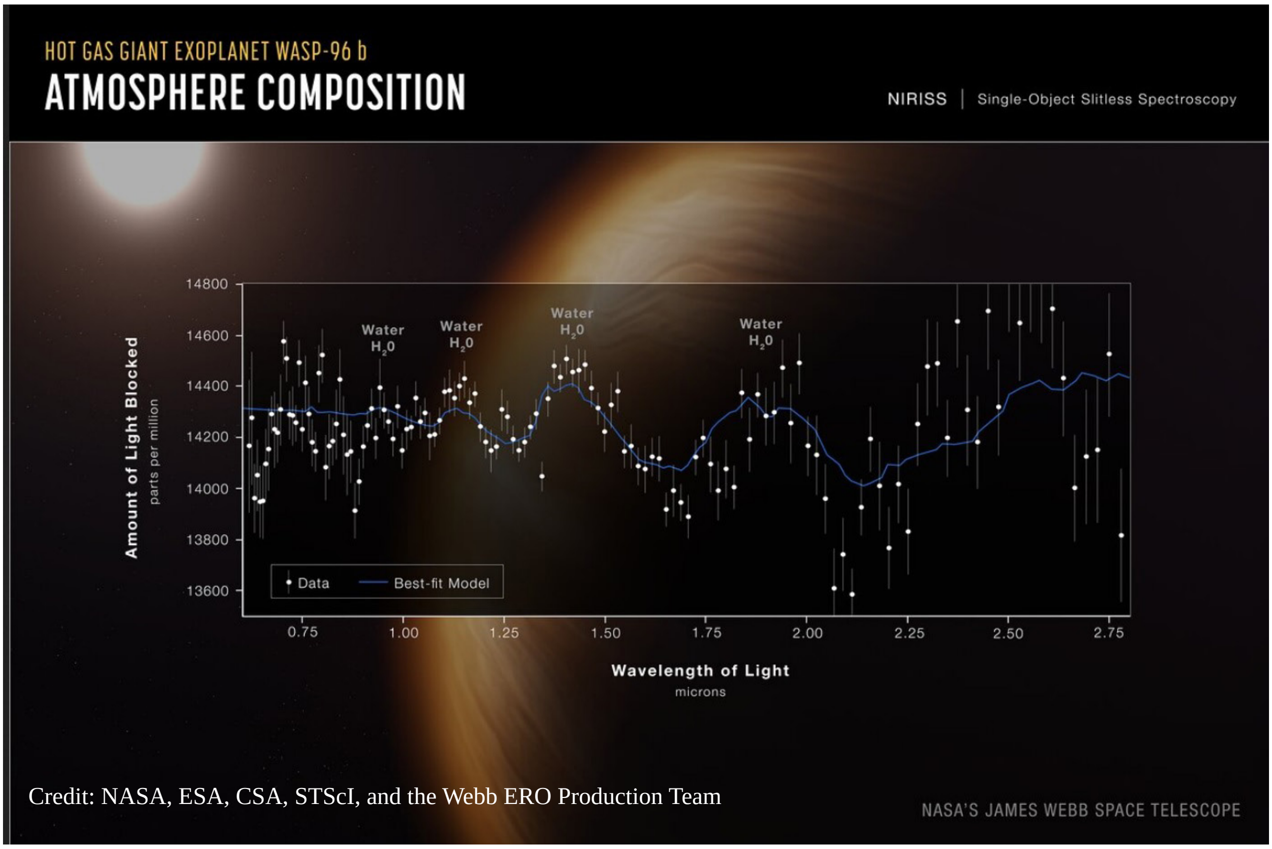
John I Davies reports on recent developments in interstellar studies



Credit: NASA, ESA, CSA, STScI, and the Webb ERO Production Team

Webb telescope: early results

The James Webb telescope is a joint project by NASA, ESA and the Canadian Space Agency. ESA published lots of striking early images and results (esawebb.org/) but from the i4is point of view this exoplanet atmosphere result above is one of the most striking, *Webb Reveals Steamy Atmosphere of Distant Planet in Exquisite Detail* (esawebb.org/news/weic2206/).

As ESA notes "...Webb's Near-Infrared Imager and Slitless Spectrograph (NIRISS) measured light from the WASP-96 system for 6.4 hours as the planet moved across the star. The result is a light curve showing the overall dimming of starlight during the transit, and a transmission spectrum revealing the brightness change of individual wavelengths of infrared light between 0.6 and 2.8 microns." and "the transmission spectrum reveals previously hidden details of the atmosphere: the unambiguous signature of water, indications of haze, and evidence of clouds that were thought not to exist based on prior observations."

Not necessarily a happy home from home for our species but much detail that was not obtainable previously and this is a first indication of the ground breaking capabilities of this magnificent instrument.

Warp Drive Aerodynamics

Warp Drive Aerodynamics (arxiv.org/abs/2207.06458) [1] analyses the potential for a warp drive spacetime to develop instabilities due to the presence of quantum matter. They find that warp-drive bubbles in dimension 2+1 or higher are in fact likely to be stable and that certain instabilities in Alcubierre warp-drive spacetime can be diminished with particular, more "aerodynamic" shapes and trajectories for the drive. They conclude that while this work does not prove that warp drives are a completely viable option for faster-than-light travel, they strongly evidence that these instabilities do not, in principle, preclude "aerodynamic" configurations of the Alcubierre drive from being able to sustain a net superluminal speed and states that "The launchpad for our future superluminal journeys is thus left with one less obstruction".

[1] *Warp Drive Aerodynamics*, Carlos Barcel (Instituto de Astrofısica de Andalućıa (CSIC), Spain), Valentin Boyanov, Luis J Garay and Jose M Sanchez Velazquez (Universidad Complutense de Madrid), Eduardo Martın-Martınez (University of Waterloo)

Artist's illustration of interstellar asteroid 'Oumuamua.
Credit: Gemini Observatory/AURA/NSF/Joy Pollard

Traversable wormhole?

In *Traversable wormholes with like-Casimir complexity supported with arbitrarily small amount of exotic matter* [1] researchers from Universidad San Francisco de Quito, Ecuador, and Universidad Central de Venezuela provide the redshift function of a Casimir traversable wormhole which leads to a traversable wormhole with a minimum amount of exotic matter. They report "...we found that the solution connects two asymptotically flat regions through a tunnel with the size of the Earth-Moon distance and the time required to traverse the wormhole from a spatial station located in the asymptotically flat region it is on the order of a few hours".

They refer especially to a paper by a good friend of i4is, Remo Garattini of Bergamo University, Italy, *Casimir wormholes* (epjc.epj.org/articles/epjc/abs/2019/11/10052_2019_Article_7468/10052_2019_Article_7468.html). His lectures for i4is and others are reported in *Traversable Wormholes and the Casimir Energy in Modified Gravity* (Principium 10, August 2015), *Wormholes, Energy Conditions and Time Machines* (Principium 22, August 2018), *Foundations of Interstellar Studies Workshop 2019* (Principium 26, August 2019) and *Interstellar Workshop of the European Space Agency* (Principium 30, August 2020). All Principium issues are available at i4is.org/publications/principium/.

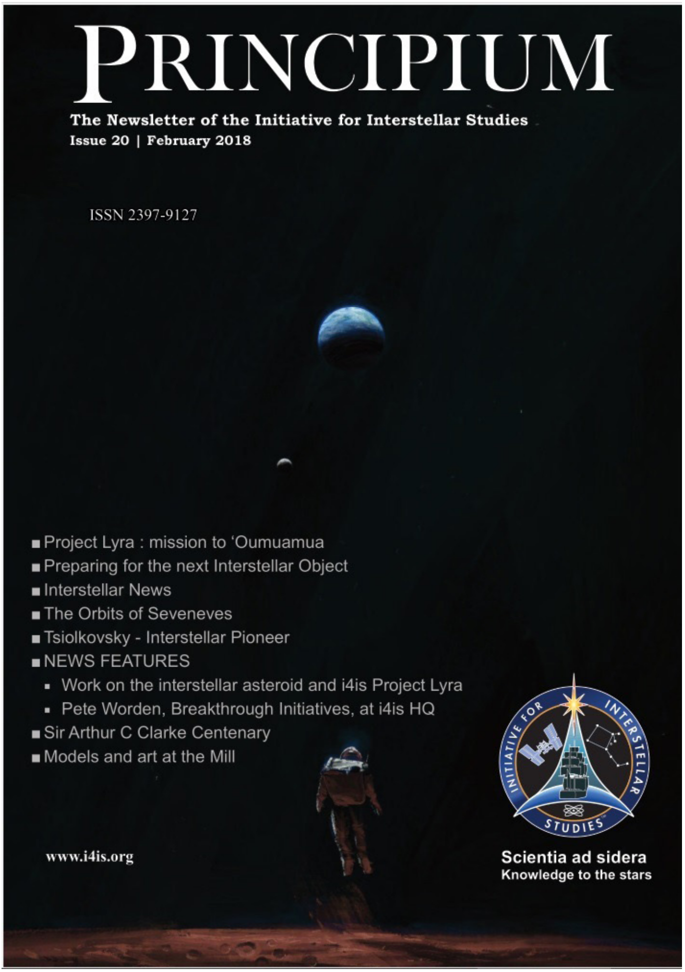
The view from 'Oumuamua's perspective

Adam Hibberd has produced a brilliant short piece - *1I/'Oumuamua's Orbit As It Encountered The Inner Solar System* (i4is.org/1i-oumuamuas-orbit-as-it-encountered-the-inner-solar-system/). Imagine being the astronaut on 1I/'Oumuamua visualised on our P20 (February 2018) cover - right.

Adam tells how the Earth's appearance would change as viewed by that astronaut as 1I/'Oumuamua zoomed past.

Here is a purely personal view of things from Principium editor, John Davies -

> The longer we go without finding a similar object the greater the urgency of a mission to what remains a unique ISO. As Popper[2] would put it, all conjectures about 'Oumuamua need to seek means of refuting them. A mission is feasible, as i4is Project Lyra has demonstrated many times, and such a mission is the only way we may support or refute conjectures about its nature.


PRINCIPIUM

The Newsletter of the Initiative for Interstellar Studies
Issue 20 | February 2018

ISSN 2397-9127

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- Sir Arthur C Clarke Centenary
- Models and art at the Mill

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INITIATIVE FOR INTERSTELLAR STUDIES

Scientia ad sidera
Knowledge to the stars

[1] *Traversable wormholes with like-Casimir complexity supported with arbitrarily small amount of exotic matter*, R Avalos, E Fuenmayor, E Contreras, link.springer.com/content/pdf/10.1140/epjc/s10052-022-10389-8.pdf

[2] *Conjectures and Refutations: The Growth of Scientific Knowledge*, Karl Popper, Harper & Row, 1963

JWST Near-Infrared Spectrograph for exoplanets

In a recent paper *The Near-Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope - IV. Capabilities and predicted performance for exoplanet characterization*, S M Birkmann (ESA) et al [1] discuss capabilities of the NIRSpec instrument on the James Webb Space Telescope for time-series observations and transit and eclipse spectroscopy of exoplanets (for an early example see *Webb telescope: early results* above).
Spectroscopic characterisation of exoplanet atmospheres has only been performed for a few dozen exoplanets so far. The JWST will open a new era in exoplanet atmosphere investigation.
Exoplanets are often detected by their transit across image of the host star and thus close-orbiting exoplanets are most easily found. Where they are well separated from their host star their resolved image may be obtainable by other JWST instruments and the NIRSpec will also be able to characterise these directly.
The NIRSpec was built by Astrium Germany (now part of Airbus Defence and Space) for ESA.

