by G. David Nordley as an alternative to breaking up the planets of a star system, to

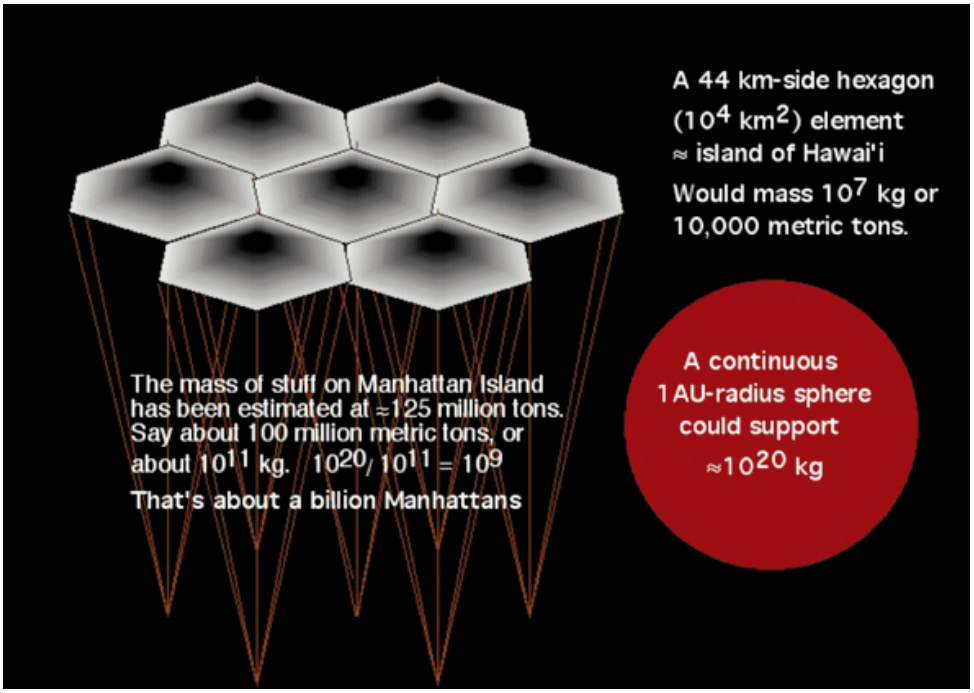

Fig. 4. G. David Nordley, flexible Dyson sphere element, design for "Empress of Starlight," (*Analog,* Nov/Dec 2018).

build a shell around their star, or a sphere of asteroids. In his novella "Empress of Starlight" (*Analog*, Nov/Dec 2018), he proposed a sphere of flexible, interlinked hexagons (Fig. 4), sustained by sunlight pressure and therefore self-correcting if disturbed.[20] Since the sphere isn't rotating, a hexagon that was cast loose for any reason would travel radially away from the star until it reached escape velocity or until the hole it left was plugged. Such a stray plate could be considered a solar sail, once it was adrift, although it wasn't intended to be one.

