‘Oumuamua is not Artificial
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ABSTRACT
I summarize evidence against the hypothesis that ‘Oumuamua is the artificial creation of an advanced civilization. An appendix discusses the flaws and inconsistencies of the “Breakthrough” proposal for laser acceleration of spacecraft to semi-relativistic speeds. Reality is much more challenging, and interesting.

1. INTRODUCTION
Recently, the popular press (New Yorker 2021; NYTimes 2021) has discussed the hypothesis, promoted in a popular book (Loeb 2021), that ‘Oumuamua, the interstellar object that transited the Solar System in 2017 (‘Oumuamua 2021), is the product of an “alien” civilization, presumably reconnoitering the Solar System, rather than a natural fragment (a “Jurad”, an asteroid or comet nucleus) that escaped from an extra-Solar planetary system (Hansen & Zuckerman 2017). There are several reasons why the alien civilization hypothesis is not credible (‘Oumuamua ISSI Team 2019):

2. RATE
The Panstarrs system detected one such object in its few years of operation. A second interstellar object, clearly cometary, has also been detected. There is some controversy over whether ‘Oumuamua is asteroidal or cometary: imaging imposed very strict upper limits on its rate of outgassing, but non-gravitational acceleration has also been claimed (Micheli et al. 2018) (disputed by Katz (2019)). Loeb (Loeb 2021) attributes this to the effect of Solar radiation or the Solar wind on an artificial structure with a low ballistic coefficient. However, Bialy and Loeb (Bialy & Loeb 2018) find that the reported acceleration would imply a thickness and ballistic coefficient orders of magnitude less than those considered for Solar sails or for laser-accelerated spacecraft (Breakthrough 2016).

‘Oumuamua had a velocity, far from the Solar System but with respect to it, of about 26 km/s. The smallest credible distance of a sending civilization is about 10 light years (this volume contains 10–20 stars, enough that if all the possible optimistic assumptions are made it might contain an advanced civilization; the closest extra-Solar star is about 4 light years away). The transit time from that distance would be about $10^5$ years$^1$.

A decision to launch toward our Solar System must have been made $\sim 10^5$ years ago. Even if one imagines the launching civilization capable of arbitrarily good observations, and able to infer from the state of the Earth then that a technological civilization worth monitoring, alerting or contacting would evolve in $\sim 10^5$ years, it could not predict the chronology of Panstarrs or a similar system accurately. Hence, unless it (or we) have been unusually lucky, they must have launched $\gg 10^4$ such probes. This would be extraordinarily inefficient.

3. WHY FLYBY?
A flyby is an inefficient way to collect data and an unreliable way to attract notice. As our space programs know, if you want to collect information about a body, send an orbiter or a lander. There is no compelling argument against the presence of artificial orbiters in the Solar System, or against landers on any body other than the Earth. ‘Oumuamua was neither.

4. TUMBLING
‘Oumuamua tumbled: its light curve was not periodic. This is unusual, but not unprecedented, among asteroids. Internal friction damps tumbling, but slowly in rocky material at low asteroidal temperatures and even more slowly at

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$^1$ The orbit of ‘Oumuamua has been extrapolated backward and does not approach any star and possible planetary system for much longer (Gaidos, Williams & Kraus 2017), but we must allow for the possibility of a non-ballistic trajectory powered by an on-board ion engine and nuclear reactor.
the interstellar temperatures to which ‘Oumuamua was long exposed. A thin sail must be composed of flexible material or hinged (otherwise, it could not be launched and deployed later). Such materials have large internal friction, as do hinges, and any tumbling might be damped rapidly (although we cannot be confident of the properties of a material to be invented by an advanced civilization).

5. FURTHER OBSERVATIONS

Loeb suggests a network of space telescopes to image any future interstellar transiter (and more ordinary Solar System objects!). A diffraction-limited 10 m aperture has a resolution of about 50 nrad in blue light. At a distance of 1 AU that corresponds to a resolution of about 8 km, far too poor to resolve an object hundreds of meters across like ‘Oumuamua. Interferometry can do better, of course, but we cannot be confident of an unambiguous difference between the visibility functions of natural and hypothetical artificial interstellar objects.

It is technically feasible to send probes to fly by such intruders. Panstarrs detects roughly one per year (and a future system likely many more). Velocity increments of 10 km/s, achievable in minutes with chemical propellants (slow acceleration by ion engines would not be sufficient) would enable interceptors stored in Solar orbits to fly by a significant fraction of interstellar intruders. Close-up imaging would be possible, or even collision whose debris could be analyzed spectroscopically from Earth.

