Interstellar News

John I Davies reports on recent developments in interstellar studies

A Dyson Sphere around a black hole?

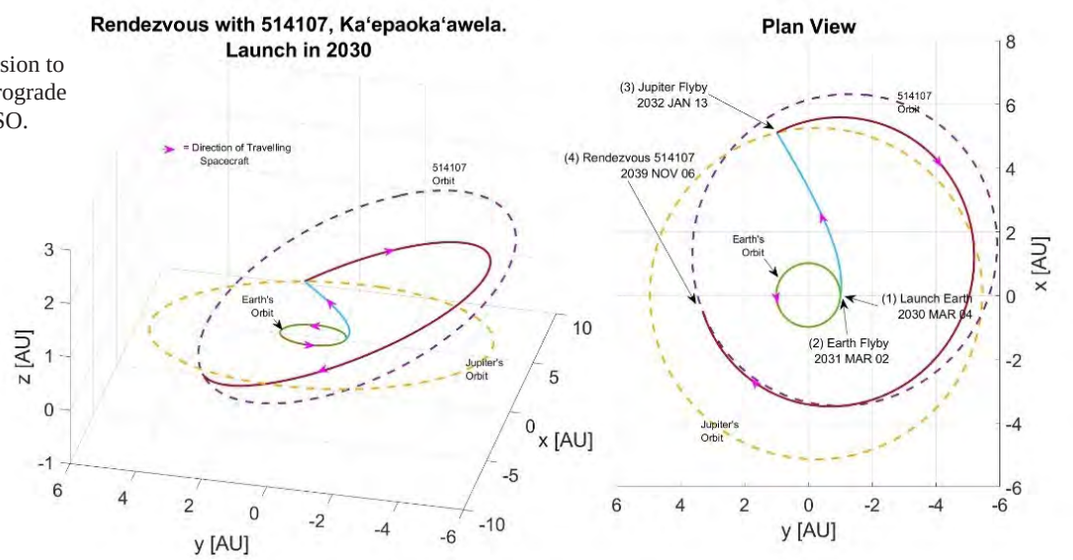
Principium readers are likely to be familiar with Freeman Dyson's concept of a sphere around a star capturing all of its radiant energy [1]. Researchers in Taiwan, UK and Turkey have been investigating the feasibility of a black hole as an alternative energy source [2]. The possible thermodynamics is complex. A black hole may be "colder" than the cosmic microwave background (CMB - the radiation remaining from the Big Bang) and the heat flow could thus be inwards or outwards depending on the temperature of the CMB (now or in the earlier universe) and the black hole. But a heat engine works as long as there is a temperature difference. Energy sources might also include -

- Hawking radiation which, in theory, causes a black hole to "boil away" its mass.
- Radiation from the accretion of matter falling into the black hole.
- Radiation from the corona (like our solar corona) of plasma around the black hole.
- Plasma jets from the axes of rotation of the black hole.

The paper considers which variants of a Dyson sphere might be used by developing civilisations and the characteristic radiation we might expect this to detect. They conclude that, in terms of usable energy "a black hole can be a promising source and is more efficient than harvesting from a main sequence star".

Interstellar Now! - in Advances in Space Research

In our November issue P31 last year we announced a preprint *Interstellar Now! Missions to and Sample Returns from Nearby Interstellar Objects*. The paper *Interstellar Now! Missions to Explore Nearby Interstellar Objects* has now been published in Advances in Space Research [3]. Adam Hibberd gave a summary of the work in *Interstellar Objects and Sample Returns* in that November issue.
The paper makes the case for in situ exploration of Interstellar Objects (ISOs) to allow the direct determination of both their structure and their chemical and isotopic composition, enabling an entirely new way of studying small bodies from outside our solar system - describing flyby, rendezvous and sample return missions.



Possible rendezvous mission to Ka'epaoka'awela - a retrograde object and possibly an ISO.

Launch 2030.

Credit: Hein *et al*

[1] *Search for Artificial Stellar Sources of Infrared Radiation*, Freeman Dyson, 1960 fermatslibrary.com/s/search-for-artificial-stellar-sources-of-infrared-radiation.

See also Dmitry Novoseltsev *Engineering New Worlds: Creating the Future - Part 3* Principium 18 August 2017.