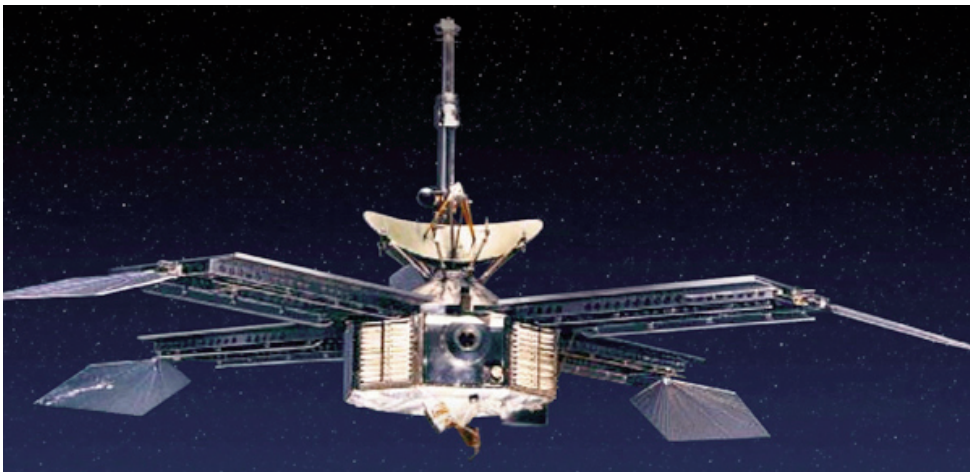

Fig. 5. Mariner 4 spacecraft with light-pressure tip-vanes (NASA, 1964).

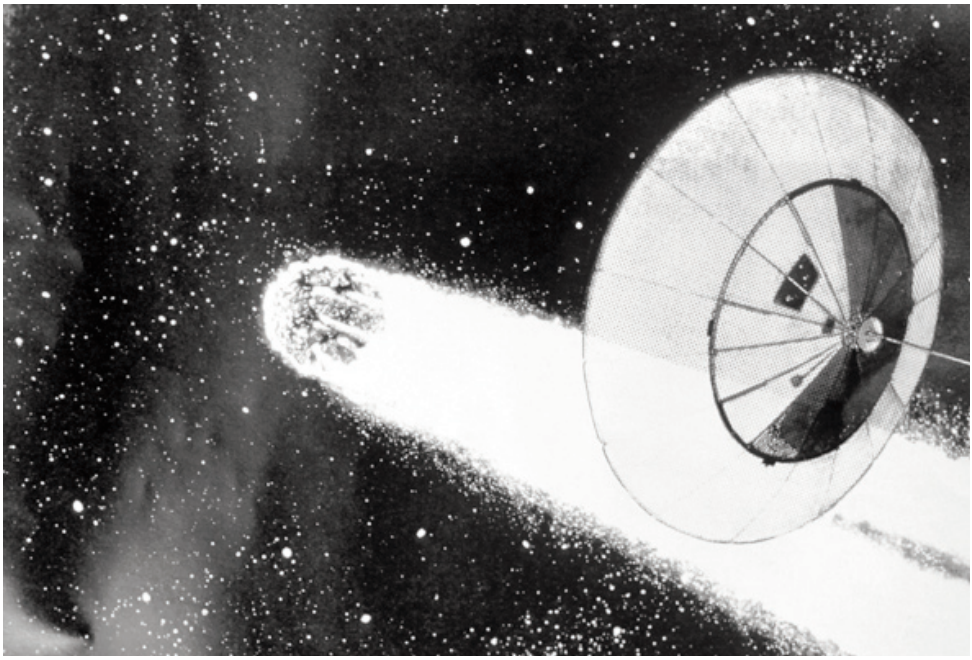

Fig. 6. Solaris "Comet-Chaser" by Sydney Jordan, design by Gordon J. Ross, for "Keep Watching the Skies." *Analog*, October 1994.

Mashchenko's paper had suggested that a plate with different reflectivity on its two sides might provide a better fit to the light-curves—but it would not explain the even acceleration, which Professor Loeb stresses eight times in his book.

Anyway, if discarded or shocked loose from its Dyson sphere, Nordley's plate would probably not remain perpendicular to the light-beam from the hole, unless it had attitude control, which it would not have needed when locked into place. Traveling around our Sun at close perihelion and then outward on a hyperbolic trajectory, it could not remain perpendicular to the incident sunlight. Its reflective area with respect to the Sun would keep changing, and the acceleration would vary in consequence.