6. CONCLUSION

The hypothesis that ‘Oumuamua is the product of an advanced civilization does not resolve any previously inexplicable conundrum, the necessary justification for a speculative hypothesis. ‘Oumuamua is entirely explicable as a fragment expelled from its parent planetary system by gravitational interaction (Hansen & Zuckerman 2017), at any time in the history of the Galaxy.

The “Breakthrough” project has argued that it is feasible to accelerate, using lasers, spacecraft of low ballistic coefficient (sails) to semi-relativistic speed, orders of magnitude greater than the observed speed of ‘Oumuamua; this is discussed in the Appendix.
APPENDIX

A. LASER-ACCELERATED SPACECRAFT

The Breakthrough project has suggested (Breakthrough 2016) that an advanced civilization may be capable, using a laser, of accelerating a spacecraft of low mass and very low ballistic coefficient, to semi-relativistic speeds. Their analysis is neither quantitative nor detailed. Here I take their parameters of a 1 g spacecraft with $A = 10 \text{ m}^2$ sails composed of 300 $\mu\text{m}$ thick Al foil, accelerated to $0.2c$ in $10^{11}$ cm by radiation pressure. The sails have an areal mass loading (ballistic coefficient) of $10^{-5} \text{ g/cm}^2$ and a mass of $m = 1$ g; larger ratios of sail to payload mass produce only marginal increases in performance. The number of spacecraft is not defined beyond “thousands”, nor is it stated whether they are all to be accelerated simultaneously or one at a time; the latter reduces the peak power requirement but, unless the initial injection (by conventional means) is into geostationary orbit, requires complex timing and orbital manipulation. I will assume the latter.

A.1. Apertures

For $1\mu$ laser light this corresponds to diffraction limited apertures of about 300 m; the requirement is to focus light at $10^{11}$ cm onto a 3 m sail.

A.2. Focusing

A 1 g spacecraft traveling at $0.2c$ has a kinetic energy of $1.8 \times 10^{19}$ ergs. A 100 GW laser operating for 120 s radiates $1.2 \times 10^{20}$ ergs. The required acceleration time is $mcv/2P$, where $P$ is the laser power, or 90 s. The distance traveled is $(mc/4P)v^2 = 2.7 \times 10^{11}$ cm, a few times greater than the nominal $10^{11}$ cm specified by Breakthrough. This demands more performance from the focusing system.

A.3. Laser power

Power engineers (quite apart from laser designers) will find the requirement of delivering $100/\epsilon$ GW, where $\epsilon$ is the laser efficiency, formidable. Fortunately, the lasers can be distributed over much of a hemisphere of the Earth if the laser acceleration begins from geostationary orbit. Still, it would require use of a large portion of the US electrical generating capacity for an hour to accelerate even one 1 g spacecraft.

A.4. Vaporization

The sail will vaporize.

A.4.1. Thermal loads

The energy expended to accelerate a 1 g spacecraft is $Pt$ or $9 \times 10^{19}$ ergs. This should be compared to the latent heat of melting of 1 g of aluminum of $\sim 10^{19}$ ergs. If even $10^{-10}$ of the incident laser energy is absorbed, the sail melts. This estimate is pessimistic because it ignores radiative cooling of the sail, though metals are poor radiators for precisely the reason they are good reflectors, but it indicates a formidable problem. No metal has a reflectivity higher than 0.9999. In other words, 100 GW over $10 \text{ m}^2$ is 1 MW/cm$^2$, about $10^7$ times the intensity of sunlight, and several orders of magnitude times intensities known to vaporize metallic surfaces.

A.4.2. Radiative cooling

Including radiative cooling in steady state (rapidly achieved for a very thin sail) the sail’s temperature is

$$T = T_{bb}(\epsilon_{laser}/\epsilon_{th})^{1/4} \quad (A1)$$

where $T_{bb}$ is the gray-body temperature $[P/(A\sigma_{SB})]^{1/4} = 20000 \text{ K}$, $A$ is the sail area ($10 \text{ m}^2$), $\sigma_{SB}$ is the Stefan-Boltzmann constant, $\epsilon_{laser}$ is the sail’s absorptivity (equal to its emissivity) at the laser wavelength ($1\mu$) and $\epsilon_{th}$ is the sail’s emissivity at MWIR and LWIR wavelengths corresponding to its equilibrium temperature. The ratio of emissivities is greater than unity because metals are better reflectors (and worse emitters) at longer wavelengths and because very thin metal layers have smaller emissivities than thick layers. Hence thermal emission cannot save the sail from thermal destruction if its absorptivity exceeds the unrealistic value of $10^{-10}$. 

A.4.3. Better radiator?