The NIRSpec logo. Credit: Space Telescope Science Institute, Baltimore, Maryland

The ET mission to search for Earth 2.0s

A team from Shanghai Astronomical Observatory (Chinese Academy of Sciences) and NASA Ames have published a proposal for an improved exoplanet finding space telescope to improve upon the results of the Kepler space telescope [2]. Called *ET (Earth 2.0)* it will carry seven 30 cm refracting telescopes, of which six are wide-field transit telescopes and one is a microlensing telescope. Contrast Kepler which has a single 95 cm reflector. The proposal states that ET will have a larger field of view (FOV), higher precision photometry than Kepler and improved CMOS detectors with much lower noise than Kepler. They aim to find the first Earth 2.0 - one with environmental conditions similar to those found on Earth - and determine planet density, internal structure, and atmospheric composition to assess their habitability.

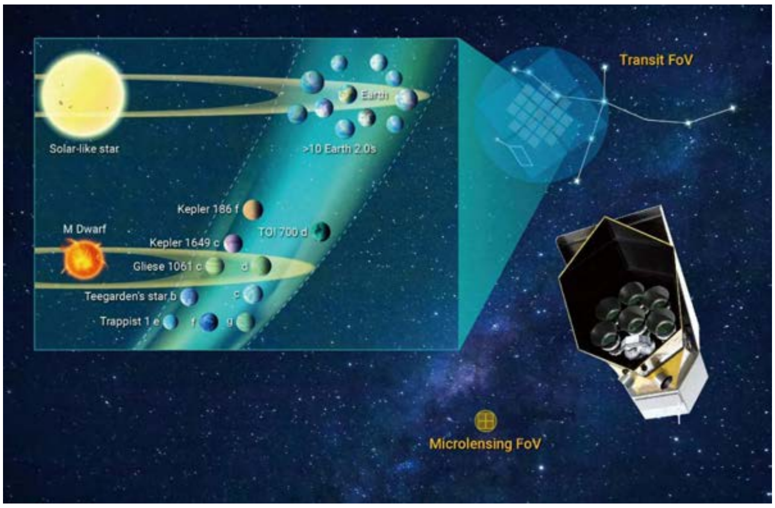
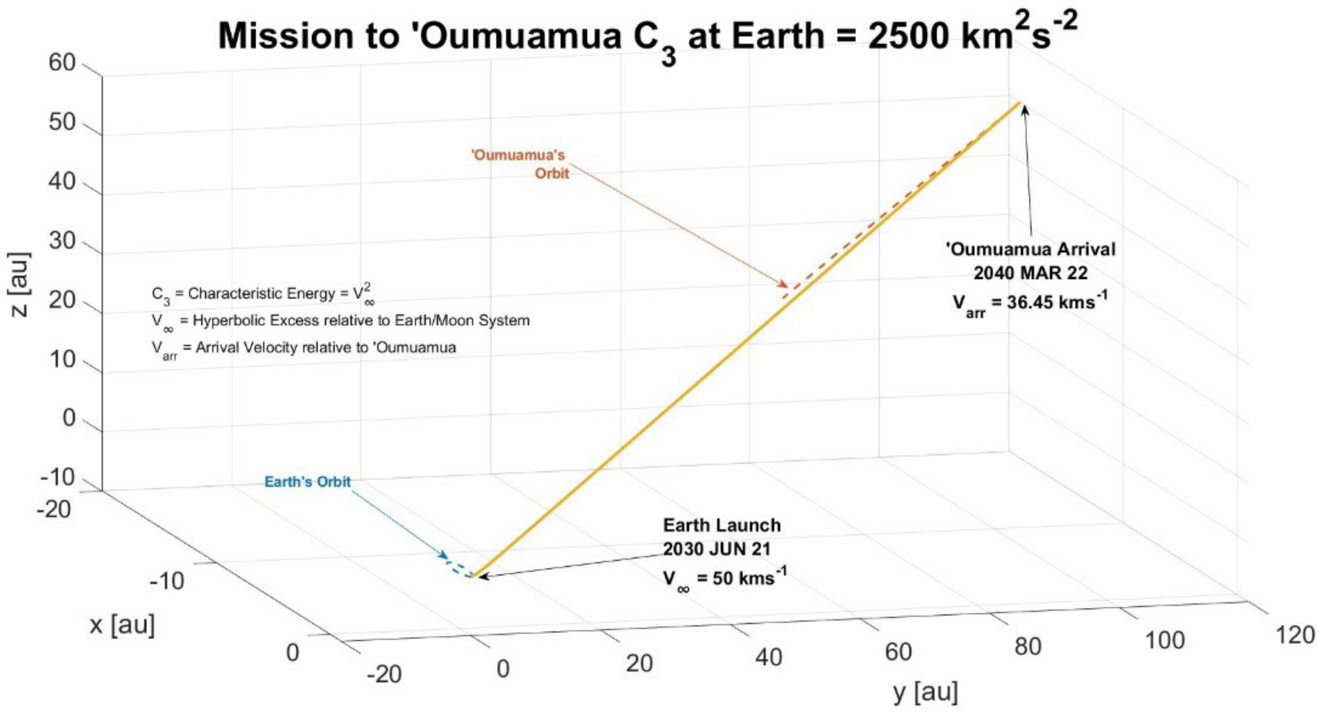


Figure 1. The design of the ET scientific payload which includes six 30 cm diameter transit telescopes and one 30 cm diameter microlensing telescope. ET's 500 square degrees of field of view (encompassing the original Kepler field) will be monitored continuously by the ET's transit telescopes over 4 years to search for transit signals from Earth 2.0s. To date, all the potentially habitable Earth-size planets were detected around M dwarfs. ET plans to find the first Earth 2.0 within the habitable zone of solar-type stars.
Credit (caption and image): The ET team

[1] *The Near-Infrared Spectrograph (NIRSpec) on the James Webb Space Telescope - IV. Capabilities and predicted performance for exoplanet characterization*, www.aanda.org/articles/aa/full_html/2022/05/aa42592-21/aa42592-21.html
[2] *The ET mission to search for Earth 2.0s.* https://www.sciencedirect.com/science/article/pii/S2666675822000674

SunDiver Workshop in Luxembourg

The SunDiver Workshop in Luxembourg, 17-18th of May, was a workshop on "Fast, Low-Cost, Interplanetary Sailcraft Science Missions". Project Lyra was presented, see *Project Lyra: Presentation at SunDiver Workshop in Luxembourg* (i4is.org/project-lyra-presentation-at-sundiver-workshop-in-luxembourg/) for a picture of Andreas and the team at the Neimenster Abbey in Luxembourg, organized by the University of Luxembourg (SnT), Breakthrough Initiatives, and NASA-JPL. i4is Executive Director Andreas Hein organized this meeting in his capacity as a professor of Space Systems Engineering at the University of Luxembourg.



Example mission to 1I/'Oumuamua. C3 is the departing velocity - which delivers a probe to 1I/'Oumuamua in 10 years. Credit: A Hibbert

The meeting featured some prominent researchers working on solar sails such as Slava Turyshev (NASA-JPL), Jan Thimo Grundmann (DLR), Bernd Dachwald (FH Aachen) with numerous space scientists such as Phil Mauskopf (Arizona State University), James Lloyd (Cornell) and Marshall Eubanks (Space Initiatives). Project Lyra was notably presented during Hein's presentation of potential SunDiver missions to interstellar objects. Another presentation suggested a planetary defence concept, see next item.

Sundiver Lightsail Technology - To The Kuiper Belt

To The Kuiper Belt! Solar System Precursor Missions with Solar and Laser-Driven Sailcraft [1] was a presentation to the *Breakthrough Initiatives/University of Luxembourg "Sundiver" workshop on Fast, Low-Cost, Interplanetary Sailcraft Science Missions*, a 2-day meeting of scientists and engineers to discuss possibilities for fast, low-cost planetary science missions into the solar system using smallsats with solar sails, May 17-18, 2022. Hosted at the Neimenster Abbey, a conference venuein Luxembourg, it included several members of the i4is technical team. This presentation offers a number of high speed probe missions including one to the still-mysterious interstellar object (ISO), 1I/'Oumuamua.

[1] *To The Kuiper Belt! Solar System Precursor Missions with Solar and Laser-Driven Sailcraft* tinyurl.com/ToTheKuiperBelt T M Eubanks - (wpb@space-initiatives.com), W P Blase, A Hibberd, R G Kennedy III, A M Hein - of Space Initiatives Inc, Initiative for Interstellar Studies (i4is) and Institute for Interstellar Studies US (i4is- US), *www.researchgate.net/publication/360937695*

Fast interception of threats to Earth

A recent presentation, *Sailing to Apophis* [1], by a team from i4is and Space Initiatives Inc, proposes laser-driven quick-reaction missions to intercept potentially hazardous objects (PHOs) approaching Earth. In order to maximize the time available for planning and carrying out actions, it would be useful to launch an intercept mission as soon as possible after initial detection of potentially PHOs approaching Earth. However, keeping a fuelled rocket with a conventional probe on standby would be logistically difficult and prohibitively expensive. This paper proposes using laser-driven light-sail probes to implement quick-reaction missions to intercept PHOs approaching Earth, with an initial test of this capability using the upcoming close approach of Asteroid 99942 Apophis. A major challenge for laser-driven probes is that, for several proposed geometries, the payload will be subjected to the full intensity of the drive beam. The paper therefore suggests a solid-sail approach in which the sail is a solid body, made from ultra-light materials, with the entire rear surface being the reflective sail element and the electronics mounted on the forward layer. The vehicle would be a shallow conical disk, 450 mm diameter and approximately 5 mm thick in the centre, with a taper of approximately 2 degrees so that the edges are approximately 2 mm thick. The first launch would use a humble sounding rocket rather than an orbit-capable launcher.

A drive beam of 17 MW would be required. A standard UK socket delivers a maximum of 13 amps at 240 volts RMS, a power of 3 kW, for example to an electric kettle. So 17 MW represents $17*10^3$ kW = 5,667 kettles turned on a once! That's about 5 typical UK villages with all needing a "nice cup of tea" at the same time [2] so not much by comparison with industrial furnaces and the like.

More about such missions in Interstellar News item *Proposed rendezvous missions to asteroid Apophis*, in Principium 34 August 2021 page 17 [3].

The paper concludes that laser-driven sail-craft launched by sounding rockets offer a relatively inexpensive, way to launch quick-reaction fly-by missions to PHOs and near-Earth asteroids. With some enlargement of the drive laser and the probe, low-cost missions to the Kuiper Belt, the Oort Cloud, and even passing free-flying interstellar visitors could be mounted.