To maintain a constant attitude to the Sun, a flat plate solar sail would need adjustable vanes at the corners, like those on the solar panels of the Mars probe Mariner 4 (Fig. 5, Page 34). They proved effective but unnecessary, so subsequent probes have relied on attitude control jets, not an option for 'Oumuamua. Although Mashchenko considered that better fits to the light-curves might be found if the sail wasn't flat, tip-vanes alone are not enough to explain the variations in 'Oumuamua's brightness; likewise a parabolic sail, like the Solaris Comet-Chaser designed by Gordon Ross [21] (Fig. 6), could change its orientation by adjusting the tension on shroud lines, or by varying the pressure in gas-filled ribs, but again could not explain the observed light-curves unless it was tumbling, in which case the acceleration would not be constant.

The cancelled U.S. mission to Halley's Comet might have been a flat sail with tip-vanes (Fig. 7, page 36), but a more advanced design called the Heliogyro would have had individually adjustable vanes and be spun to keep them under tension (Fig. 8, page 37). As it did so, the Heliogyro could turn most of them to the Sun for continuous propulsion, and angle others for navigation, ringing the changes as it rotated—just what 'Oumuamua would need to keep thrusting as it moved outward on its hyperbolic path, even though it was rotating and spin-stabilized. But the Heliogyro components would have to be active and mobile; at a pinch they might be self-correcting, but inevitably one starts to think of artificial intelligence.

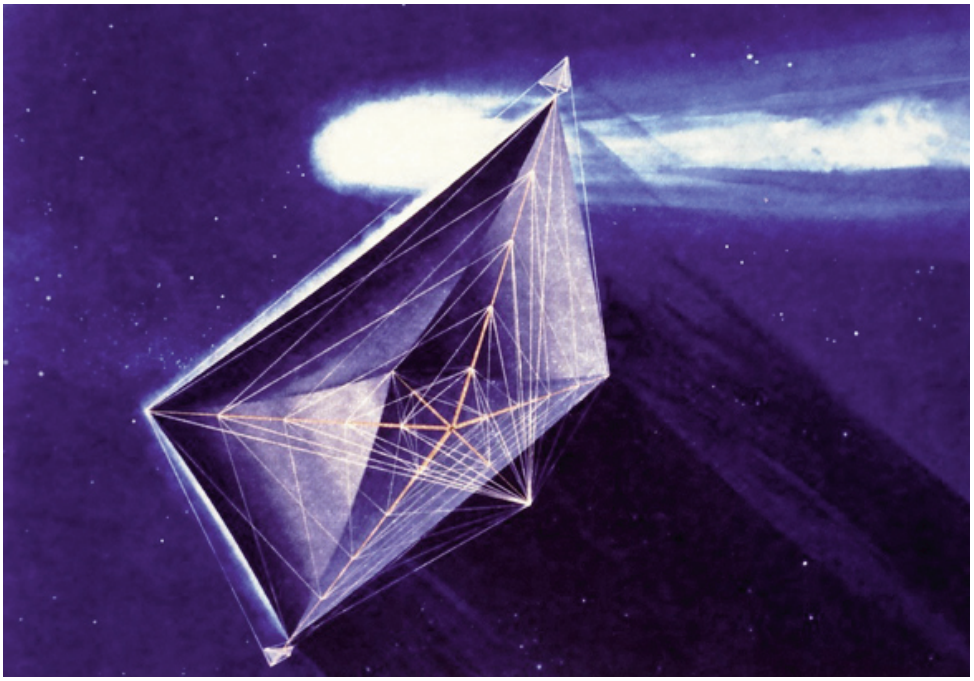

Fig. 7. Halley's Comet solar-sail design with tip-vanes, JPL-NASA 1979

Perhaps 'Oumuamua could be a faceted spheroid of hexagons, like a much smaller version of Gerry Nordley's Dyson Sphere. If the facets could both absorb and emit radiation as the spheroid rotated, one or more of them could be absorbing solar power while the reflected sunlight provided propulsion, and others could be tracking and transmitting data to any distant target on the celestial sphere, undetectable from here unless the beam happened to sweep across the Earth. To explain the light-curve fully, the spheroid might have to be patterned, as the Apollo spacecraft were for temperature control. Perhaps the hexagons could be individually articulated, with a fixed number facing the Sun at all times as the sphere rotated. Again Mashchenko was ahead of me, finding that a sphere with black and white hemispheres was a possible fit, which could be enhanced by more complex markings, but he didn't investigate further because 'Oumuamua's surface shows no sign of volatiles.[11]