[2] *A dyson sphere around a black hole,* Tiger Yu-Yang Hsiao *et al*, Monthly Notices of the Royal Astronomical Society July 2021 academic.oup.com/mnras/advance-article-abstract/doi/10.1093/mnras/stab1832/6312510. Open publication at arxiv.org/abs/2106.15181

[3] *Interstellar Now! Missions to Explore Nearby Interstellar Objects*, Andreas M Hein (Université Paris-Saclay) T Marshall Eubanks (Space Initiatives Inc) Manasvi Lingam (Florida Institute of Technology) Adam Hibberd (i4is) Dan Fries (University of Texas at Austin) Jean Schneider (Observatoire de Paris) Pierre Kervella (Observatoire de Paris) Robert Kennedy (i4is) Nikolaos Perakis (Space Initiatives Inc) Bernd Dachwald (FH Aachen University of Applied Sciences), Advances in Space Research, © 2021 COSPAR. Published by Elsevier BV. www.sciencedirect.com/science/article/abs/pii/S027311772100538X?via%3Dihub#ab005

Solar sail to an ISO

In *A Fast Response Mission to Rendezvous with an Interstellar Object* [1] Darren Garber and colleagues propose a solar sail-propelled small satellite using ideas from a proposed technology demonstrator of a mission to reach the focal region of the solar gravitational lens line - which begins at 550 astronomical units (AU) - note Voyager 1 and 2 are at 152 and 126 AU - so this is a demanding prototype. The authors anticipate that a solar sail in a close holding orbit around the Sun would be able to "launch on warning" when an ISO orbit is confirmed. This rapid response would allow an intercept within 10 AU from the Sun. A small vehicle could be reproduced so that many successive intercepts were possible.

Gigawatt laser arrays and the atmosphere

Numerical simulation "pipeline"

Inputs: Directed energy phased array (DEPA) and atmospheric models

Note the "beacon" signal which the target produces, illuminating the DEPA after being perturbed by the atmosphere.

Credit: Hettel *et al*, UCSB and MIT

Gigawatt laser arrays and the atmosphere

A team at University of California Santa Barbara (UCSB) have been studying the propagation of laser light from the sort of large Earth-based laser arrays implied by the plans of Breakthrough Starshot. Their paper *Beam propagation simulation of phased laser arrays with atmospheric perturbations* [2] demonstrates that a large array at a high altitude site can produce a stable diffraction-limited spot on a space-based target for Fried length > 10 cm [3] at angles up to 60 degrees from the zenith depending on atmospheric conditions. The paper looks, to this optically naive reader, like a good overview of the maths and simulation requirements for large terrestrial laser arrays. Most of the problems addressed would disappear for a space based system though the authors says "cost and accessibility make it far more practical to start with ground based systems". The paper assumes the target is stationary so it would not necessarily apply to fast moving targets such as interstellar sailcraft. The method used is a numerical simulation "pipeline" which corresponds to the path from source to target.

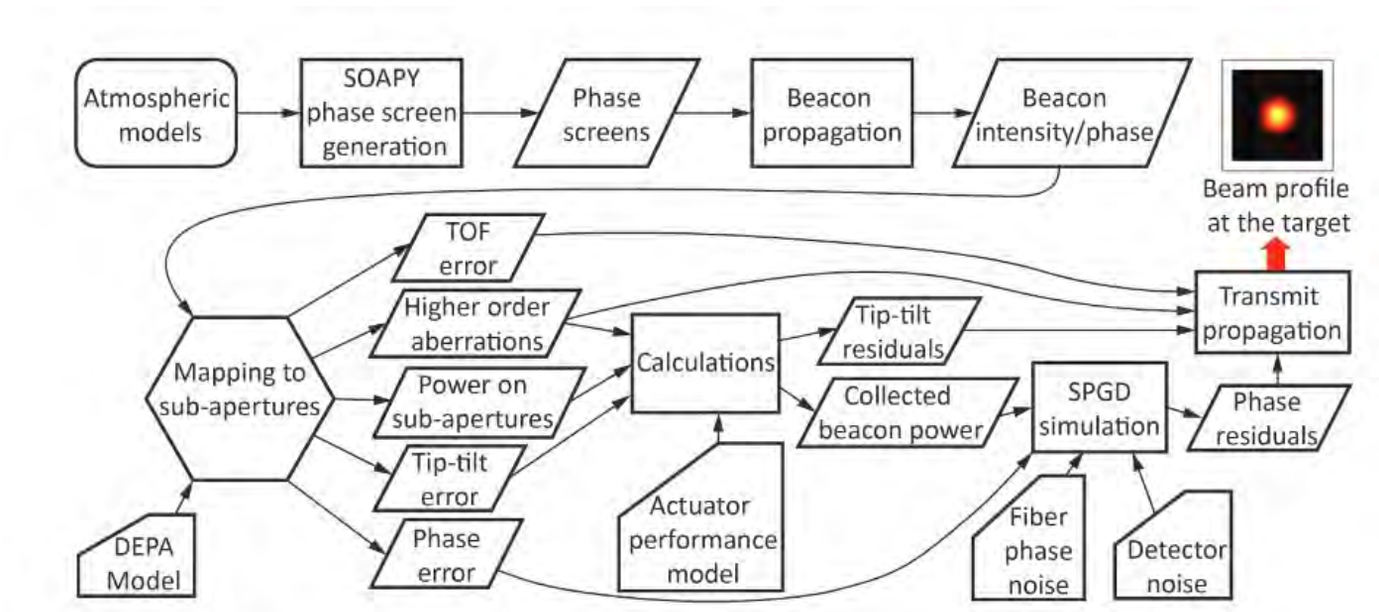


Fig. 2. Simulation flow diagram including the various processes and noise inputs.

