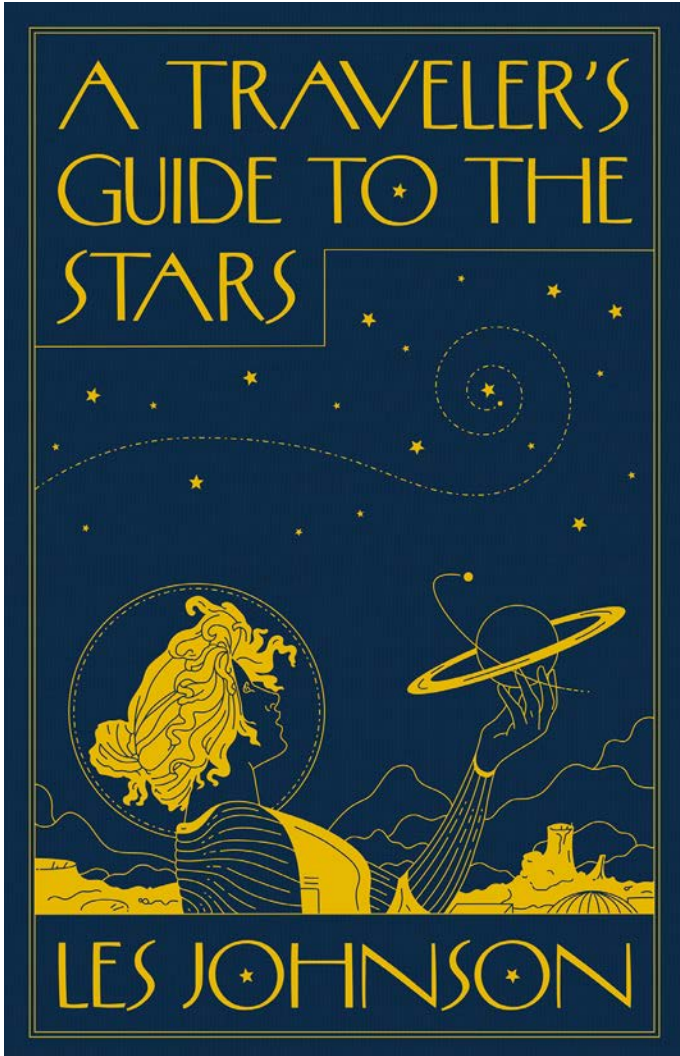


## John I Davies reports on recent developments in interstellar studies

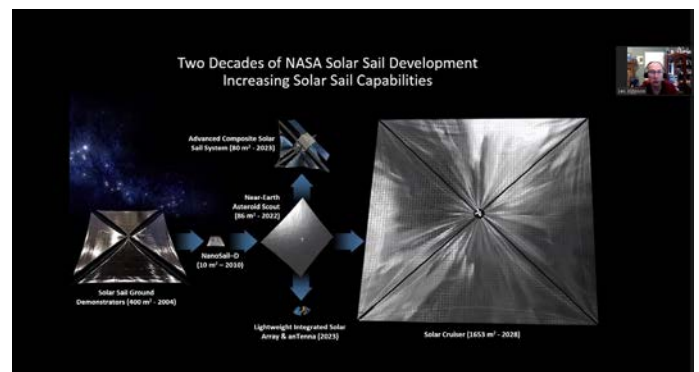
### The Possibilities of Interstellar Exploration

Les Johnson [1] is a 15 year NASA veteran with an outstanding record in interstellar studies. He has recently been on a book tour in support of *A Travellers Guide to the Stars* (Princeton University Press). We'll be reviewing this latest of his books in our next issue.

In the meantime here some shots from his presentation at the BIS 5 April 2023.



Les's intro slide with Zoom participants Alistair Scott (BIS President), our own Rob Swinney and Les Johnson



Two Decades of NASA Solar Sail Development; Increasing Solar Sail Capabilities



Will Chemical Rockets Take Us To the Stars?