Another proposed natural explanation, early on, was that 'Oumuamua could have disintegrated during perihelion passage, becoming a cloud of small particles. But when that happened with Comet ISON in 2013, the cloud dispersed and became invisible very quickly. If 'Oumuamua was a cloud, there has to be an explanation for its remaining together and remaining so bright. One possibility (ironic, in view of the "hammer" gibe above) is a cloud of Starshot-type mini-sails, under central control and maneuvering like a flock of starlings, a shoal of fish, or bats rising from a roost. At any given time, some could be under solar propulsion and others sending data, changing places as they overtake one another, looking like a single body when actually they're all in motion with respect to one another. Given the small size of the mini-sails, eight hours seems a reasonable turnover time for the continual front-to-back rearrangement, especially if the swarm's overall appearance from a distance is a thin disc. It is possible to imagine the individual processors acting to produce an apparently concerted effect, but central processing seems more likely. As with the spheroid or the heliogyro, we would have to ask, was that control purposeful? If the spacecraft or swarm was transmitting data to some distant collecting point, then it would have to be so, or intended to be.

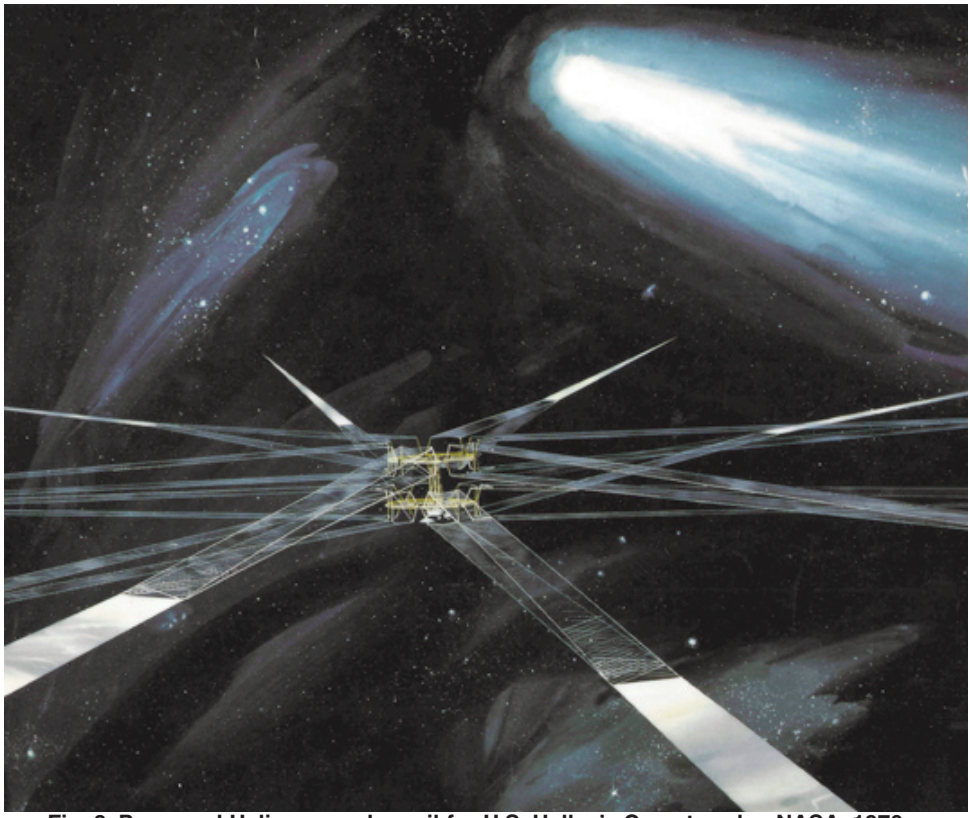

Fig. 8. Proposed Heliogyro solar sail for U.S. Halley's Comet probe, NASA, 1970s.