[1] *A Fast Response Mission to Rendezvous with an Interstellar Object* Darren Garber (Xplore Inc), Louis D Friedman (The Planetary Society), Artur Davoyan (UCLA), Slava G Turyshev (JPL), Nahum Melamed (Aerospace Corporation), John McVey (JPL) Todd F Sheerin (Aerospace Corporation) arxiv.org/abs/2106.14319

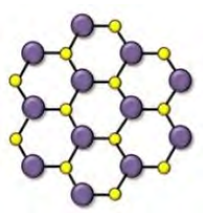
[2] *Beam propagation simulation of phased laser arrays with atmospheric perturbations*, Will Hettel, Peter Meinhold, Jonathan Y Suen, Prashant Srinivasan, Peter Krogen, Allan Wirth, Philip Lubin (all UCSB apart from Allan Wirth, MIT) arxiv.org/abs/2107.00568,

[3] The Fried length or atmospheric coherence length approximates to the size of the atmospheric turbulence cell through which light passes (see L10: Adaptive Optics slittlefair.staff.shef.ac.uk/teaching/phy217/lectures/telescopes/L10/index.html).

Optimise acceleration & thermal for lightsails

Gigawatt laser banks can deliver the acceleration to reach substantial fractions of light speed but nothing in physics and engineering is 100% efficient and the result in this case, as usual, is unwanted heating. In *Thermo-accelerative optimization of relativistic lightsails,* Brewer *et al* [1], researchers at UCLA and the University of Pennsylvania demonstrate optimisation of both acceleration and thermal performance using a sail with multilayer connected photonic crystal of layered 2H-phase Molybdenum Disulphide and crystalline Silicon Nitride. They point out that, as the sail accelerates, the received laser light is red-shifted in the sail's frame of reference - it is receding just like most of the galaxies. The requirement for near 100% reflective efficiency across the whole red-shifted frequency band is demanding and the sail must also radiate the waste heat which is generated, tolerate the stress implied by the force of the beam and remain stable in the beam. The paper references the substantial related work in this area, much of it funded by Breakthrough Starshot. The sail materials suggested in the paper are-

- 2H-phase Molybdenum Disulphide MoS_2 is a semiconductor with a planar hexagonal structure (though the compound can also be found in lubricants).
- Silicon nitride Si_3N_4 has a three dimensional molecular structure.

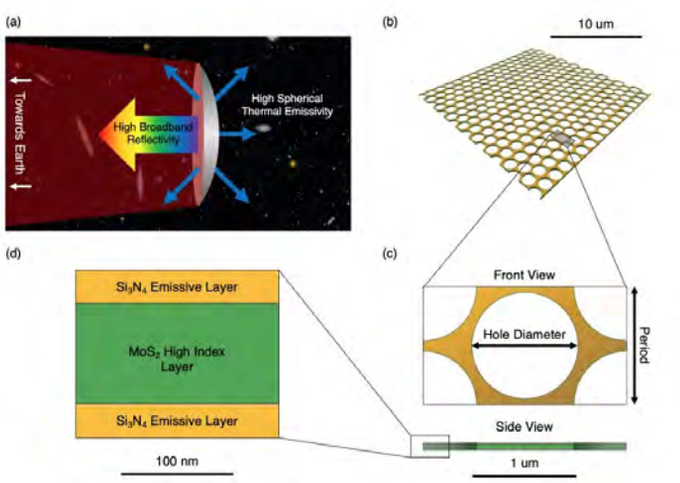


MoS_2 molecules

The paper proposes two layers of Si_3N_4 sandwiching a layer of MoS_2 in a honeycomb-like lattice structure. In the required bands MoS_2 has a high refractive index, yielding reflectivity and unmeasurably low absorption. Si_3N_4 is chosen largely for its emissivity yielding the required ability to radiate waste heat. The lattice structure provides good strength to mass properties while retaining the required thermal and optical properties. As in other contexts the holes in the structure mitigate any crack propagation. The full analysis uses basic parameters from Starshot - 10 Gw/m², 1.2 μm laser wavelength and 1 gram payload mass.

Cold fusion rises again!

Some readers may recall the cold fusion bubble which burst in 1989. Martin Fleischmann and Stanley Pons suggested that fusion might be achievable at "room temperature" but their reported experiment could not be replicated. The possibility remains very attractive and IEEE Spectrum published, *Whether Cold Fusion or Low-Energy Nuclear Reactions, U.S. Navy Researchers Reopen Case,* in March this year (spectrum.ieee.org/tech-talk/energy/nuclear/cold-fusion-or-low-energy-nuclear-reactions-us-navy-researchers-reopen-case). They reported work in progress at the US Naval Surface Warfare Center, Indian Head Division, with other US government labs including the National Institute of Standards and Technology (NIST). The Spectrum reports that the team expect results, positive or negative, by the end of the year.