**>5322 Exoplanets Known Today\***

- It is now estimated that there are **100 – 400 billion** exoplanets in the Milky Way Galaxy alone

\* <https://exoplanets.nasa.gov/>

**>5322 Exoplanets Known Today**

[1] Scientist, author, futurist, and space technologist. [lesjohnsonauthor.com/](https://lesjohnsonauthor.com/)

## 2023 Canopus Award Winners

We reported the Canopus Awards and NEXUS™ NAIROBI in our last issue, Principium 40. The 2023 Award winners include -

In the category of "Published Long-Form Nonfiction" Les Johnson for *A Traveler's Guide to the Stars*, see previous article. In the category of "Published Short-Form Nonfiction" the winners are Alex McKenzie and J Punske for "Language Development During Interstellar Travel," originally published in *Acta Futura* (the ESA technology journal), 2020 with runner up *Artificial Intelligence for Interstellar Travel*, Andreas M Hein and Stephen Baxter (Journal of the British Interplanetary Society 2018).

The full list is at [canopusawards.org/](https://canopusawards.org/)

## Another tool in the SETI toolbox

In *Multibeam Blind Search of Targeted SETI Observations toward 33 Exoplanet Systems with FAST* [1] a team from Beijing Normal University, University of Glasgow, Beijing Academy of Science and Technology, Dezhou University (China), Qilu Normal University (China), Breakthrough Listen and University of California Berkeley use a new technique, multibeam coincidence matching (MBCM) blind search mode to search for narrowband drifting signals across 1.05–1.45 GHz in two orthogonal linear polarisation directions separately. They are using the 19 simultaneous beams possible in the new Five-hundred-meter Aperture Spherical radio Telescope (FAST) [2]. The FAST 19-beam receiver allows them to minimise false positives more efficiently than the traditional on/off strategy (which checks directions other than the initial candidate source) while also spotting additional possible sources such as exoplanets in the target system and eliminating intermittent false signals whose interval just happen to coincide with switch between on and off in the traditional on/off strategy. Thanks to Fraser Cain at Universe Today for flagging this [3].

One minor error - the picture captioned "Frank Drake by the Green Bank Telescope. Credit: NRAO/

NSF/AUI" in the Universe Today article looks like Drake but the telescope shown is not the giant one the public knows but probably the 85-foot Tatel Telescope ([en.wikipedia.org/wiki/Green\\_Bank\\_Interferometer](https://en.wikipedia.org/wiki/Green_Bank_Interferometer)) he used in his pioneering SETI search, more in our Interstellar News, *Frank Drake 1930-2022*, Principium 39, November 2022 [4].

## Explanation for orbit of 1I/'Oumuamua?

In *A surprisingly simple explanation for 'Oumuamua's weird orbit* [5] the news site, ScienceX, references a new paper *Acceleration of 1I/'Oumuamua from radiolytically produced H<sub>2</sub> in H<sub>2</sub>O ice* [6] - by Jennifer Bergner, UC Berkeley, and Darryl Seligman, Cornell University, about 1I/'Oumuamua, our first detected interstellar object (ISO). A conversation with Darryl Seligman (co-author of one of the earliest astronomical papers on 1I [7] brought their respective chemistry and physics knowledge together. It was known that galactic cosmic rays acting on icy bodies would produce molecular hydrogen which would then be trapped in the ice. So 'Oumuamua began as an icy planetesimal that was irradiated at low temperatures by cosmic rays during its interstellar journey, and experienced warming during its passage through the Solar System.

Does this solve the mysteries around this ISO? They imply it is a comet, conventionally a "dirty snowball", but it was shaped more like an elongated rugby ball than a tennis ball so not snowball shaped. So its tumbling motion should have pulled it apart, but it didn't.

There is a rebuttal - *Implications of evaporative cooling by H<sub>2</sub> for 1I/'Oumuamua* ([arxiv.org/abs/2303.13861](https://arxiv.org/abs/2303.13861)). Here Thiem Hoang and Abraham (Avi) Loeb argue that the earlier paper, Bergner & Seligman, calculation of surface temperature ignored the crucial cooling effect of evaporating H<sub>2</sub>. This reduces the surface temperature by about one order of magnitude and thus the evaporative effect by a factor of 3.

There remains no strong consensus on the nature of our first observed ISO. Time to start planning a mission!