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Purposeful Explanations

Most sources say that 'Oumuamua came from very near Vega, in the constellation Lyra. Vega is a young blue-white star 25 light-years away, surrounded by what may be a disc of planet-forming material, and 'Oumuamua might have been ejected from there; but the agreement isn't all that close. 'Oumuamua came from Right Ascention. 279º.55, declination 33º.87, and the corresponding figures for Vega are 270º.61 and 38º.78. Using the Gaia satellite's all-sky astrometric survey, scientists at the Max Planck Institute identified four possible candidate stars, assuming the object hasn't changed course since escaping.[22] Closest to 'Oumuamua, about one million years ago, was the reddish dwarf star HIP 3757, at about 1.96 light-years, though with a relative speed of around 25 km/s. The other three candidate stars are no better fits. Those possible origins may not be significant, but where 'Oumuamua was immediately before it came into the Solar System probably is. Its entry point was very close to the Apex of the Sun's Way, the point toward which the Solar System is heading. There's some disagreement about the exact location of the Apex, but the closest fit to 'Oumuamua's entry point is at R.A. 277º.5, declination 30º, and its angular separation from it is only four degrees.

The Sun is moving through the interstellar medium with a velocity of twenty kps. When it began to respond to solar gravity, around 1605 AD,[23] 'Oumuamua had zero velocity up, down, or sideways with respect to us and to the galactic plane, but was coming toward us through the interstellar medium with a velocity of 11 kps, giving it a resultant velocity of 26.3 kps with respect to us.[24] It was effectively at the Local Standard of Rest, as Loeb describes it, but it is something of a relief that it wasn't precisely stationary in our frame of reference. If it were, and had

come precisely from the Apex of the Sun's Way, we might suspect that it wasn't from interstellar space at all, but from the future, like the tachyon signals of Gregory Benford's novel *Timescape.*[25]

Nevertheless, it was almost exactly in our path. Even a small diversion from that line would have allowed it to enter from anywhere on the leading hemisphere of the celestial sphere, causing it to pass the Sun more slowly and at a much greater distance. (My story, "The Comet, the Cairn and the Capsule," envisaged an interstellar comet passing further from the Sun and taking six months to cross the inner Solar System.)[6] In a recent online discussion, it was put to me that 'Oumuamua's reflectivity could be explained if it previously had a dark crust, which flaked off during the approach to the Sun. But spalling on that scale would surely affect the orbit, which would have given 'Oumuamua a different apparent point of origin, of no particular significance. The loss of the supposed crust might make it *look* as if it came from the Apex; the odds against it are very large, but it's not inconceivable—but that doesn't, or shouldn't, mean that therefore it *must* be what happened. If 'Oumuamua was actually floating virtually at rest in the interstellar medium, and so closely aligned with the Sun's path, that's either an extraordinary coincidence or it implies deliberate placing. It might tie in with Loeb's ideas that it could be a buoy, or an interstellar beacon—although either would imply that it is indeed still functional. Then it had either been there for a very long time or it was left in the Sun's way by accident, which negates purpose, shows astonishing carelessness, and is coincidence piled upon coincidence.

If 'Oumuamua's path through the Solar System was deliberately chosen, did the supernovae shortly beforehand (Tycho's Star in 1572 and Kepler's Star in 1604) provide some useful fine-tuning of the approach? With 400 years to take effect, even a small impulse might make quite a difference to the apparent point of entry. But where 'Oumuamua is going as a result of that gravitational slingshot is highly significant. In 29,000 years 'Oumuamua will pass the star Ross 248 at 0.459 pc (1.5 light-years) with a velocity of 104 km/s. For living beings that wait would be unconscionable, but for an artificial intelligence the time spent in transit is nothing—literally, neither here nor there. But in that time, if the sail or the swarm can adjust its orientation to starlight, probably 'Oumuamua can tack to another close encounter—the average shift required is only 3.337 Astronomical Units per year.