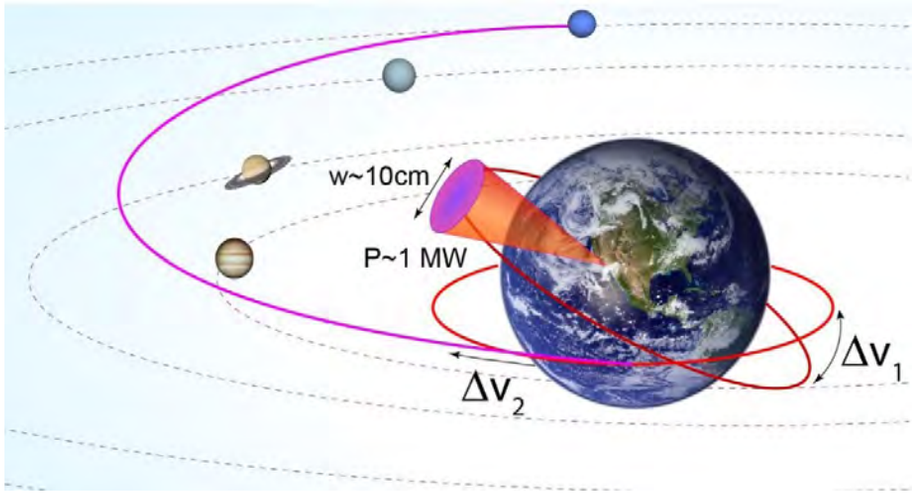


Starshot sail design.
(a) Schematic diagram demonstrating relevant optical considerations for accelerating lightsail
(b) Section of sail, approximate hole-fill ratio of 76%
(c) Front and side view of single design period.
(d) Enlarged view of multilayer structure.Yellow regions represent Si_3N_4 while green regions represents MoS_2.
Credit (image and caption): Brewer *et al.*

[1] *Thermo-accelerative optimization of relativistic lightsails* John Brewer (UCLA) and Matthew F Campbell, Pawan Kumar, Sachin Kulkarni, Deep Jariwala, Igor Bargatin, Aaswath P Raman (all University of Pennsylvania), arxiv.org/abs/2106.03558

Laser sails for manoeuvring and solar system/ISM missions

In *Light-Sail Photonic Design for Fast-Transit Earth Orbital Maneuvering and Interplanetary Flight* arxiv.org/abs/2107.09121 Ho-Ting Tung and Artur Davoyan of UCLA suggest the use of laser-driven light-sailing for agile Earth orbital maneuvering and for fast-transit exploration of the solar system and interstellar medium. They describe lightweight (1 g – 100 g & ~10 cm) spacecraft propelled by lasers to orbits that are beyond the reach of current systems, comparing their findings with previous interstellar laser propulsion studies.



Schematic illustration of laser sailing for Earth orbital maneuvering and for fast transit interplanetary missions. Here a laser beam with ~1MW power propels a wafer-scale (~10 cm) light-sail. Powered by laser propulsion such a spacecraft can perform highly energetic orbital maneuvers that require very large velocity gain, Δv. Two examples (not to scale) of such maneuvers are schematically shown: inclination change at low Earth orbit and fast transit to Neptune and beyond.

Credit (caption and image) ; Ho-Ting Tung and Artur Davoyan

AIAA Propulsion and Energy 2021 Forum

A number of papers of interstellar significance have been announced for the AIAA Propulsion and Energy 2021 Forum August 9-11, 2021[1]. Here are the ones we spotted so far -

Continued development of the pulsed magnetic nozzle for the Pulsed Fission Fusion (PuFF) vehicle, Schilling *et al*, arc.aiaa.org/doi/10.2514/6.2021-3608 "High thrust, high specific impulse propulsion systems, such as PuFF (Pulsed Fission-Fusion) offer a new paradigm of speed and safety when exploring the solar system. To realize these possibilities, PuFF needs a mature magnetic nozzle design." See *The State of the Art in Fusion Propulsion,* Kevin Schillo, in Principium 26 August 2019 for an overview of PuFF technology.

Experimental Validation Testing of a Paired-Particle Matter/Anti-Matter Propulsion System, with Proposed Project Management, Mark Pickrell, arc.aiaa.org/doi/10.2514/6.2021-3251 "This paper outlines experimental steps and proposed project management for experimental validation of the feasibility of a paired-particle matter/anti-matter propulsion system. The purpose of the experiments is to determine the practical feasibility of a matter/anti-matter propulsion system for generating relativistic speeds in space."

Numerical Optimization of Warp Drive Geometries, Helmerich *et al*, arc.aiaa.org/doi/10.2514/6.2021-3596 "Warp drive research has primarily focused on the evaluation of analytic solutions to Einstein's field equations. In this paper, we take a different approach and compute the stress-energy-momentum tensor numerically using Einstein's field equations for a given space-time metric."