[1] Xiao-Hang Luan et al [arxiv.org/abs/2301.10890](https://arxiv.org/abs/2301.10890)

[2] see *The FAST radio telescope works with Breakthrough Listen to push SETI forwards* in Principium 29 May 2020 page 54

[3] *The World's Largest Radio Telescope Just Scanned 33 Exoplanets for a Signal From Aliens*, Matt Williams, February 7, 2023, [www.universetoday.com/159855/the-worlds-largest-radio-telescope-just-scanned-33-exoplanets-for-a-signal-from-aliens/](https://www.universetoday.com/159855/the-worlds-largest-radio-telescope-just-scanned-33-exoplanets-for-a-signal-from-aliens/)

[4] [i4is.org/wp-content/uploads/2022/11/interstellar-news-Principium39-2211291202opt-2.pdf](https://i4is.org/wp-content/uploads/2022/11/interstellar-news-Principium39-2211291202opt-2.pdf)

[5] [phys.org/news/2023-03-simple-explanation-oumuamua-weird-orbit.html](https://phys.org/news/2023-03-simple-explanation-oumuamua-weird-orbit.html)

[6] Jennifer B Bergner & Darryl Z Seligman, Nature volume 615, pages 610–613 (2023), <https://arxiv.org/abs/2303.13698>

[7] *The Feasibility and Benefits of In Situ Exploration of 'Oumuamua-like objects*, Darryl Seligman and Gregory Laughlin, [arxiv.org/abs/1803.07022](https://arxiv.org/abs/1803.07022)

## Exploring an exoEarth using the Solar Gravitational Lens

Expeditions to Brazil and the South Pacific in 1919 [1] confirmed Einstein's conjecture that mass would bend light. This prediction of an effect of general relativity makes it possible to use the nearest very massive object to hand, the Sun, as the focussing component of a 650 AU long telescope. Slava Turyshev of NASA JPL proposes a multi-satellite project to allow us to image exoplanets at a resolution of 15 to 25 km - or even better. Bruce Dorminey of Forbes magazine describes the proposal *Radical New Space Observatory Would Gravitationally Lens Exoearths* [2].

The *Solar Gravitational Lens Foundation*, due to launch in June, will promote the idea and seek funding to plan it. Both image and spectroscopic study at this resolution are likely to confirm, or possibly deny, the presence of life on an exoplanet.

## Extraterrestrial Artificial Intelligence

In *Extraterrestrial Artificial Intelligence: The Final Existential Risk?* [3], Wim Naudé, Rheinisch-Westfälische Technische Hochschule Aachen (RWTH) suggests that the possibility that artificial extraterrestrial intelligence poses an existential threat to humanity is neglected. It is also the case in economics, where both AI existential risks and the potential long-term consequences of an AGI are neglected. This paper presents a thought experiment to address these neglected areas. Naudé argues that it is likely that any advanced extraterrestrial civilization that we may encounter will be an AGI, and such an AGI will pose an existential risk.

The paper presents two arguments for this;

- The Dark Forest Hypothesis [4]
- The Galactic Colonization Imperative [5]

The latter is also a key plot element in the SF novel, *Neptune's Brood* by Charles Stross [6].

Naudé suggests -

- accelerating the development of AI as a precautionary step
- maintaining economic growth until we attain the wealth and technological levels to create AGI and expand into the galaxy
- putting more research and practical effort into solving the Fermi Paradox.

Naudé cites sources for the problem that AI's values may not align with humanity's, an alignment problem. Even if the terrestrial alignment problem can be solved there remains the possibility of an extraterrestrial AI which no human would have been able to "bring up properly".

This very brief review has not done justice to Naudé's paper and we will be returning to this subject in a later issue of *Principium*.

## Feminism and ETI scenarios

In *Feminism and gender in thinking about extraterrestrial intelligence* [7]

Konrad Szocik (Yale) and Rakhat Abylkasymova suggest that our attempt to understand a prospective ETI have been biased towards a thinking driven primarily of individualism, abstractionism, rationality and exposition of autonomy. They suggest a broader, feminist, approach would be a useful addition to our ways of attempting to understand a prospective ETI since we cannot even imagine it based on any analogies with human history. One interesting consequence they believe may arise from this is a scepticism about applying the precautionary principle.