Self-replicating probes and SETI

In *Self-replicating probes are imminent - implications for seti* [4], Alex Ellery argues that humans are developing self-replication technology today so an advanced ETI would have developed self-replication technology long ago and thus we would have noticed them. This supports the thesis that ETIs do not exist, we are alone in the universe and thus SETI is pointless. He backs this up with descriptions of nascent in-space self-replication, a wide range of terrestrial self reproduction work, a survey of available in-situ resources and the exponential nature of self replication. Even if there is only one advanced ETI in the Galaxy its self-replicating probes would have reached us long ago. It even applies between galaxies since with billions of years available probe velocities at small fractions of the speed of light would have populated the known universe by now. Even the "Great Filter", the idea that civilisations meet their end before spreading by self replication, will soon no longer apply to us and thus to older civilisations. All this tends to support the rare Earth hypothesis, that we are alone or near-alone in the universe. Ellery touches on a number of related issues including the predator-prey ecology, genetic mutation, panspermia, first-mover advantage, interstellar propulsion and of course Kardashev. However, he wraps up by suggesting that SETI remains essential if we follow Popper's principle that science demands an endless search for evidence against our theories with full certainty

[1] *Sailing to Apophis*, W P Blase (wpb@space-initiatives.com) and T M Eubanks (both at Space Initiatives Inc), A Hibberd and A M Hein (both at Initiative for Interstellar Studies), R G Kennedy III (Institute for Interstellar Studies US (I4IS-US) presented at *Apophis T-7 Years: Knowledge Opportunities for the Science of Planetary Defense*, held virtually 11-12 May, 2022. LPI Contribution No. 2681, id.2016, https://www.hou.usra.edu/meetings/apophis2022/pdf/2016.pdf

[2] Average UK household 2021 = 2.42 people, 68 million people in UK so 68/2.42=28 million households, typical village Brinkworth, Wiltshire 2,400 people so about 1000 households.

[3] i4is.org/wp-content/uploads/2021/08/Interstellar-News-Principium34-print-2108231132opt-2-1.pdf

[4] *Self-replicating probes are imminent - implications for seti*, Alex Ellery (Carleton University, Ottawa) International Journal of Astrobiology (2022) https://www.cambridge.org/core/services/aop-cambridge-core/content/view/2CB214D26020D497D48AE489756BEE77/S1473550422000234a.pdf/self-replicating-probes-are-imminent-implications-for-seti.pdf.

approached but never quite achieved - at least from his philosophical point of view. And whatever the outcome of this "the self-replicating machine is the ultimate machine affording unchallenged cosmological power to the human species over the longest term".
This is a 31 page paper full of detailed exposition and argument - and with over 180 references, many of which will "ring bells" with those of us interested in interstellar studies in the broad sense.

Radiation hazards for interstellar probes

A new paper from UC Santa Barbara and UC Berkeley, *Radiation Effects from the Interstellar Medium and Cosmic Ray Particle Impacts on Relativistic Spacecraft* [1], considers relativistic spacecraft will have to survive radiation that is unique when compared to conventional spacecraft. At relativistic speeds, the interstellar medium (ISM) will appear as a nearly monoenergetic beam of charged particles impinging on the leading edge of the spacecraft. ISM protons and electrons will travel characteristic lengths through the spacecraft shield and come to a stop via electronic and nuclear stopping mechanisms producing,

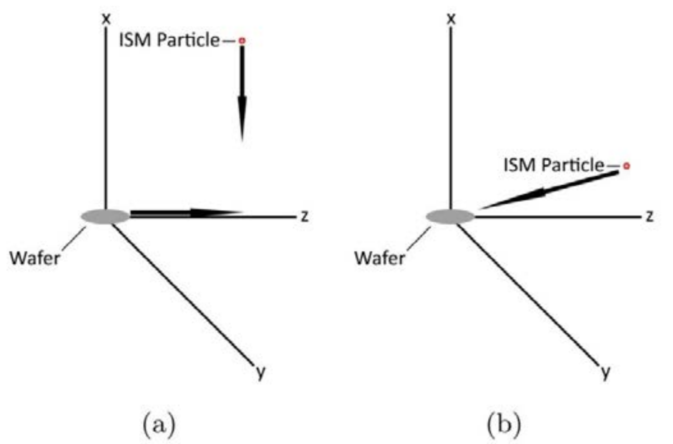


Figure 1. (a) Stationary ISM reference frame, with spacecraft shown as a thin gray wafer with the x-axis along its axis of symmetry and a velocity vector along the z-axis. An example ISM particle is shown with arbitrary velocity vector. (b) Spacecraft reference frame (primed frame), wherein the composite ISM particle velocity vector is shown. As will be shown in this section, the ISM particle distribution function becomes strongly peaked in the forward direction in the reference frame of a relativistic spacecraft. Credit(image and caption): Lubin et al

bremsstrahlung [2] photons within the shield. Here they discuss the implications of the interstellar environment for relativistic spacecraft.
They consider radiation damage and tolerance of onboard devices to expected radiation doses. They conclude -

> "While the bremsstrahlung production from incident electrons is small (less than a medical X-ray), incident protons have the ability to produce cascades of bremsstrahlung photons deeper below the surface. Material choice for the shield will be key in mitigating these damage mechanisms. In addition to incident ISM species, the spacecraft will also have to weather much higher energy, though much less frequent, cosmic ray impacts. Even in the frame of a relativistic spacecraft, GeV/nucleon cosmic rays will impact practically isotropically, and thus a raised-edge shield will do little to protect the spacecraft. However, due to their comparatively low flux, shielding schemes from cosmic rays for a relativistic spacecraft may not need to differ significantly from an ordinary spacecraft."

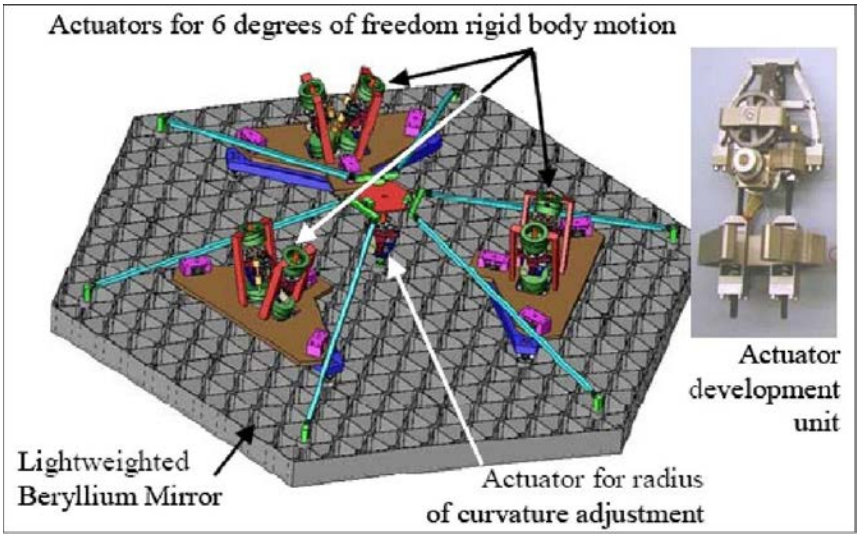
Trapped interstellar matter surrounding the solar system?

In a recent paper, Jorge Peñarrubia, of the Institute for Astronomy and Centre for Statistics at Edinburgh University, suggests that the solar system may be surrounded by a halo that contains the order of N^{ISO} 10^7 energetically-bound 'Oumuamua-like objects, and a dark matter mass of M^{DM} of approximately 10^{-13} solar masses, *A halo of trapped interstellar matter surrounding the solar system* [3]. He suggests that the presence of trapped interstellar matter in the solar system can affect current estimates on the size of the Oort Cloud, and leave a distinct signal in direct dark matter detection experiments.
If his conjecture is right, it seems likely that missions to this distance will have much to investigate.

[1] *Radiation Effects from the Interstellar Medium and Cosmic Ray Particle Impacts on Relativistic Spacecraft*, Philip Lubin and Alexander N Cohen (both UCSB) and Jacob Erlikhman (UC Berkeley), American Astronomical Society. The Astrophysical Journal, 20 June 2022, iopscience.iop.org/article/10.3847/1538-4357/ac6a50
[2] "braking radiation" produced when a charged particle is deflected by an electric field, typically an atomic nucleus, faculty.wcas.northwestern.edu/yoram/teaching/23astron441CP2013/00web/01papers/rlChap5.pdf
[3] A halo of trapped interstellar matter surrounding the solar system, https://arxiv.org/abs/2206.08535

A peek at the JWST technology

There's a lot of rather superficial material about how the marvellous James Webb telescope works. Looking a bit more deeply we found the ESA Earth Observation Portal (eoPortal) has - *JWST (James Webb Space Telescope)*, (directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/jwst-content).
A good example is the adjustment of the 18 primary mirror segments. Popular accounts mention six actuators plus one central actuator for each segment. They don't mention that this gives 6 degrees of freedom (in aircraft/spacecraft terms - three translations - up-down, left-right, forward-back and three rotations - pitch, roll and yaw) and how this is done - by three bipod actuator pairs. Here's the picture of them from the ESA eoPortal.



An approximation to determine the source of the WOW! Signal

Alberto Caballero has a paper, *An approximation to determine the source of the WOW! Signal*, in the International Journal of Astrobiology, Cambridge University Press: 06 May 2022 [1].
The WOW! Signal remains a live issue in SETI research. Seth Shostak of the SETI Institute surveyed the subject in 2017 [2].
Caballero has developed a number of theories in recent years with varying degrees of attention in the professional press and a lot of notice in the UK popular press. This recent paper in the International Journal of Astrobiology identifies the source, 2MASS 19281982-2640123, as the best possibility amongst the small number of potential sources of the signal [3].
Caballero is an accomplished amateur astronomer and the professionals often rely on the serious amateurs in this field. His methodology reflects this. He uses the massive amount of data from the Gaia space telescope system, which has been mapping the universe for nearly s years and has produced positions, motions and spectra for thousands of stars [4]. The paper filters Gaia data for a number of star characteristics likely to support life - radius, luminosity, spectral type, temperature - and arrives at a short list of 38. Caballero notes that Claudio Maccone predicted that the nearest ETI must be at least 500 light years away [5] and that his shortlist conforms to this assumed limit.

Direct Imaging and Spectroscopy of Extrasolar Planets

In *Direct Imaging and Spectroscopy of Extrasolar Planets* [6] researchers suggest that direct imaging and spectroscopy is the likely means by which we will someday identify, confirm, and characterize an Earth-like planet around a nearby Sun-like star. They set out the current state of knowledge regarding discovering and characterizing exoplanets by direct imaging and spectroscopy.