Crilly (Green Bank) on interstellar communications

William J Crilly Jr, Green Bank Observatory, West Virginia, USA, has published two papers on interstellar communications -

An interstellar communication method: system design and observations, arxiv.org/abs/2105.03727 "A system of synchronized radio telescopes is utilized to search for hypothetical wide bandwidth interstellar communication signals. Transmitted signals are hypothesized to have characteristics that enable high channel capacity and minimally low energy per information bit, while containing energy-efficient signal elements that are readily discoverable, distinct from random noise."

Radio interference reduction in interstellar communications: methods and observations, arxiv.org/abs/2106.10168 "The discovery of interstellar communication signals is complicated by the presence of radio interference. Consequently, interstellar communication signals are hypothesized to have properties that favor discovery in high levels of local planetary radio interference. A hypothesized type of interstellar signal, delta-t delta-f polarized pulse pairs, has properties that are similar to infrequent elements of random noise, while dissimilar from many types of known radio interference."

[1] American Institute of Aeronautics and Astronautics (AIAA) Propulsion and Energy 2021 Forum, August 9-11, 2021, Virtual Event arc.aiaa.org/doi/book/10.2514/MPEF21

i4is Human Exploration course delivered

As we announced in our last issue P33, May 2021, i4is delivered the first running of the course, *Human exploration of the far solar system and on to the stars*, for the Limitless Space Institute, 26-30 July 2021. We hope and believe that this will advance both our subject and the reputation of the Initiative and Institute for Interstellar Studies as one of the leading organisations beating a path for humanity to the stars. We will be reporting in detail on this in our next issue, P35 November 2021.

Frequency of Life in the Universe

Karl-Florian Platt, Department of Media and Social Science, Fresenius University of Applied Sciences, Berlin, has reviewed some modifications to the Drake equation, *Drake-like Calculations for the Frequency of Life in the Universe*, in the journal Philosophies, Vol 6, Issue 2 (www.mdpi.com/2409-9287/6/2/49). He summarises the history (and pre-history) of Drake's 1961 formula including the work of the "Order of the Dolphin" who he believes to have been behind the original version. He mentions some objections to Drake and suggests a modified Drake Equation as motivation to pursue astrobiology using an estimate of the number of life-carrying planets rather than the number of communicating civilisations. Drake was, of course, essentially interested in SETI rather than the existence of life, astrobiology. He also suggests that stellar type is a factor since this affects biological evolution.

Embryo space colonisation 'considered harmful'

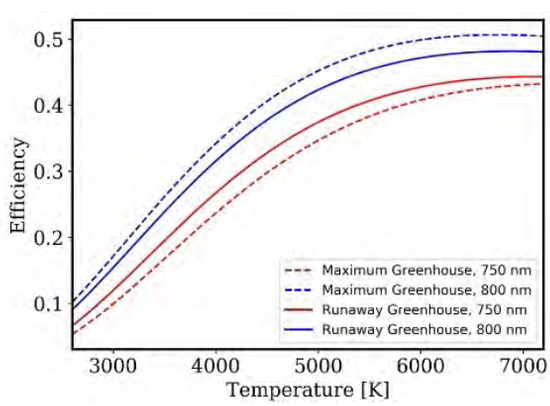
A recent paper in the International Journal of Astrobiology (pay-walled publication and no open publication found) examines the idea that humanity will send cryopreserved embryos on a mission to an exoplanet to forestall the extinction of our species. In *Humanity should colonize space in order to survive but not with embryo space colonization*, [1] Konrad Szocik suggests that, technology permitting, though this is an interesting, very rational and quite effective way to guarantee the survival of the human species it "departs from what should be understood by the concept of saving humanity through space colonization" and that there are "ethical controversies that make this concept perhaps unsuitable for implementation" by contrast to "the concept of saving humanity by sending adult living persons on space missions".

Are Earth-like biospheres on other planets rare?

A news item from the Royal Astronomical Society (RAS), *Earth-like biospheres on other planets may be rare* [2] announces a paper in Monthly Notices of the Royal Astronomical Society. The paper *Efficiency of the oxygenic photosynthesis on Earth-like planets in the habitable zone*, arxiv.org/abs/2104.01425, by Giovanni Covone, Riccardo M Ienco, Luca Cacciapuoti and Laura Inno (Università di Napoli Federico II and Parthenope University of Naples) argues that, since oxygenic photosynthesis is the most important biochemical process in the Earth biosphere and thus likely on other habitable terrestrial planets, we should evaluate the possibility of oxygenic photosynthesis on exoplanets as a function of their spectral type and planet-star separation. They state that so far, we have not observed terrestrial planets comparable to Earth in terms of useful photon flux, exergy and exergetic efficiency [3]. But their conclusion mentions that -

- Kepler-442b receives a photosynthetically active radiation (PAR) photon flux slightly larger than necessary to sustain a large biosphere,
- Earth processes are often grossly energy-inefficient and could thus be out-performed elsewhere, and
- thus the estimated PAR could permit a biosphere comparable to Earth.