[1] *General Relativity and the 1919 Solar Eclipse*, [www.royalobservatorygreenwich.org/articles.php?article=1283](http://www.royalobservatorygreenwich.org/articles.php?article=1283)

[2] [www.forbes.com/sites/brucedorminey/2023/04/22/radical-new-space-observatory-would-use-sun-to-gravitationally-lens-exoearths/](http://www.forbes.com/sites/brucedorminey/2023/04/22/radical-new-space-observatory-would-use-sun-to-gravitationally-lens-exoearths/)

[3] Institute of Labor Economics discussion paper February 2023, IZA DP No. 15924: [www.iza.org/publications/dp/15924/extraterrestrial-artificial-intelligence-the-final-existential-risk](http://www.iza.org/publications/dp/15924/extraterrestrial-artificial-intelligence-the-final-existential-risk)

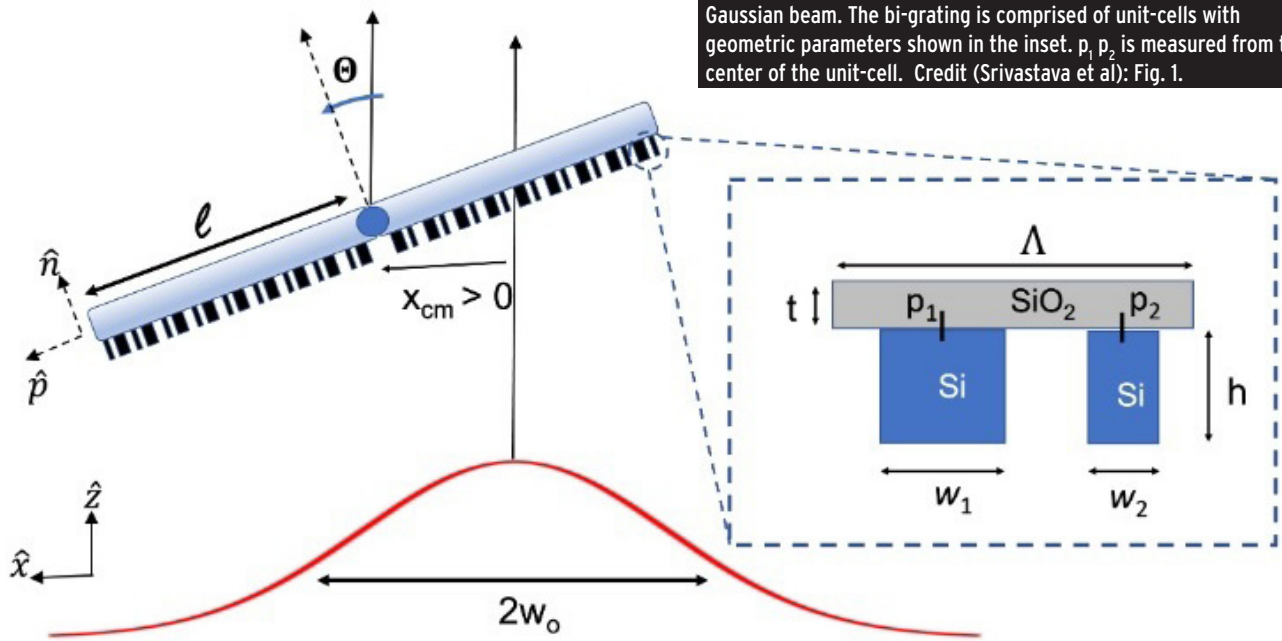
[4] See *Cassidy Cobbs - Bioscientist - Part 2* interviewed by Robert Kennedy and John Davies in *Principium* 30, August 2020 and Chao Yu and Jiajun Liu, *The Dark Forest Rule: One Solution to the Fermi Paradox*, JBIS V68 #5/6, May/June 2015

[5] See *The Theory of Interstellar Trade*, Paul Krugman, in *Economic Inquiry* V48 #4, October 2010 [www.princeton.edu/~pkrugman/interstellar.pdf](http://www.princeton.edu/~pkrugman/interstellar.pdf)

[6] See Crib Sheet: *Neptune's Brood* By Charlie Stross, [www.antipope.org/charlie/blog-static/2014/09/crib-sheet-neptunes-brood.html](http://www.antipope.org/charlie/blog-static/2014/09/crib-sheet-neptunes-brood.html)