This problem might be mitigated if the metal were backed with a thin layer of an effective (necessarily insulating) radiator. Supposing a black radiator and an overoptimistic \( \epsilon_{\text{taser}} = 10^{-3} \) yields \( T = 2050 \) K, still exceeding the melting point of Al of 933 K. Each of these assumptions is unrealistically optimistic (the actual emissivity at 1\( \mu \) of Au is 0.03 and that of Al 0.07), and ignores the difficulty of fabrication.

A.5. Mass of the sail

The force on the spacecraft \( F = 2P/c = 7X10^{7} \) dynes. This must be transmitted from the sail to its compact 1 g payload. The payload dimensions are not specified, but one thinks of an integrated circuit with area 10 cm\(^2\). The stress in the sail where it is attached to the payload is \( F/Ch \), where \( C \) is the payload circumference and \( h \) the sail’s thickness. For \( C = 20 \) cm and \( h = 300 \) Å the stress is \( > 1000 \) kbar, \( > 300 \) times the strength of aluminum. Making the sail thicker makes it more massive; the minimum mass is obtained if the thickness varies inversely as the distance from the payload. A simple calculation shows that the sail mass is \((2P/c)(\rho/\sigma)R\), where \( \rho \) and \( \sigma \) are the density and strength of the sail, \( \rho/\sigma \approx 10^{-9} \) s\(^2/cm^2\) and \( R \) is the sail’s radius. The result is that the sail’s mass \( M \approx FR\rho/\sigma \).

The hypothetical 10 m\(^2\) \((R = 1.7 \) m\) sail would have a mass of 14 g, inconsistent with the required acceleration that assumed a 1 g payload and ignored the mass of the sail itself.

To reduce the sail mass to that of the payload for an acceleration \( a \) would require \( R \leq \sigma/(a\rho) \), which for the assumed \( a = 7 \times 10^7 \) cm/s\(^2\) and the parameters of Al would require \( R \leq 14 \) cm. The corresponding area would be \( \leq 0.06 \) m\(^2\), much less than the assumed 10 m\(^2\). The laser intensity would then be at least 170 times greater than that previously assumed, that would already exceed the tolerable heat load on the sail. The proposed design is not self-consistent.

A.6. Utility?

How does a 1 g spacecraft carry any useful sensors? How can it determine what is around \( \alpha \) Centauri (presumably the interest is in habitable planets)?

A.7. Data return?

How can a 1 g spacecraft transmit any detectable signal back to the Earth from a distance of 4X10\(^{18}\) cm?

A.7.1. Signal strength

A half-wave dipole antenna, using a hypothetical 100 W of power obtained from photocells illuminated by the parent star of the planet studied, would produce \( 10^{-36} \) W/cm\(^2\) at the Earth at 1 pc distance, or \( 10^{-26} \) W in a 1 km\(^2\) array. For a bandwidth \( B \) the corresponding temperature would be \( \sim 1(1 \text{ Hz}/B) \) mK, that may be compared to present-state-of-the-art antenna temperatures \approx 20 K. Extensive coherent integration would be required to discriminate the signal from the incoherent thermal cosmic 3 K background and the thermal emission of the parent star. A high gain transmitting antenna would improve these values, but would be difficult to include within a 1 g mass budget.

A.7.2. Visible light?

An optical system could collimate the beam, but at the price of quantum noise more than \( 10^6 \) times greater than at 100 MHz, and folding such optics into a 1 g spacecraft would be a formidable problem. A diffraction-limited 1 m aperture would increase the received intensity by \( 10^{12} \) compared to a dipole, or \( 10^{-18} \) W in a 10 m telescope, or 3 photons/s. It is difficult enough to detect planets, reflecting \( 10^{17} \) W of visible light (giving the same brightness as the hypothetical diffraction-limited aperture transmitting \( 10^5 \) W) near stars.

A.8. Relays

The total power required to transmit a signal may be reduced by a factor of about \( N \) if a relay chain of \( N \) equally spaced transceivers is established along the transmission path; the power at each transceiver is reduced by a factor of about \( N^2 \). These transceivers would be in deep space where the only plausible power source would be reactors, and the requirement of achieving criticality implies minimum masses of tens of kg each. Decay of isotopes like \( ^{90}\text{Sr} \) and \( ^{137}\text{Cs} \), with half-lives of decades, produces \( \sim 1 \) W/g, that can only be converted to electricity with efficiency of a few percent. To be useful, this massive relay chain would have to be deployed behind the high-velocity probe at speeds approaching that of the probe; deployment at conventional spacecraft speeds \( \sim 30 \text{ km/s} \) would require tens of thousands of years to reach the nearest stars at distances of \( \sim 1 \) parsec.
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