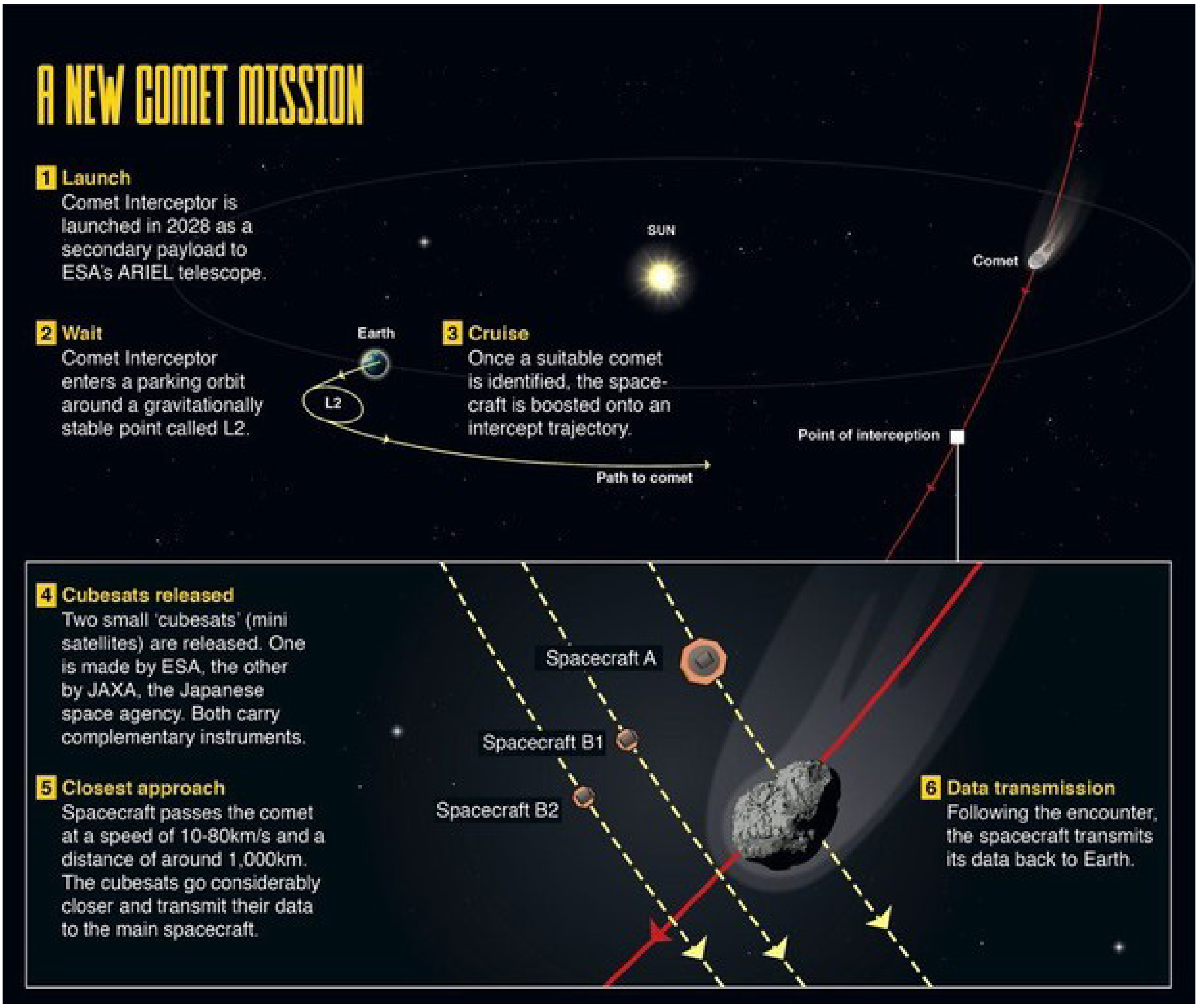
[1] www.cambridge.org/core/journals/international-journal-of-astrobiology/article/an-approximation-to-determine-the-source-of-the-wow-signal/4C58B6292C73FE8BF04A06C67BAA5B1A
[2] *Was it ET on the line? Or just a comet?* www.seti.org/was-it-et-line-or-just-comet
[3] Wow!_signal#Celestial_location, en.wikipedia.org/wiki/Wow!_signal#Celestial_location
[4] for an interactive visualisation of Gaia results, see Gaia Sky zah.uni-heidelberg.de/gaia/outreach/gaiasky
[5] Maccone, C (2010) *The statistical Drake equation*. Acta Astronautica. No public source found.
[6] *Direct Imaging and Spectroscopy of Extrasolar Planets*, Thayne Currie & Olivier Guyon (National Astronomical Observatory of Japan), Beth Biller (University of Edinburgh), Anne-Marie Lagrange (Observatoire de Paris), Christian Marois (Herzberg Astronomy & Astrophysics, Canada), Eric L Nielsen (New Mexico State University), Mickael Bonnefoy (Univ. Grenoble Alpes, France) and Robert J De Rosa (European Southern Observatory) arxiv.org/pdf/2205.05696.pdf

Comet Interceptor approved for construction

ESA and JAXA have given the go ahead for the Comet Interceptor (www.esa.int/Science_Exploration/Space_Science/Comet_Interceptor_approved_for_construction). The Comet Interceptor website is www.cometinterceptor.space/ [1].

More at *Comet Interceptor Could Snag an Interstellar Object* [2] - from the ever watchful Paul Gilster and see IAC21 report in Principium 35 (i4is.org/wp-content/uploads/2021/11/International-Astronautical-Congress-2021-The-Interstellar-Papers-Principium35-print-2111260906-opt-2.pdf).

With its "linger" at Lagrange 2 (alongside Gaia and JWST), launching from there when the target appears and its probe plus two sub-probes architecture, this is a unique piece of spacecraft mission planning and engineering. Fingers crossed for an ISO like 1I/'Oumuamua!



Mission plan and architecture. Credit BBC Science Focus Magazine

[1] Executive Summary to ESA at www.cometinterceptor.space/uploads/1/2/3/7/123778284/comet_interceptor_executive_summary.pdf
[2] www.centauri-dreams.org/2022/06/14/comet-interceptor-could-snag-an-interstellar-object/

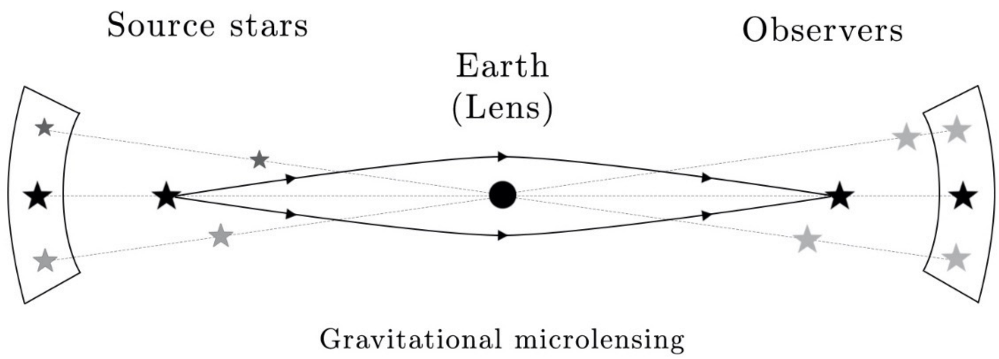


Figure 3. An illustration of a gravitational microlensing event and observer source pairings for this study. In order to calculate microlensing properties of each observer an observer is selected from stars within HEALpix area (hierarchical equal area isolatitude pixilation) area [1] and paired with every star in its antipode HEALpix area.
Credit (image and caption): Suphapolthaworn et al

Earth through the looking glass

In *Earth through the looking glass: how frequently are we detected by other civilisations through photometric microlensing?* [2], a team from Japan (Hokkaido University), Thailand (National Astronomical Research Institute, Chiang Mai University - 3 contributors), UK (Jodrell Bank Centre for Astrophysics) and France (Observatoire de Besançon) propose we should aim, as Robert Burns advises, to "To see oursels as others see us!". Microlensing using the Sun is technically tough (focus at about 300 AU - well beyond the Kuiper belt) but we would expect ETIs to acquire that capability. The team postulate an "Earth microlensing zone" from which we may be observed.
They have used the *Gaia DR2 catalogue magnitudes <20* to generate earth microlensing probability and detection rate maps for these external observers [3]. They expect photometric microlensing signatures from Earth to be observable on average only tens per year by any of these candidate "snoopers".

Gravitational Microlensing and the Solar Gravitational Lens

Einstein's General Theory of Relativity (1907-1915) was experimentally supported by Eddington's observation of deflection of light by the Sun during the 1919 solar eclipse. The fact that the path of light is deflected by gravitational fields leads to both microlensing - most practically when a distant object happens to fall into the line of sight of an even more distant object - and to the potential usefulness of our own Sun as such a primitive but powerful lens if we can place a telescope somewhere far enough from it to achieve the effect, the Solar Gravitational Lens.
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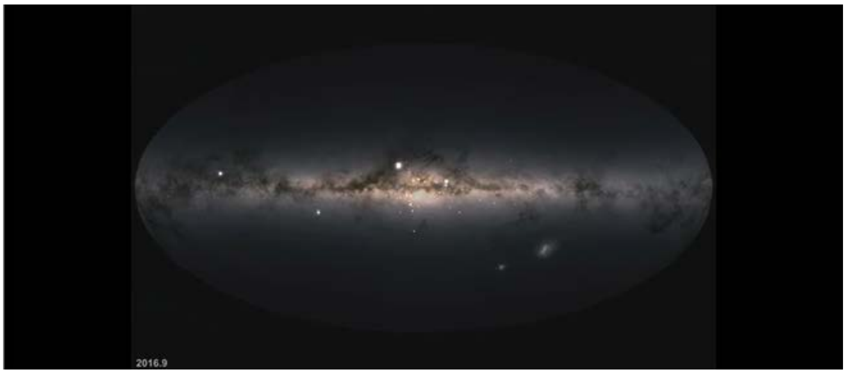


Microlensing events in Gaia's Data Release 3 captured in 30 seconds (video)
https://www.cosmos.esa.int/web/gaia/dr3-do-they-go-boom

[1] HEALPix is a Hierarchical, Equal Area, and iso-Latitude Pixelisation of the sphere designed to support efficiently - local operations on the pixel set, see *The HEALPix Primer*, Gorski et al arxiv.org/abs/astro-ph/9905275
[2] S Suphapolthaworn et al, arxiv.org/abs/2206.09820, publication expected in Monthly Notices of the Royal Astronomical Society
[3] Recall that magnitudes work backwards, magnitudes <20 means brighter than magnitude 20. The ISS is typically -3 to -4, very bright!

Exoplanets with Chinese characteristics

A recent proposal by Jianghui Ji et al, *CHES: a space-borne astrometric mission for the detection of habitable planets of the nearby solar-type stars* [1] suggests a Close-by Habitable Exoplanet Survey (CHES) mission to discover habitable-zone Earth-like planets of the nearby solar-type stars via micro-arc-second relative astrometry. This will survey systems at distances up to 10 parsecs, about 33 light-years (ly) - many of these are distinguishable by normal unaided vision [2]. The telescope would be a fairly modest 1.2 metre aperture three-mirror instrument [3] with the important capability of "ultra-high-precision relative astrometry" of 0.3 micro-arc-seconds [4] using the radial velocity method [5]. The paper suggests that "habitable-zone Earth-like planets orbiting the nearby solar-type stars are rarely found" illustrating this with a striking graphic of the distribution of known habitable-zone planets showing stellar temperature versus effective flux incident on the planet (see diagram on the right).