[7] *International Journal of Astrobiology* 2023 [www.researchgate.net/profile/Konrad-Szocik/publication/367450644\\_Feminism\\_and\\_gender\\_in\\_thinking\\_about\\_extraterrestrial\\_intelligence/links/63f9d9a0b1704f343f803e3e/Feminism-and-gender-in-thinking-about-extraterrestrial-intelligence.pdf](http://www.researchgate.net/profile/Konrad-Szocik/publication/367450644_Feminism_and_gender_in_thinking_about_extraterrestrial_intelligence/links/63f9d9a0b1704f343f803e3e/Feminism-and-gender-in-thinking-about-extraterrestrial-intelligence.pdf)





High contrast metasurface bi-grating configuration propelled by a Gaussian beam. The bi-grating is comprised of unit-cells with geometric parameters shown in the inset.  $p_1, p_2$  is measured from the center of the unit-cell. Credit (Srivastava et al): Fig. 1.

## High Forward Thrust Metasurface Beam-Riding Sail

The possibility of laser sail propulsion as a means of reaching the nearest stars well with a human lifetime is what drives a great deal of research and the beginnings of development by researchers, much of it through finance and initiatives from *Breakthrough Starshot*. There are many challenges to achieving this and a major one is that, given a laser beam of sufficient power, how do we provide a sail which can use that power to propel our interstellar probe. Stability of the sail (and the attached probe) in the beam is a major element of the problem. In the paper *High Forward Thrust Metasurface Beam-Riding Sail*, Srivastava et al [1], researchers from Rochester Institute of Technology and the University of Utah supported by NASA and Breakthrough Starshot consider a metamaterial composed of Si-SiO<sub>2</sub>. Metamaterials are materials deliberately manufactured to have properties different from those naturally in the constituent molecules. The researchers explain how the proposed metamaterial provides both the very high reflectivity required and inherent self-correcting forces, both linear and rotational, against small destabilising forces. They also suggest that this approach obviates the need for any separate supporting structure for the sail.

Their diagram (above) shows the structure composed of two different panels L (left) and R (right) each of length  $l$ . Each unit-cell of which is a ridge-width-modulated high contrast grating with silicon (Si) nano-pillars on a low index SiO<sub>2</sub> substrate. They state that this structure gives stable levitation thrust, optimal thermal management via radiative cooling and may be easily realised with existing e-beam lithography technology.

They conclude with some reservations including -

- the design is very sensitive to wavelength and becomes unstable for Doppler-shifted wavelength in the case of relativistic sails of Breakthrough Starshot
- The design is (only?) ideal provided a tunable phased-array laser becomes a reality.

## Interstellar Objects and Exocomets

A new paper by Alan Fitzsimmons, Queen's University Belfast, Karen Meech, Institute for Astronomy, Honolulu, Luca Matrà, Trinity College Dublin and Susanne Pfalzner, Forschungszentrum Julich, Germany reviews our knowledge of our galaxy's cometary population outside our Oort Cloud - *Exocomets and Interstellar Objects (ISOs)* [2]. This is a review chapter to appear in the book, *Comets III*.

[1] [arxiv.org/abs/2303.06793](https://arxiv.org/abs/2303.06793)

[2] [arxiv.org/abs/2303.17980](https://arxiv.org/abs/2303.17980)

◀ At the time of publication of the predecessor book, *Comets II* [1], the presence of cometary bodies around other stars had been well established. But the existence of ISOs was merely hypothesised in *Comets II*, although their discovery was widely anticipated. Detection of ISOs passing through the Solar system would in principle allow remote (and eventually in-situ) sampling of bodies from other planetary systems. The surety that such a discovery would eventually occur grew with increasingly refined models of planetary system evolution, and a growing understanding of how cometary bodies are lost to interstellar space and potential evolutionary processes. Some of the most important questions about the first ISO include: (1) Where did it come from? and (2) What is it made of? As the authors point out, we still don't know the answers to these questions. 1I/'Oumuamua was easily observable from the ground for a little over a week, but as it moved away from the Earth it faded quickly, and large telescopes were able to observe for only about 1 month. The last Hubble Space Telescope observations were made in Jan 2018. It is remarkable that we know as much about this object as we do, because all of the large telescope time had to be secured through Director's requests. In total approximately 100 hrs on 2.5-10-m ground-based telescopes were devoted to characterizing this exceptional object. To date, over 200 refereed papers have been written on both interstellar objects, and nearly 450 papers. This review highlights key papers and some reviews of the field. It also mentions concepts for missions to reach 1I/'Oumuamua including Seligman and Laughlin, *The Feasibility and Benefits of In Situ Exploration of 'Oumuamua-like Objects* (2018), discussing launch-on-detection scenarios (implying assumptions about future sightings of Oumuamua-like ISOs), and the numerous i4is Project Lyra papers - mainly concentrating on the one such object we know of, Oumuamua itself.