So their conclusion looks much less gloomy than implied by the RAS news headline.

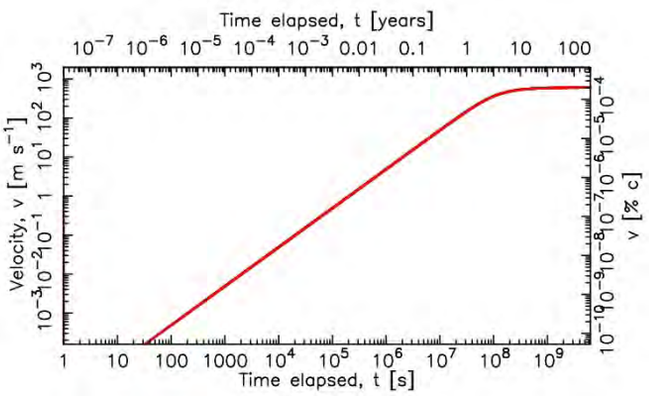


Exergetic efficiency versus the host star effective temperature for planets at the edges of the HZ for the two different PAR ranges
Credit (caption and image); Covone *et al*

[1] www.cambridge.org/core/journals/international-journal-of-astrobiology/article/abs/humanity-should-colonize-space-in-order-to-survive-but-not-with-embryo-space-colonization/474332A09E34142E77684A49B95A7684

[2] ras.ac.uk/news-and-press/research-highlights/earth-biospheres-other-planets-may-be-rare

[3] exergy is the thermodynamic limiting energy available when a system is brought into equilibrium.



Velocity of ‘Oumuamua based upon its observed acceleration - showing terminal velocity.
Credit: Stephen Curran

Peaceful Use of Lasers in Space

Given that laser sails are currently our most promising candidate for propulsion of interstellar probes the safe regulation of large laser arrays will be vital. A paper, *Initiative for the Peaceful Use of Lasers in Space* from Petr Bohacek of the Institute of Political Studies, Charles University, Prague, addresses this issue [1]. It reports on the Prague Laser SpaceApps Workshop 2019 in the Czech Republic, September 25-27 2019. This included laser and optics scientists from Russia, United States, Europe and Australia. The workshop identified three concrete follow-up steps -

- draft a declaration to inspire and motivate global scientific and diplomatic participation and put forward non-binding objectives and visions [2].
- establish scientific working groups to review the state of research, define main challenges and bottlenecks, and outline the discussion about solutions and steps forward.
- organise a series of international conferences on the *Peaceful Use of Lasers in Space* with adequate support and coordination from the United Nations, national governments, and scientific bodies.

This topic falls under the United Nations General Assembly (UNGA) Resolution 75/36, *Reducing space threats through norms, rules and principles of responsible behaviours*, 7 December 2020 [3].

Parent population of known ISOs

A recent paper, *Interstellar objects follow the collapse of molecular clouds*, asserts that the parent population of 1I/Oumuamua and 2I/Borisov, are abundant in the interstellar medium of the Milky Way [4]. It infers that a typical molecular cloud of 10 parsec (about 33 light years) diameter contains some 10^{18} ISOs at typical sizes ranging from hundreds of metres to tens of km. Using simulations of the collapse of molecular clouds containing ISOs toward the point where stars form, the authors conclude that ISOs are a relevant component of star formation.

Oumuamua not artificial (again)

In *‘Oumuamua as a light sail – evidence against artificial origins* (arxiv.org/abs/2105.09435) Dr Stephen Curran (Victoria University of Wellington, NZ) examines the non-gravitational acceleration of this ISO. He concludes that if radiation pressure is responsible for this acceleration then such an artificial solar sail cannot accelerate to considerable fractions of the speed of light and thus cannot be capable of rapid interstellar travel. He cites the technical challenges associated with the laser sources proposed by Breakthrough Starshot but his principal argument appears to be based on the inability of less powerful sources to overcome the problem of the decrease of accelerating force by the inverse square law as the sail accelerates much more slowly than proposed by Starshot. He observes that ‘Oumuamua, from known evidence, cannot have the extreme properties required for the proposed Starshot probe. He also cites sources ruling out cometary outgassing as the source of the non-gravitational acceleration of this ISO. He reaches no specific conclusion as to the cause of the acceleration and leaves open the possibility that ‘Oumuamua is simply a very poor solar sail and thus likely to be a natural object with unprecedented properties. This paper may thus provide further support for the idea of a mission to ‘Oumuamua to discover its nature - the objective of numerous papers published by the i4is Project Lyra team.