The paper states that exoplanet detection by astrometry will produce unbiased observations - for example in not requiring that the orbital plane of the planet intersect our line of sight as in the transit method. The paper includes an interesting "Decomposition of detection requirements" looking at positioning accuracy, telescope parameters (aperture, focal length, field of view) and interstellar distance measurement accuracy. The telescope has 1.2 m aperture, 36 m focal length and a camera pixel size of 6.5 µm yielding a single pixel field of view of 0.037 arc-seconds. To achieve the required micro-arc-second relative astrometric precision.

This means -

- near diffraction-limited imaging from the telescope and thus on-orbit optical calibration, precise detector pixel positioning
- ultra-high attitude stability - note attitude control is entirely by gas thrusters so system lifetime will be less than if momentum exchange methods (reaction wheels or control moment gyros) were used
- excellent telescope thermal control
- heterodyne laser interferometry [6] to deliver accurate inter-pixel calibration

Like the James Webb and Gaia instruments the spacecraft will be placed near the Earth-Sun Lagrange 2 point. So far operators seem to be keeping L2 tidy by moving defunct ones to less popular destinations [7].

China is beginning to contribute substantially to SETI activities. SETI is already an explicit objective of the Five-hundred-metre Aperture Spherical radio Telescope (FAST) - the biggest dish on Earth.

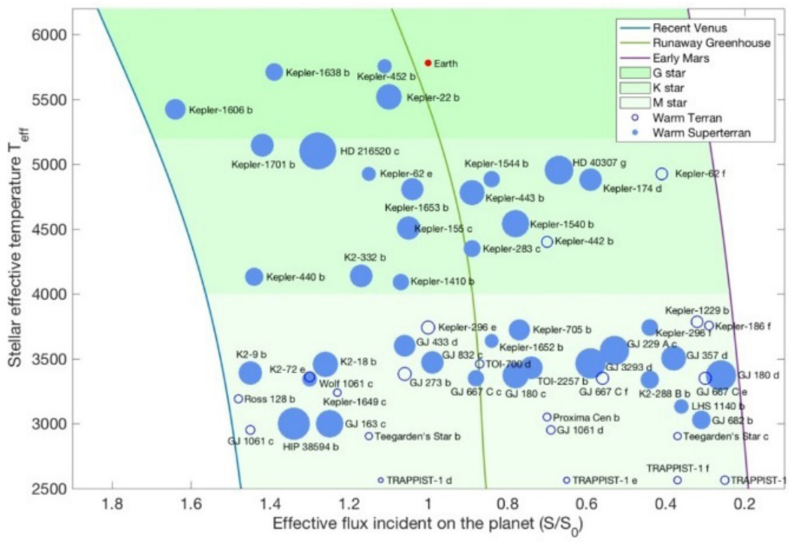


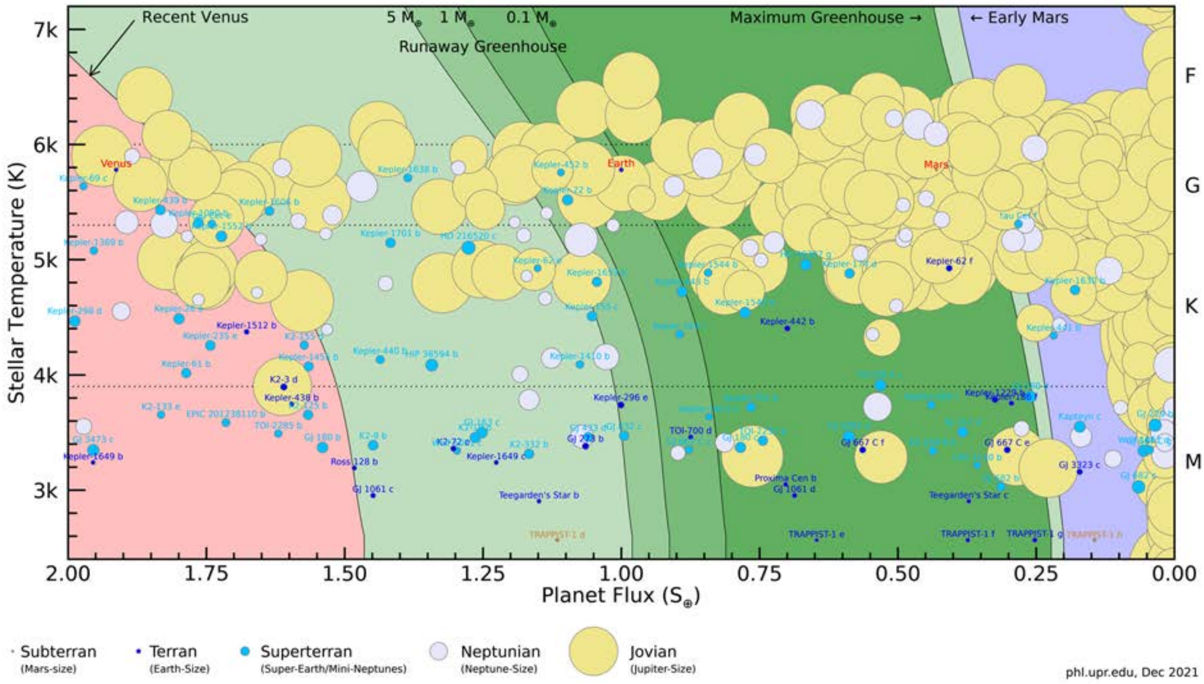
Fig. 2: Distribution of known habitable-zone planets.

Distribution of known habitable-zone planets. "Earth is indicated by red dot whereas the blue circles stand for warm terrestrial planets and super Earths, and the three separated curves, respectively, indicate the habitable border of the Recent Venus, Runaway Greenhouse and Early Mars [scenarios]" [8]
Credit (image and caption): Jianghui Ji et al

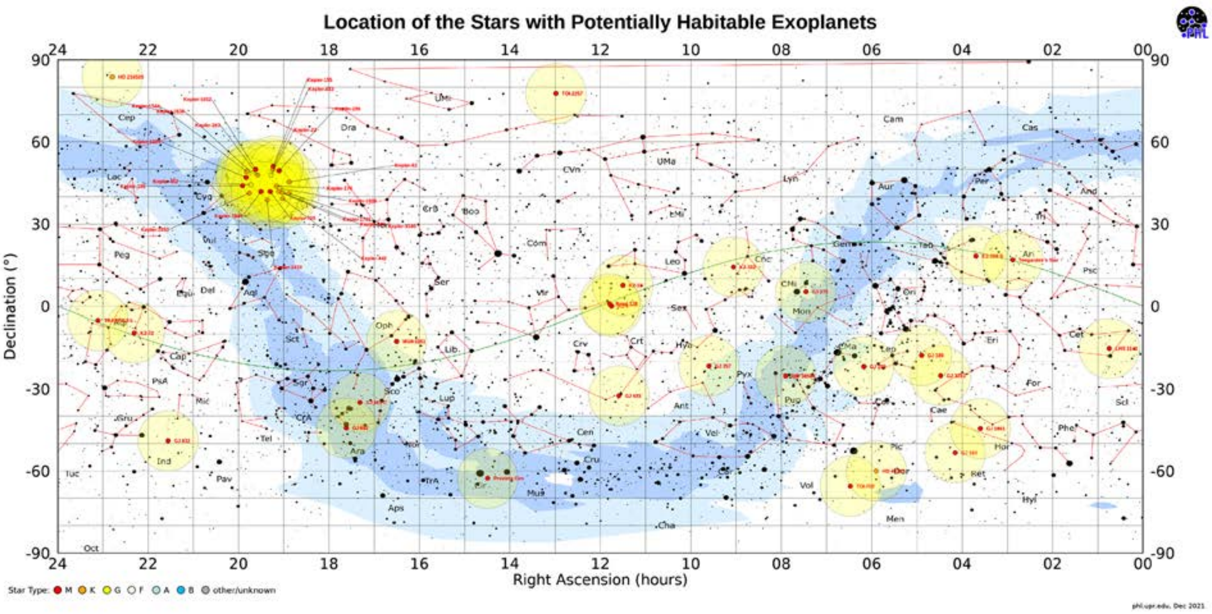
[1] *CHES: a space-borne astrometric mission for the detection of habitable planets of the nearby solar-type stars.* Jianghui Ji, Haitao Li, Junbo Zhang, Liang Fang, Dong Li, Su Wang, Yang Cao, Lei Deng, Baoquan Li, Hao Xian, Xiaodong Gao, Ang Zhang, Fei Li, Jiacheng Liu, Zhaoxiang Qi, Sheng Jin, Yaning Liu, Guo Chen, Mingtao Li, Yao Dong, Zi Zhu, CHES consortium; [v3] Thu, 9 Jun 2022 arxiv.org/abs/2205.05645 with publication expected in the Institute of Physics journal, *Research in Astronomy and Astrophysics (RAA)*
[2] en.wikipedia.org/wiki/List_of_nearest_bright_stars#Stars_within_10_parsecs
[3] Cassegrain plus a plane mirror to fold the optical path to the focal plane
[4] Compare the Gaia astrometry mission www.cosmos.esa.int/web/gaia/science-performance - though not primarily looking for exoplanets
[5] The slight wobble produced in a star's position by the gravity from its planets, en.wikipedia.org/wiki/Methods_of_detecting_exoplanets#Radial_velocity
[6] There are two types of laser interferometers: homodyne and heterodyne. A homodyne interferometer uses a single-frequency laser source, whereas a heterodyne interferometer uses a laser source with two close frequencies. spie.org/publications/tt61_541_laser_interferometer
[7] en.wikipedia.org/wiki/List_of_objects_at_Lagrange_points#L2
[8] *Habitable Zones Around Main-Sequence Stars: New Estimates*, Kopparapu et al, 2013, The Astrophysical Journal, https://iopscience.iop.org/article/10.1088/0004-637X/765/2/131/pdf

Habitable Exoplanets Catalogue

The Planetary Habitability Laboratory (PHL), University of Puerto Rico at Arecibo, maintains a Habitable Exoplanets Catalog (HEC) using the NASA Exoplanet Archive (exoplanetarchive.ipac.caltech.edu/index.html). The PHL catalogue (phl.upr.edu/projects/habitable-exoplanets-catalog) tabulates relevant exoplanets and includes some helpful graphics. Just two of them here -



Habitable Zone Plot. The figure above shows all planets near the habitable zone (darker green shade is the conservative habitable zone and the lighter green shade is the optimistic habitable zone). Only those planets less than 10 Earth masses or 2.5 Earth radii are labeled. The different limits of the habitable zone are described in Kopparapu et al (2014). Size of the circles corresponds to the radius of the planets (estimated from a mass-radius relationship when not available).
Credit (image and caption): PHL @ UPR Arecibo.