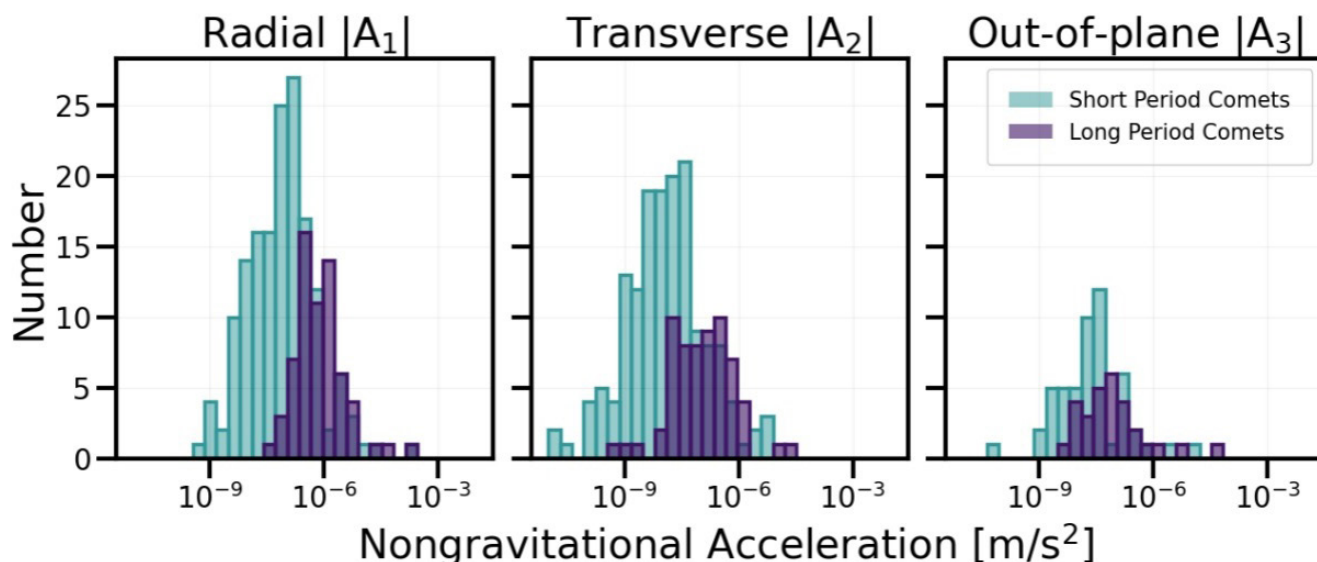
## ISOs from Broken Dyson Spheres

Avi Loeb comes up with another striking speculation. In *Interstellar Objects from Broken Dyson Spheres* [2], the distinguished Harvard scientist, asserts that without extensive maintenance, Dyson spheres will inevitably disintegrate by asteroid impacts over billions of years and the resulting fragments would appear as anomalous interstellar objects, potentially sharing the unusual shape and motion of 1I/'Oumuamua or the unusual material strength of the first two interstellar meteors, IM1 and IM2. He observes that Olaf Stapledon's novel "Star Maker", imagined the use of a technologically-manufactured shell of matter to tap the energy output of a host star. The concept was subsequently formalised by Freeman Dyson. Dyson reasoned that as the energy needs of humanity will steadily increase, our civilisation might aspire to tap all the energy output of the Sun. Loeb reasons that if Dyson spheres existed to serve their civilisations for a limited time, most of them would have disintegrated within billions of years in the absence of extensive maintenance and that their ejected fragments could appear as interstellar objects. He also recalls that Robert Forward proposed a tiled structure for a Dyson sphere [3], with each component functioning as a solar sail for which the star's gravity is exactly balanced by the star's outward radiative push, thus maintaining a fixed position without orbiting the star. If disintegration occurred then these components of the sphere would inevitably have sail-like properties, possibly accounting for the anomalous acceleration observed in Oumuamua. As Clarke remarked in his first law "When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong". Avi Loeb is only 61 so is not yet elderly but he is certainly distinguished. We should therefore consider carefully if his idea fits the facts - and to gather facts we need closer observation of this single instance of such an anomalous object. i4is Project Lyra has a continuing mission to help to explore such strange new worlds.