Ross 248 is currently one of the closest stars to the Sun, at 3.15 parsecs [10.269 light-years] in Andromeda—but in 33,000 years from now, it will be the closest star to the Solar System, passing us at 3.024 light-years.[26] The only closer stars which 'Oumuamua might have targeted would be Proxima or Alpha Centauri. Ross 248 is an M5 red dwarf, and therefore likely to have planets, though none have been detected yet. It makes one wonder what 'Oumuamua or its creators may know about it that we don't.

Intercepting 'Oumuamua was out of the question, at such short notice, but chasing it is possible with near-future technology (Project Lyra). [27] It won't be beyond the Sun's pull until 2430,[23] which is surely time enough to catch up with it. The case for doing it now seems a great deal stronger. At the very least—whatever Professor Loeb's detractors may say—it seems the story is still far from over.

References

1. Deborah Byrd, "Small Object Visits from Beyond the Solar System," *EarthSky*, October 29, 2017. https://earthsky.org/space/a2017u1-comet-asteroid-interstellar-beyond-solar-system.
2. Fraser Cain, "Has the First Interstellar Comet Been Discovered?", *Universe Today*, October 26, 2017. https://www.universetoday.com/137621/first-interstellar-comet-discovered.
3. Matt Williams, "Updates on 'Oumuamua, Maybe It's a Comet, Actually. Oh, and No Word from Aliens," *Universe Today*, December 19, 2017. https://www.universetoday.com/138108/updates-oumuamau-maybe-comet-actually-oh-no-word-aliens.
4. Matt Williams, "That Interstellar Object Is Probably Pretty Strange Looking," *Universe Today*, November 20, 2017. https://www.universetoday.com/137944/interstellar-asteroid-probably-pretty-strange-looking.