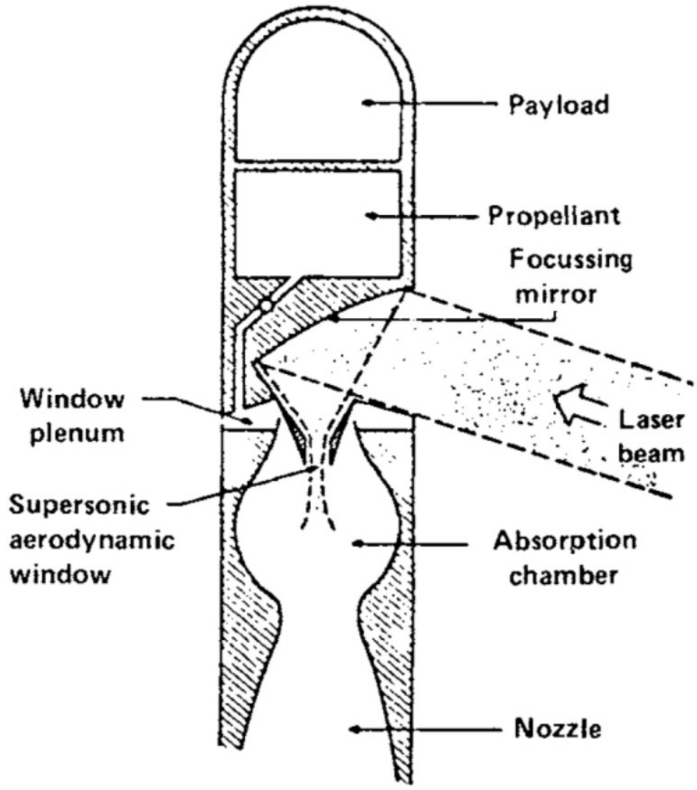


Stellar Map. Location in the night sky of all the known stellar systems with potentially habitable worlds (some systems have more than one planet). There is also a "click to enlarge" version www.hpcf.upr.edu/~abel/phl/hec2/images/hec_starmap.png

Credit: PHL @ UPR Arecibo, Jim Cornmell.

Have Starship Will Travel & IRG 2023

The 26th edition of *Have Starship, Will Travel* (HSWT) is now available. It's good to see the Interstellar Research Group (IRG) is still using that playful name despite their recent name change from Tennessee Valley Interstellar Workshop (TVIW). Fans of old TV westerns will recognise the reference!
Find it at - irg.space/wp-content/uploads/2022/07/IRG_Newsletter_N26_v2.pdf
It's got the usual good mixture of topics including -
Laser Thermal Propulsion tor Rapid Transit to Mars, Andrew Higgins.
Andrew is a prof of mechanical engineering at McGill University, Montreal. He is an old friend of i4is and next year he's hosting the IRG 8th Interstellar Symposium, 10 – 13 July, 2023 (irg.space/irg-2023/).
His paper is about the McGill work on laser-thermal rocketry designs. In this case as applied to fast missions to Mars. Based on the work of Philip Lubin's group at UC Santa Barbara on laser sailing, this looks at how we might make an intermediate step using less powerful laser banks. Andrew describes himself as "an old-time gasdynamicist" (pause while those of us who never got thermodynamics through their heads at college to tip the hat). He therefore thought about heating propellant that is expanded out of a traditional nozzle, ie a giant steam kettle in space. There's a lot more about the background to this in his piece but the basic ideas come from the emergence of inexpensive fibre-optic lasers and gas-core nuclear thermal rockets (see the News Feature on IAC 2022 elsewhere in this issue [1]). For a one ton payload (based on a NASA requirement) a 100 MW laser would point at the vehicle for about an hour. They aim to use a large inflatable reflector at the target spacecraft to accelerate it to about 14 km/s.
They have a paper published in Acta Astronautica Volume 192, March 2022, pp. 143-156 *Design of a rapid transit to Mars mission using laser-thermal propulsion*, (arxiv.org/abs/2201.00244).
How Will Aliens Land Their Spacecraft? Probably Using Magnetohydrodynamics, Colin Warn.
Maybe curious ETIs will find atmospheric braking in their attempt to visit earth would be thermodynamically challenging?



Concept for a laser-thermal rocket from the early 1980s, using a 10-micron-wavelength CO2 laser.
Credit: Kemp, Physical Sciences Incorporated (1982)

Magnetohydrodynamic (MHD) Braking is what they need! Colin Warn reviews *Magnetohydrodynamic Enhanced Entry System for Space Transportation (MEESST) as a Key Building Block for Low-Cost Interplanetary Missions*, Manuel La Rosa Betancourt et al JBIS 74 #12, December 2021. This suggests use of electromagnetic fields to exploit Magnetohydrodynamic (MHD) principles to displace the ionised gas away from the spacecraft, reducing the thermal loads and even opening a magnetic window for radio waves, mitigating the blackout phenomenon you may have observed so unnerving if you watch a returning spacecraft live and especially challenging for the Apollo astronauts on a Moon-Earth transit trajectory. High Temperature Superconductors (HTS) have now reached industrial maturity offering the necessary low weight and compactness required for space applications. The work has the support of a grant from the EU Horizon 2020 programme. For non-UK readers it's worth noting that UK researchers are no longer eligible for EU Horizon funding - as a result of the UK Brexit decision.

[1] Joint Session on Advanced and Nuclear Power and Propulsion Systems IAC-22,C3-4

Internet of Spacecraft

Internet of Spacecraft for Multi-planetary Defense and Prosperity, Yiming Huo, University of Victoria, British Columbia, in *Signals*, Vol 3 #3 2022 (arxiv.org/abs/2205.08567) is a substantial review of the necessity of a network infrastructure for space including a revisit to the K-Pg extinction event, the Chelyabinsk event, extra-terrestrialisation, terraforming, planetary defence, including the emerging near-Earth object (NEO) observation and NEO impact avoidance technologies and strategies and a consequent prediction. Topics include the proposed framework of a novel Solar Communication and Defense Networks (SCADN) using advanced algorithms and high efficacy to enable an internet of distributed deep-space sensing, communications, and defence to cope with disastrous incidents such as asteroid/comet impacts with perspectives on legislation, management, and supervision of founding the proposed SCADN.

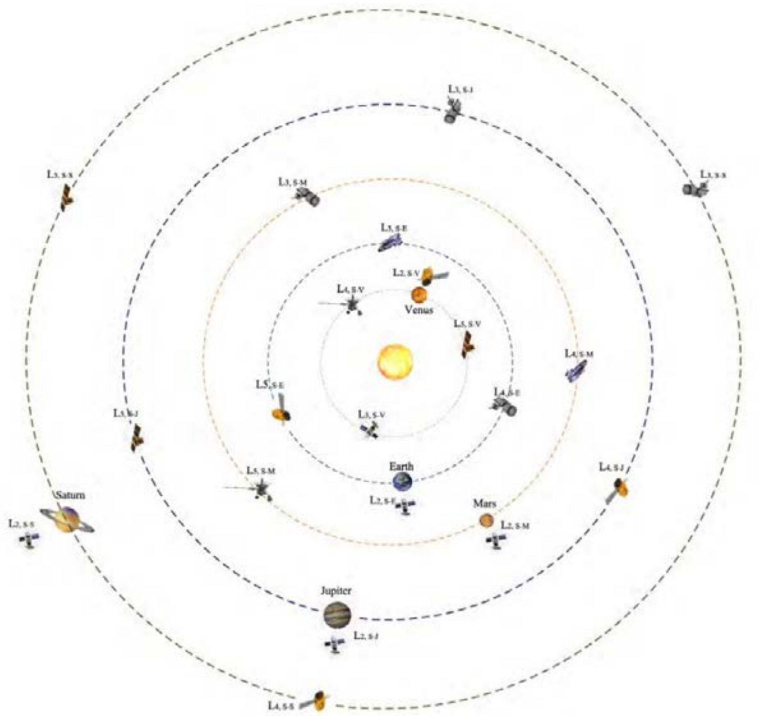


Fig. 17. An exemplary illustration of survey stations and spacecraft deployed under the SCADN framework, in particular, where survey stations/spacecraft are deployed at Lagrange points of the solar planets
Credit: Yiming Huo

The paper considers the challenges of wireless communications over extremely long propagation, particularly the very large latency, using Earth as the only routing point to store, exchange, and process data and telemetry commands from survey stations/spacecraft with resulting very long latency and low efficiency. Potential solutions include artificial intelligence (AI) and edge computing on the survey stations/spacecraft so that they could process the image and data extracted from the space and determine if a detection is of interest. Communication interruption due to interference could be mitigated and eventually, such an AI and edge computing assisted architecture can improve the overall system efficiency of wireless communications in deep space and identify the objects of interest.

It's striking that this otherwise wide-ranging paper makes no reference to the work on Vinton G Cerf, the grandfather of the interplanetary internet (and much else in the internet), for example in *Delay-Tolerant Networking Architecture*, 2007 [1].

In i4is work there was some dialogue back in 2018 on the possibilities for machine learning for chipsat data reduction between Pete Warden (then Google Brain) and Andreas Hein (then and now Technical Director of i4is). Mainly about edge computing for intelligent data filtering on very small Earth observation satellites on the Google side and of obvious interest to the twin i4is projects, Glowworm [2] and Pinpoint [3].

[1] *IETF RFC 4838 Delay-Tolerant Networking Architecture*, Cerf et al www.rfc-editor.org/rfc/rfc4838. This draft standard has gathered 1732 citations according to Google Scholar

[2] *News Feature: i4is Project Glowworm update*, Dan Fries and John Davies, in Principium 31, November 2020 (i4is.org/wp-content/uploads/2021/08/News-Feature-i4is-Project-Glowworm-update-Principium31-print-201129l231-opt-5.pdf)

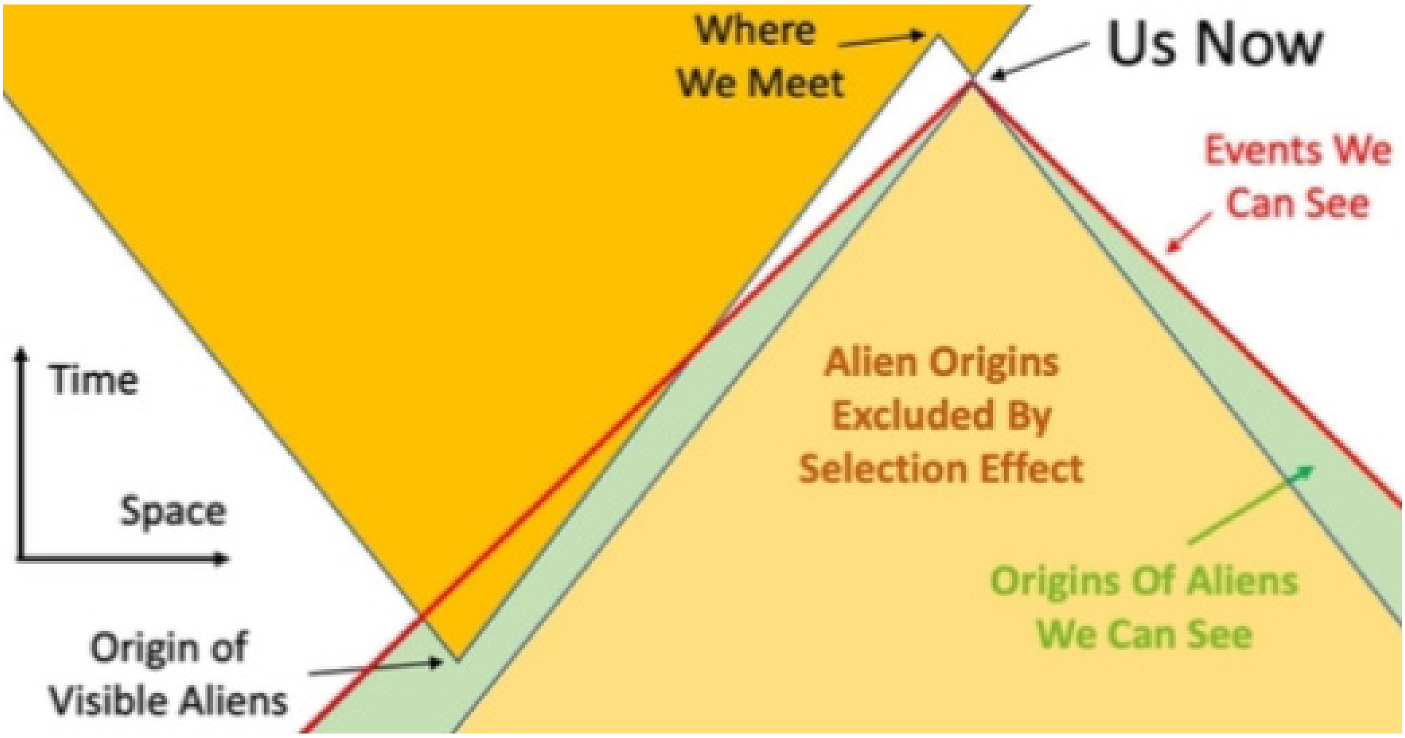
[3] *Project Pinpoint: Pushing the Limits of Miniaturization*, Andrew Broeker, in Principium 33, May 2021 (i4is.org/wp-content/uploads/2021/05/Project-Pinpoint-Pushing-the-Limits-of-Miniaturization-Principium33-print-2105280923.pdf)