[1] Reviewed in the the *Journal of the British Astronomical Association*, [britastro.org/journal\\_old/pdf/116-3shanklin.pdf](http://britastro.org/journal_old/pdf/116-3shanklin.pdf)

[2] [curiosmos.com/wp-content/uploads/2023/02/Dyson\\_arXiv.pdf](https://curiosmos.com/wp-content/uploads/2023/02/Dyson_arXiv.pdf)

[3] *Statite - A spacecraft that does not orbit*, Forward, Journal of Spacecraft and Rockets, 1991



## Number of ISOs

A new paper by Darryl Z Seligman (Cornell University) and Amaya Moro-Martin (Johns Hopkins University), *Interstellar Objects* ([arxiv.org/abs/2304.00568](https://arxiv.org/abs/2304.00568)) makes the following bold statement (in the abstract) "We describe 1I/'Oumuamua and 2I/Borisov in the context of active asteroids and comets in the Solar System. The discovery of these two objects implies a galactic-wide population of 10<sup>26</sup> similar bodies.". They discuss cometary outgassing as a contributor to non-gravitational acceleration (as in 1I/'Oumuamua). They use a graphic from the JPL Small Body Database to show the distribution of these accelerations in Solar System comets (above) and describe the sublimation processes for various constituents which typically occur in Solar System comets. They go through the observations of 1I/'Oumuamua in some detail observing that "Some of these provided critical upper limits on the production rates of dust and certain volatile species." (ie typical cometary outgassing) and report that observations produced no detectable outgassing. And even the dimensions of 1I remain uncertain with the long dimension uncertain by a factor of at least two. They cite a couple of elongated Solar System asteroids including 216 Kleopatra ([en.wikipedia.org/wiki/216\\_Kleopatra](https://en.wikipedia.org/wiki/216_Kleopatra))

The measured non-gravitational accelerations of Short-Period Comets (teal) and Long-Period Comets (purple). The three panels show the radial (left), transverse (middle) and out-of-plane (right) components of measured accelerations. Non-gravitational accelerations are taken from the JPL Small Body Database.

Credit (image and caption): Seligman and Moro-Martin Figure 1.