[1] lasers4space.com/wp-content/uploads/2021/05/Bohacek_PeacefulUseOfLasersInSpace.pdf

[2] *Declaration on the Peaceful Use of Lasers in Space* lasers4space.com/wp-content/uploads/2020/06/PULS-Declaration-eng-v2.4.4-1.pdf.

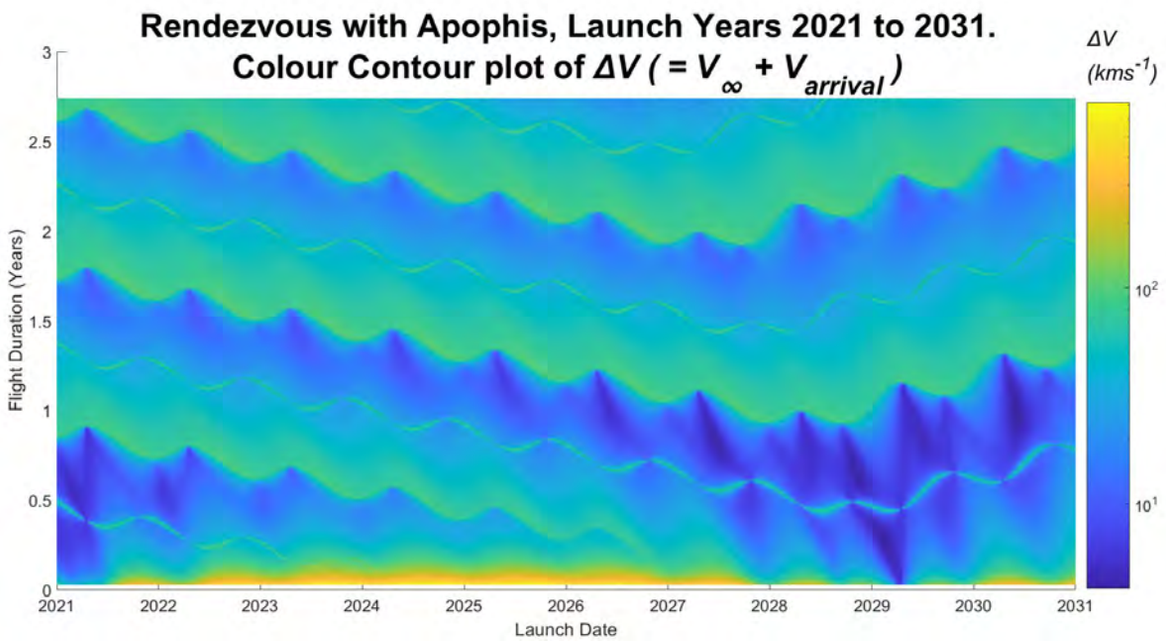
[3] UNGA A/RES/75/36 digitallibrary.un.org/record/3895440?ln=en

[4] *Interstellar objects follow the collapse of molecular clouds*, Susanne Pfalzner (Jülich Supercomputing Center, Germany), Dylan Paterson & Michele T Bannister (University of Canterbury, Christchurch, NZ) and Simon Portegies Zwart (Leiden Observatory, the Netherlands) arxiv.org/abs/2106.08580

Proposed rendezvous missions to asteroid Apophis

Two papers discuss missions to asteroid (99942) Apophis, a potentially hazardous asteroid. Though no danger is anticipated for at least 100 years this asteroid looks like a good opportunity to examine a near-Earth object. In *Apophis Rendezvous Mission for Scientific Investigation and Planetary Defense*, Moon (Seoul National University) *et al* [1] observed that Apophis will approach the Earth to come within the geostationary orbit in 2029 and suggest that launch windows in July 2026 and in January 2027 are the best opportunities for a rendezvous. Following up, Fumi Yoshida *et al* (Planetary Exploration Research Center, Chiba Institute of Technology, Japan), have published *Photometric observations of the potentially hazardous asteroid (99942) Apophis from Kawabe Cosmic Park* [2].

Our i4is colleague Adam Hibberd has developed rendezvous contours for missions to Apophis.



Rendezvous contours for missions to Apophis.
Credit: Adam Hibberd (personal communication).

Relativistic light sails need to billow

Maintaining the geometry of light sails is one of the major challenges for laser-propelled interstellar probes and indeed for all sailcraft. In *Relativistic light sails need to billow*, Matthew F Campbell (University of Pennsylvania) *et al* (arxiv.org/abs/2105.10849) argue that light sails that are rapidly accelerated to relativistic velocities by lasers must be significantly curved in order to reduce their mechanical stresses and avoid tears - and that when sufficient laser power is available, a sail's acceleration length decreases and its chip payload capacity increases as its curvature increases. They observe that this mirrors the behaviour of parachutes and nautical sails. They consider the sail's acceleration length, the photon pressure on it, and the equilibrium temperature attained as a result of imperfect reflection of photons and determine how these parameters scale in relation to fundamental design properties. They observe that photon pressures and sail temperatures increase inversely with the acceleration length, so that mechanical factors constrain feasible light sail designs and that the sail's reflectivity decreases as it becomes more curved (ie as its spherical radius of curvature decreases), suggesting a trade-off between the sail's mechanical integrity and its optical attributes.