5. Harry Harrison, Sydney Jordan, "Out of Touch," *Jeff Hawke* strip*, Daily Express,* October 4 1957–April 5 1958, reprinted in *Jeff Hawke's Cosmos,* Vol. 5 No. 2, June 2009.
6. Duncan Lunan, "Comet, Cairn and Capsule," *Worlds of If,* July-August 1972.
7. Duncan Lunan, "Derelict," *Amazing*, April 1974.
8. Michael Belton et al, "The Excited Spin State of 1I/2017 U1 'Oumuamua," *Astrophysical Journal Letters*, 856:L21, March 26, 2018.
9. Deborah Byrd, "Interstellar Asteroid Update: It's a Comet!", *EarthSky*, June 28, 2018. https://earthsky.org/space/interstellar-asteroid-oumuamua-is-really-a-comet.
10. Todd F. Sheerin and Abraham Loeb, "Could the Interstellar Object 'Oumuamua Be a Solar Thermal Propulsion Vehicle?", *Journal of the British Interplanetary Society*, 74, 11, 427-432, November 2021.
11. Sergey Mashchenko, "Modelling the light curve of 'Oumuamua: evidence for torque and disc-like shape," *Monthly Notices of the Royal Astronomical Society*, 489, 3, 3003-3021, August 29, 2019.
12. Abraham Loeb, "How to Search for Dead Cosmic Civilizations," *Scientific American*, September 27, 2018; Shmuel Bialy, Abraham Loeb, "Could Solar Radiation Pressure Explain 'Oumuamua's Peculiar Acceleration?", *Astrophysics*, October 30, 2018; Matt Williams, "Could 'Oumuamua Be an Extra-Terrestrial Solar Sail?," *Universe Today*, October 31, 2018. https://www.universetoday.com/140391/could-oumuamua-be-an-extra-terrestrial-solar-sail; Paul Scott Anderson, "Could 'Oumumua Be an Interstellar Light Sail?", *EarthSky*, November 6, 2018. https://earthsky.org/space/could-oumuamua-be-an-alien-lightsail.
13. Avi Loeb, *Extraterrestrial, The First Sign of Intelligent Life Beyond Earth*, Haughton Mifflin Harcourt, 2021.
14. Matt Williams, "'Oumuamua Was Just the Beginning: Astronomers Find an Interstellar Asteroid Orbiting Retrograde Near Jupiter." https://www.universetoday.com/139285/oumuamua-was-just-the-beginning-astronomers-find-an-interstellar-asteroid-orbiting-retrograde-near-jupiter; "The Solar System Probably Has Thousands of Interstellar Asteroids," *Universe Today*, May 23, 2018 and February 7, 2018. https://www.universetoday.com/138494/solar-system-probably-thousands-captured-interstellar-asteroids.
15. Anon, "News: Interstellar Comet Was Exceptionally Pristine," *Astronomy Now*, 35, 5, 20 (May 2021).
16. Thiem Hoang, A. Loeb, "Destruction of Molecular Hydrogen Ice and Implications for 1I/2017 U1 ('Oumuamua)," *Astrophysical Journal Letters*, 889, 2, August 17, 2020.
17. Alan P. Jackson and Steven J. Desch, "1I/'Oumuamua as an N_2 Ice Fragment of an Exo-Pluto Surface: I. Size and Compositional Constraints," *Journal of Geophysical Research: Planets*, 126, 2021; "1I/'Oumuamua as an N_2 Ice Fragment of an Exo-Pluto Surface II: Generation of N_2 Ice Fragments and the Origin of 'Oumuamua," *Journal of Geophysical Research: Planets*, 126, 2021 Anon: "News: Was 'Oumuamua a Nitrogen Iceberg from a Pluto-like Planet?", *Astronomy Now*, 35, 5, 20, May 2021.
18. Fraser Cain, "Interview: On 'Oumuamua, Aliens and Astrophysics, with Dr. Avi Loeb," *Universe Today*, April 9, 2021. https://www.youtube.com/watch?v=m7h46sP1Euk.
19. William A. Hartmann, personal communication, June 14, 2021.
20. G. David Nordley, "Empress of Starlight," *Analog* Nov/Dec 2018; "Astronomical and Astronautical Concepts Used in 'Empress of Starlight,'" personal communication, 2021.
21. Duncan Lunan, "Keep Watching the Skies," *Analog*, October 1994; *Incoming Asteroid! What could we do about it?*, Springer, New York, 2013, Chap. 5.
22. Coryn A.L. Bailer-Jones, Davide Farnocchia, Karen J. Meech, Ramon Brasser, Marco Micheli, Sukanya Chakrabarti, Marc W. Buie, Olivier R. Hainaut. "Plausible Home Stars of the Interstellar Object 'Oumuamua Found in Gaia DR2," *Astronomical Journal*, October 2018.
23. Anton Petrov, "'Oumuamua Finally Explained Using a Brilliant Analysis," March 2021. https://www.youtube.com/watch?v=hkZRUs8A_9Q.
24. Erik Mamajek, "Kinematics of the Interstellar Vagabond 1I/'Oumuamua (A/2017 U1)," *Research Notes of the American Astronomical Society*, 1, 1, November 2017.

25. Gregory Benford, *Timescape*, Simon & Schuster, New York, 1980.
26. "Ross 248," https://en.wikipedia.org/wiki/Ross_248.
27. Matt Williams, "Project Lyra, a Mission to Chase Down That Interstellar Asteroid," *Universe Today*, November 23 2017. https://www.universetoday.com/137960/project-lyra-mission-chase-interstellar-asteroid-1.