Loud and quiet aliens

Paul Gilster's Centauri Dreams (www.centauri-dreams.org) is probably the most fruitful single source on interstellar technology and SETI. This is a particularly relevant posting, *If Loud Aliens Explain Human Earliness, Quiet Aliens Are Also Rare: A review* [1]. This reports a recent paper on the perennial "where are they" question. Gilster analyses it in some detail. It refers back to some of Gilster's own work and explains the Hard Steps Power Law, which argues that each evolutionary "hard step" multiplies the difficulty of achieving the anticipated outcome. The recent paper divides exosolar technological civilizations (ETCs) into loud and quiet categories and reports simulations based on loudness and number of hard steps required. It concludes -

- We have appeared very early in the history of civilizations arising in the universe.
- For SETI to be successful, there needs to be a loud ETC close by, and for one to be close by, the conversion rate of quiet civilizations to expansive, loud ones must be in the order of one per billion.
- Speed of expansion of ETCs, see diagram.

Gilster comments that the pessimistic conclusion (we are one of the first) leads to the probability that "there should be lots of places (planets, moons) with life at some step in their evolution, so while SETI searches don't look promising from the conclusions of this paper, the search for signs of exosolar life may be productive." He believes that this paper gives us a new framework for SETI and is part of a process which will eventually see the Drake equation supplanted.



The orange portion of the diagram shows the origin and expansion of an ETC at a significant proportion of the speed of light. We—by looking out into space are also looking back in time—can only see what is in our light cone (that which is below the red line), so we see the origin of our aliens (say one billion years ago) and their initial spread up to about half that age. After which, the emissions from their spreading civilization have not yet had time to reach us.
The tan triangle represents the area in space from which an ETC spreading at the same rate as the orange aliens would already have arrived at our planet (in which case we would either not exist or we would know about it), so we can assume that there were no expansive aliens having originated in this portion of time and space.
If we make the spread rate a smaller proportion of the speed of light, then this has the effect of making both the orange and tan triangles narrower along the space axis. The size of the tan exclusion area becomes smaller, and the green area, which is the area that can contain observable alien civilizations that haven't reached us yet, becomes bigger.
You'll also notice that the narrower orange triangle of the expansive ETC crosses out of our light cone at an earlier age, so we'd only see evidence of their civilization from an earlier time.
Credit (image and caption): Gilster

[1] *If Loud Aliens Explain Human Earliness, Quiet Aliens Are Also Rare*. A review (www.centauri-dreams.org/2022/05/20/if-loud-aliens-explain-human-earliness-quiet-aliens-are-also-rare-a-review/, Robin Hanson et al

Interstellar quantum communication

In *Viability of quantum communication across interstellar distances* [1] (arxiv.org/abs/2205.11816), Arjun Berera and Jaime Calderon-Figueroa of the University of Edinburgh, investigate the possibility of quantum communication using photons across interstellar distance. Factors that could induce decoherence of photons include the gravitational field of astrophysical bodies, the particle content in the interstellar medium, and the more local environment of the Solar System. They concentrate on the potential factors that could prevent us from detecting quantum signals (or establishing quantum communication channels) at interstellar scales.

They explain this potential communication mechanism as "quantum teleportation". Note that the no-communication theorem (en.wikipedia.org/wiki/No-communication_theorem) excludes super-luminal communications so this is not an "ansible" mechanism as envisaged by SF writer Ursula K Le Guin (sf-encyclopedia.com/entry/ansible).

Berera and Calderon-Figueroa go into detail about the interaction between the basic quantum mechanics and those external factors such as gravitation. They discuss communication with an unknown distant ETI through quantum teleportation. They assert that quantum computation would be required at both ends to achieve the bandwidth benefits theoretically available and that our current quantum computation technology is not yet sufficiently capable - there is a lot of "it has been shown that..." theory here. They also mention astronomical observation through this mechanism although it's not clear how this could be so since they also state that a quantum teleportation signal received would be an indication of ETI so outside the realm of astronomy.

Migrating ETI

A new paper, *Migrating Extraterrestrial Civilizations and Interstellar Colonization: Implications For SETI And SETA* [2] considers SETI and the search for extraterrestrial artefacts (SETA). Within this context, Irina K Romanovskaya considers searching for migrating extraterrestrial intelligence (SMETI), contrasting interstellar spacecraft versus free-floating planets as interstellar transport. Scenarios include using free-floating planets that pass by home worlds of extraterrestrial civilizations, using free-floating planets steered towards extraterrestrial civilizations' home worlds by means of astronomical engineering, using free-floating planets ejected from planetary systems by means of astronomical engineering and using cosmic objects ejected from extraterrestrial civilisations' home worlds by their host post-main-sequence stars. An example local flyby was the star GJ 433, which experienced a close flyby of the solar system a few thousand years ago. However, are interstellar spacecraft more likely than free-floating planets as interstellar transport? The paper sees the advantages a SMETI search for free-floating planets to be -

- Plentiful space for habitation, technologies and resources for in-situ resource utilization
- Availability of liquid water for space radiation shielding
- Constant surface gravity
- Possibility of applying astronomical engineering

We would need to search for technosignatures produced by extraterrestrial civilizations using free-floating planets including unexplained electromagnetic radiation and astrophysical phenomena. Similar technosignatures produced in more than one planetary system would be another strong clue.

Where should we search for technosignatures and artefacts (SETA) produced by ETIs using free-floating planets - In Oort clouds? In neighbourhoods of what stellar types?

The paper cites 81 references.

We looked at moving solar systems using their stars as propulsion (Shkadov thrusters) in articles by Dmitry Novoseltsev, *Engineering New Worlds: Creating the Future* in Principium 17, May 2017 (i4is.org/principium-17/), and Principium 18, August 2017 (i4is.org/principium-18/), but this sort of engineering is well up the Kardashev scale from ourselves and even moving planets is tough until we invent the spindizzy! [3].

[1] Physical Review D, Volume 105, Issue 12, article id.123033, June 2022
[2] International Journal of Astrobiology Vol 21 # 3, April 2022, https://www.cambridge.org/core/services/aop-cambridge-core/content/view/BFFC1BB63FED869C85172BB3CC88DBBB/S1473550422000143a.pdf/migrating-extraterrestrial-civilizations-and-interstellar-colonization-implications-for-seti-and-seta.pdf
[3] *Earthman come home*, James Blish, Putnam 1955 (en.wikipedia.org/wiki/Cities_in_Flight and en.wikipedia.org/wiki/Spindizzy) and sf-encyclopedia.com/entry/spindizzy.

Mission architecture to the solar gravitational lens

In *A mission architecture to reach and operate at the focal region of the solar gravitational lens* [1], Henry Helvajian et al suggest using a metre-class telescope to produce images of an exoplanet with a surface resolution tens of kilometres to identify signs of habitability. The data would be acquired pixel-by-pixel while moving an imaging spacecraft within the image plane. Given the long duration of the mission, decades to reach 900 AU, they aim for the fastest possible transit time while reducing mission risk and overall cost using solar sailing and in-space aggregation of modules to form mission capable spacecraft. They identify and characterise major challenges in propulsion (a direct ascent cannot deliver the required vehicle), long-life nuclear power sources (since the Sun is too weak to help at this distance) and communication (need for LAN between multiple spacecraft and long distance laser downlink).

They conclude that this is a challenging mission but nevertheless feasible with technologies that are either extant or in active development. They suggest small satellites (10-20 kg), sail technology with articulated vanes, Brayton cycle power generation to deliver better efficiency than the radioisotope thermoelectric generators (RTGs) currently used and mass production of the satellite components.

Optimal mass and speed for interstellar flyby

In *Optimal mass and speed for interstellar flyby with directed-energy propulsion*, Messerschmitt, Lubin & Morrison [2] address the design of mission scenarios for the flyby investigation of nearby star systems by probes launched using directed energy. This work is supported by grants from NASA, the Limitless Space Institute [3], Breakthrough Initiatives and the Emmett and Gladys W Technology Fund.

Multiple probes are sent from a single launch infrastructure. They assume the primary goal is to reliably recover the largest volume of scientific data with the least data latency (elapsed time from launch to complete recovery of the data). They show that there is an efficient frontier where volume cannot be increased for a given latency and latency cannot be reduced for a given volume. For each probe launch, increasing the volume by increasing the probe mass results in a reduced probe speed (thus adding to latency). They determine that aiming for the highest feasible probe speed does not necessarily achieve a good tradeoff of volume versus latency. They conclude that the download time duration approximates to a fixed fraction of the launch-to-target transit time. Longer propulsion duration when probe mass is increased to increase data volume adds to a cost via the additional launch energy expended, though there are economies of scale. Thus an important characteristic of any probe technology is an efficiency scaling law that relates probe mass to transmit data rate.