[1] Presented at conference *Apophis T–9 Years: Knowledge Opportunities for the Science of Planetary Defense* : November 4–6, 2020 https://repository.hou.usra.edu/handle/20.500.11753/1760.

[2] Astronomical Society of Japan, July 2021, academic.oup.com/pasj/advance-article/doi/10.1093/pasj/psab072/6327221.

ET Technology - the Galileo Project

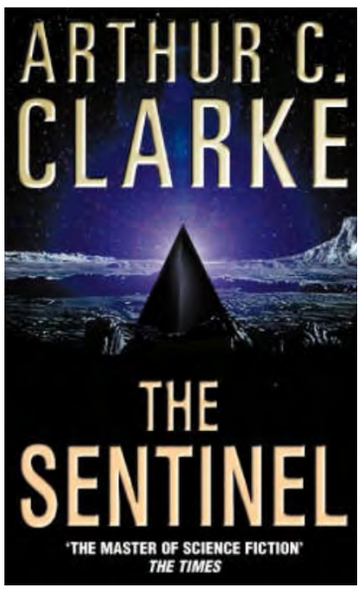
Professor Avi Loeb is not backing down in his contention that ET technologies are, or have been, in our Solar System. In *The Galileo Project: "Daring to Look Through New Telescopes - The Galileo Project for the Systematic Scientific Search for Evidence of Extraterrestrial Technological Artifacts"* (projects.iq.harvard.edu/galileo) he and his team declare that the scientific community "needs the determination to systematically, scientifically and transparently look for potential evidence of extraterrestrial technological equipment". They assert that their ground-based project is complementary to traditional SETI, in that it searches for physical objects rather than interstellar signals or technosignatures.

His team includes project co-founder Frank Laukien, president and CEO of Bruker Corporation (a major manufacturer of scientific and medical instrumentation), academics at Caltech, the universities of Princeton, Harvard, Bern, North Carolina at Chapel Hill, Chicago, California at Berkeley, Aberdeen and Cambridge,

The Galileo Project has set three major tasks -

- High-resolution, Multi-detector Images of Unidentified Aerial Phenomena (UAP), UFOs to the pop press.
- Find and research 'Oumuamua-like Interstellar Objects (ISOs) using existing and future astronomy.
- Find Potential Satellites from Extraterrestrial Technological Civilisation (ETC).

This is clearly a major addition to the search for ETI. If it yields a positive result then we will need to rethink not only the existence of ETI but its immediate importance for the whole of our species. The clear parallel is the story *The Sentinel* by Arthur C Clarke and film *2001: A Space Odyssey* by Clarke and Stanley Kubrick.



Cover of an anthology of stories by Arthur C Clarke with title from the story, The Sentinel. The was the first appearance of Clarke's idea of a monolith buried on the Moon, set by an ETI as an alarm to be triggered by human activity.

Credit: HarperCollins

Origins of Directed Panspermia

In *The History and Origins of Directed Panspermia* [1], Idan Ginsburg (Georgia State University) and Manasvi Lingam (Florida Institute of Technology), emphasise the long history of the idea of deliberate "seeding" of life throughout the universe. Early scholars were Francis Crick (the DNA Crick) and Leslie Orgel in 1973 but biologist J B S Haldane in 1954 suggested it as one possible origin of life on Earth and thought that a check of molecular chirality (left or right handedness) might suggest different ancestries, on and off Earth. This is a brief piece but it is peppered with references. A good starting point if you suspect that your great^{n} grandma might be from Mars or even Epsilon Eridani!

IRG 7th Interstellar Symposium, Tucson - next month

The Symposium will be in Tucson, Arizona, September 25-27, 2021 (with pre-symposium seminars on Friday 24 September). Details at irg.space/irg-2021/. Sign up at www.eventbrite.com/e/7th-interstellar-symposium-registration-148839060637 and note that, for those of us who can't make it to Tucson either for virus, cost or calendar conflict reasons, it is also being streamed online. Just $50 to register and participate by Zoom. All the talks will be available and you will be able to ask questions via online chat. And, of course, we'll be reporting in our next issue.

Topics (irg.space/irg-2021-abstracts-accordion/) include much on propulsion of course but also on aspects of SETI, cryopreservation, communications, ISRU and synthetic biology. Speakers include Pete Worden, David Messerschmitt, Ken Roy, Marc Millis, James Benford, Louis Friedman, Jeffrey Greason, Sonny White, Andrew Higgins, Al Jackson, Geoff Landis, Philip Mauskopf and Avi Loeb.

[1] in Research Notes of the AAS June 2021 iopscience.iop.org/article/10.3847/2515-5172/ac0f5a