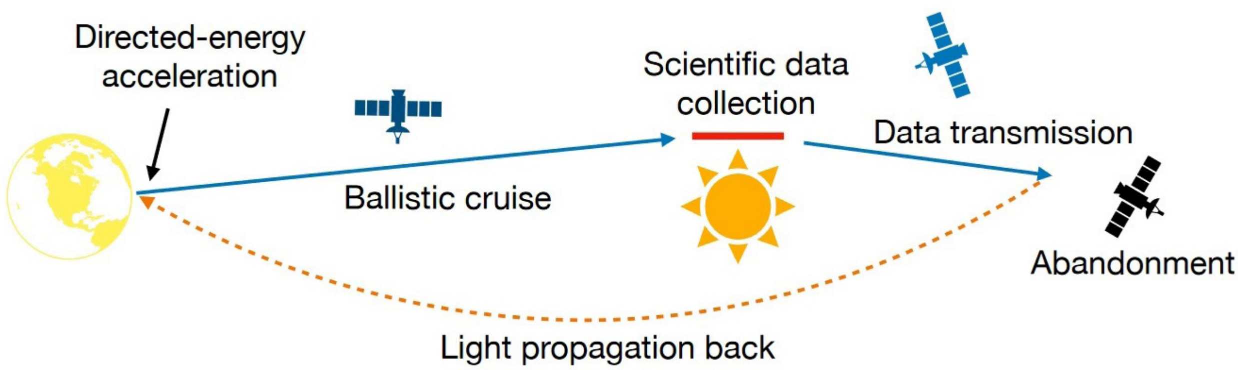


Figure 1: Illustration of the phases of a flyby mission for a probe propelled by directed energy from the launch site. The goal is to reliably recover the collected scientific data at the launch site. Credit(image and caption): Messerschmitt et al

[1] *A mission architecture to reach and operate at the focal region of the solar gravitational lens*, Henry Helvajian et al at The Aerospace Corporation, California and NASA's JPL, 2022, arxiv.org/abs/2207.03005
[2] *Optimal mass and speed for interstellar flyby with directed-energy propulsion*, David G Messerschmitt (UC Berkeley), Philip Lubin (UC Santa Barbara) and Ian Morrison (Curtin University, Australia) https://arxiv.org/abs/2206.13929
[3] LSI funds i4is courses *Human Exploration of the Far Solar System and on to the Stars* i4is.org/summer-course-25-29th-july-2022/

So Messerschmitt et al observe that despite the minimum cost versus minimum journey time calculation which governs much investigation of the feasibility of interstellar probes "...the ultimate purpose of a mission is an important consideration in the development of new propulsion technologies as well as in mission design". They muse that, for a ballistic flyby mission as envisaged by Starshot, there is a preference for slower speeds to maximise the time for information gathering at the target system. They offer two tables to summarise the dilemma -

Table 1: Flyby mission scientific performance metrics

Variable	Definition
V_{data}	Total received volume of scientific data reliably recovered at Earth
$T_{latency}$	Data latency = time elapsed from launch to reception of scientific data in its entirety

Table 2: Flyby mission parameters

Variable	Definition
t	Classical coordinate time at launch site and at probe
T_{down}	Time duration of transmission in coordinate time
m_P	Mass of probe, including sail, instrumentation, and communications
ξ_P	Mass ratio, equal to mP /m0 , where m0 is a baseline value for mass (ξ_P = 1 for some baseline case)
u_P	Ballistic probe coordinate speed, with value u0 for $\xi_P = 1$
D_{star}	Distance from launch to target star, and from probe transmitter to receiver at the start of downlink operation
R_{start}	Initial data rate at start of transmission, with value R0 for $\xi_P = 1$
k	Mass ratio to data-rate scaling exponent, so the data rate R scales by $\xi_P^{\ k}$

Credits: Messerschmitt et al

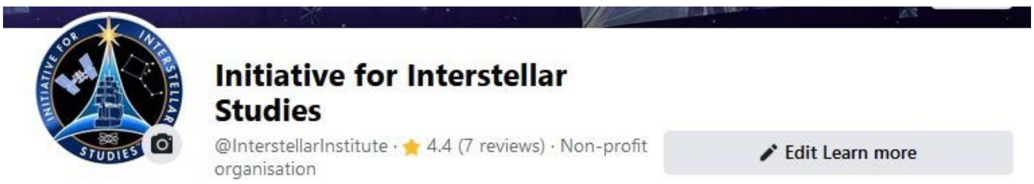
- where the mission performance metrics V_{data} and $T_{latency}$ should be jointly optimised to achieve the most favourable tradeoff between them.

Downlink data is an essential requirement of course and they suggest that the performance in this respect can be wrapped into a single parameter: a baseline data rate R_0.

They assume a launch system ("laser farm") that is shared between probes with different instrumentation, data volume, and latency parameters. Their analysis leads to consequences for launch energy cost and resultant economies of scale.

KEEP AN EYE ON OUR FACEBOOK PAGE

Our Facebook page at **www.facebook.com/InterstellarInstitute** is a lively forum much used by our own Facebookers and others active in our subject area.

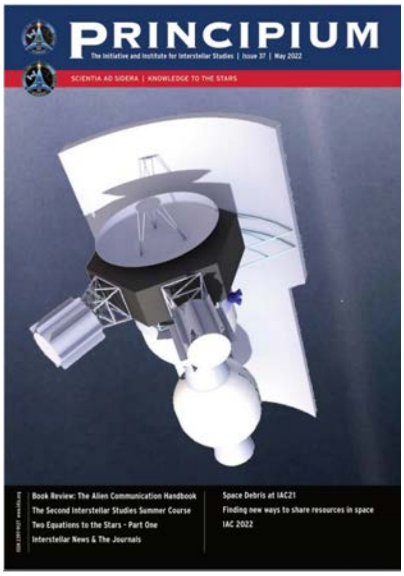


Project Lyra: Another way to 1I/'Oumuamua

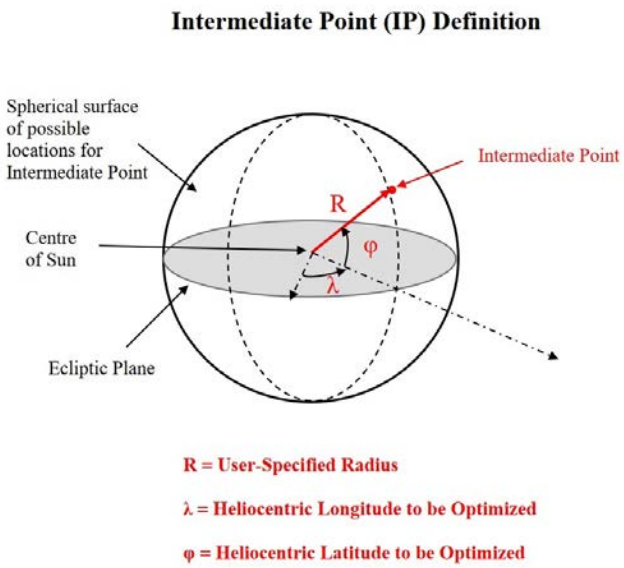
Adam Hibberd of the i4is Project Lyra team has published *Project Lyra: Another Possible Trajectory to 1I/'Oumuamua* (https://arxiv.org/abs/2205.04693). Adam suggests a mission to the interstellar object (ISO), 1I/'Oumuamua, using an Oberth manoeuvre at Jupiter (JOM) to accelerate the spacecraft towards its target. This route requires little or no deltaV (ΔV) en route to Jupiter and thus need not carry a liquid propellant stage. The cost is higher ΔV needed at Jupiter, requiring either 2 or 3 staged solid rocket motors. Adam's animation (www.youtube.com/shorts/MfWXpwuiEbo) shows how this also avoids the solar Oberth manoeuvre which can deliver maximum ΔV but at the cost of substantial heat shielding, as in our P37 front cover image.

Adam also has a more general paper, *Intermediate Points for Missions to Interstellar Objects Using Optimum Interplanetary Trajectory Software* (arxiv.org/abs/2205.10220) explaining the concept of an Intermediate Point (IP), its incorporation as a node along an interplanetary trajectory, and how it permits the determination and optimisation of trajectories to interstellar objects (ISOs). For example this is used to include the impulse at perihelion for a solar Oberth manoeuvre or modelling of V_∞ Leveraging Manoeuvres (VLM) to reduce the total ΔV needed to achieve the asymptotic velocity - Vinfinity (V_∞) - to reach ISOs or other distant objects. The paper covers the theory applied by Adam's Optimum Interplanetary Trajectory Software (OITS) and gives some example solutions.

Animation, https://www.youtube.com/shorts/MfWXpwuiEbo
Credit: Adam Hibberd



Principium 37 front cover visualisation of a probe using a solar Oberth manoeuvre showing the shielding required.The image depicts such a craft as it heads outwards to intercept the ISO 1I/'Oumuamua with Sagan's Pale Blue Dot of the Earth in the middle of the misty band to the right. The mass penalty of the shield is avoided in Adam's latest proposal.



Intermediate Point (IP) Definition from - *Intermediate Points for Missions to Interstellar Objects Using Optimum Interplanetary Trajectory Software.*

The stages of development of extraterrestrial civilizations (cultural evolution), and increment their requirement for mineral and energy resources. Credit(image and caption): Veysil

ETI evolution

The IRG database (irg.space/database/) draws attention to three recent papers -

Technological Evolution of Extraterrestrial Civilizations: Dyson Spheres, Warp Drives, Energy Capturing Conquerors, Hadi Veysi, Shahid Beheshti University, Tehran, Iran - in Journal of Astrobiology.
journalofastrobiology.com/Extraterrestrial1.pdf
Veysi surveys the range of possible ET civilisations adding zero to Kardashev's classic I, II and III categories (I guess we rate about 0.5?) and speculating mainly about post-biological civilisations. A diagram illustrates this. The paper includes about 75 references.

Extraterrestrial Intelligence: A Cognitive Evolutionary Perspective
Gordon Gallup and Hesper E Faliveno, University at Albany, The State University of New York
Journal of Astrobiology 2022
www.researchgate.net/publication/358629839_Extraterrestrial_Intelligence_A_Cognitive_Evolutionary_Perspective (open access)
The paper evaluates claims for extraterrestrial intelligence based on the logic behind assertions such as the absence of evidence is not evidence of absence via "two of the principle scientific claims for intelligence on Earth" (I think they mean "principal" here). Gallup and Faliveno are psychologists. Asking what distinguishes intelligent life from other life they cite Richard Dawkins "intelligent life comes of age when it works out the reasons for its own existence" and contrast Falk (see below) on brain size, cognition and intelligence pointing out that despite their large brains cetaceans lack the ability to create tools and technology, whereas a subset of primates developed tool technology and grammatical language and became the intellectually dominant species on this planet. They discuss self-awareness, are sceptical about intellectual parsimony "God, metaphorically speaking, does not always shave with Occam's Razor" and extinction events, something close to Liu Cixin's Dark Forest thesis (in his novels in that sequence) "Maybe Intelligent Extraterrestrial Life Does Not Want to be Found".

Implications of Brain Evolution in Cetaceans and Primates for Highly Intelligent Extraterrestrial Life,
Dean Falk, Florida State University, Journal of Astrobiology 2022
diginole.lib.fsu.edu/islandora/object/fsu:791448.
Falk suggests that the evolution of cetaceans (whales, dolphins, etc) and primates on Earth may provide some clues as to how intelligent life may have evolved on other planets. He asserts that "If intelligent cetacean-like beings evolved convergently in other worlds in response to aquatic habitats similar to Earth's, they would not be expected to have complex tools and technologies". He is sceptical about relative brain size (RBS) as a correlate. His essential thesis seems to be incorporated in -
"on planet Earth only the human primate has evolved full-blown symbolic, grammatical language that may be used to generate and receive an endless stream of ideas. Put that ability with two (or more) manipulative extremities in an environment that has "stuff" and the sky's, literally, the limit."
So whales don't have hands and that makes the difference. He does not consider cephalopods, who do have similarly useful appendages, tentacles.