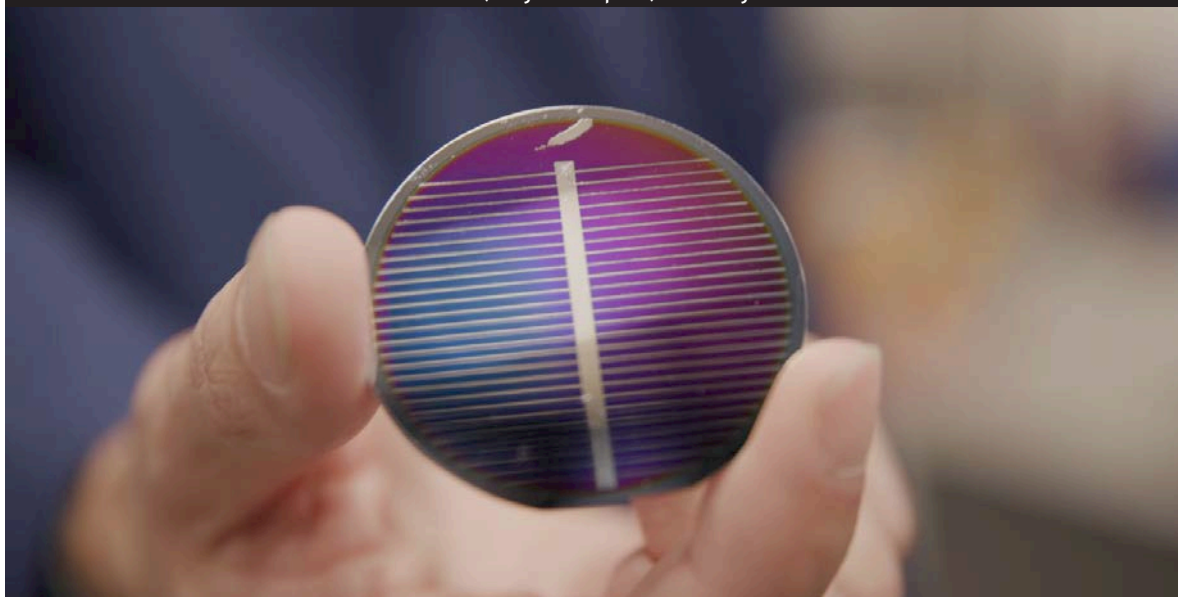
which is quite elongated but may be a close or contact binary object [1] and 1998 KY26, which radar imaging shows is irregular but not elongated [2]. The authors mention a number of Solar System objects which may have similar acceleration properties to 1I, these include active asteroids and dark comets. The Japanese probe JAXA Hayabusa2 will rendezvous with 1998 KY26 in 2031 [3]. The paper also deals extensively with the interstellar comet 2I/Borisov and discusses the galactic population of interstellar objects in terms of numbers, kinematics, origin determination, size-frequency distribution, the possible presence of captured ISOs in the Solar System and the possibility of interstellar planetesimals seeding planet formation. There is some discussion of future detection of ISOs and a brief mention of the planned ISA Comet Interceptor mission but nothing on other interceptors apart from a brief mention of Seligman's own 2018 paper (with Greg Laughlin) *The Feasibility and Benefits of In Situ Exploration of 'Oumuamua-like Objects* in The Astronomical Journal ([iopscience.iop.org/article/10.3847/1538-3881/aabd37/pdf](https://iopscience.iop.org/article/10.3847/1538-3881/aabd37/pdf)).

[1] Shepherd et al, *A revised shape model of asteroid (216) Kleopatra*, 2018 [facstaff.bloomu.edu/mshepard/research/kleopatra/Shepard\\_Kleopatra\\_revised\\_shape\\_model\\_2018.pdf](https://facstaff.bloomu.edu/mshepard/research/kleopatra/Shepard_Kleopatra_revised_shape_model_2018.pdf)

[2] [en.wikipedia.org/wiki/1998\\_KY26](https://en.wikipedia.org/wiki/1998_KY26) - also Ostro et al *Radar and Optical Observations of Asteroid 1998 KY26* 1999

[3] [en.wikipedia.org/wiki/Hayabusa2](https://en.wikipedia.org/wiki/Hayabusa2)

Blue Origin manufactured this working solar cell prototype from lunar regolith simulants.  
Credit (image and caption): Blue Origin.



## Photon Sailing to Proxima B

In March 2023, TU Delft published a notable master thesis by Tim Rotmans titled *Photon-sail trajectories to exoplanet Proxima b using heteroclinic connections*. The paper investigates photon-sail trajectories towards a rocky, Earth-like exoplanet, Proxima b, located in the habitable zone of the star Proxima Centauri. While much research has been done on designing interstellar missions to go to Proxima Centauri, the same cannot be said of Proxima B. Since Proxima Centauri is part of a binary star system, this presents a unique challenge when it comes to determining the orbital trajectory of such an interstellar spacecraft. To solve this issue, the paper uses heteroclinic connections to search for a link between the equilibrium points of both stars in the system and to find transfer trajectories from the AC-A/AC-B star system towards Proxima B. The paper suggests using the colinear Lagrange points AC-A/AC-B to allow the probe to escape the orbit of Proxima Centauri and travel to Proxima B. The paper provides a detailed breakdown of how a solar sail probe would have to be designed to be suitable for such a trajectory, exploring multiple sail configurations and their pros and cons. The thesis also uses a genetic algorithm to model potential missions and provide quantitative descriptions of their feasibility. The full paper can be found here: [repository.tudelft.nl/islandora/object/uuid:f1784fa7-2c8c-47fb-b2a9-d79d1153aeef?collection=education](https://repository.tudelft.nl/islandora/object/uuid:f1784fa7-2c8c-47fb-b2a9-d79d1153aeef?collection=education).

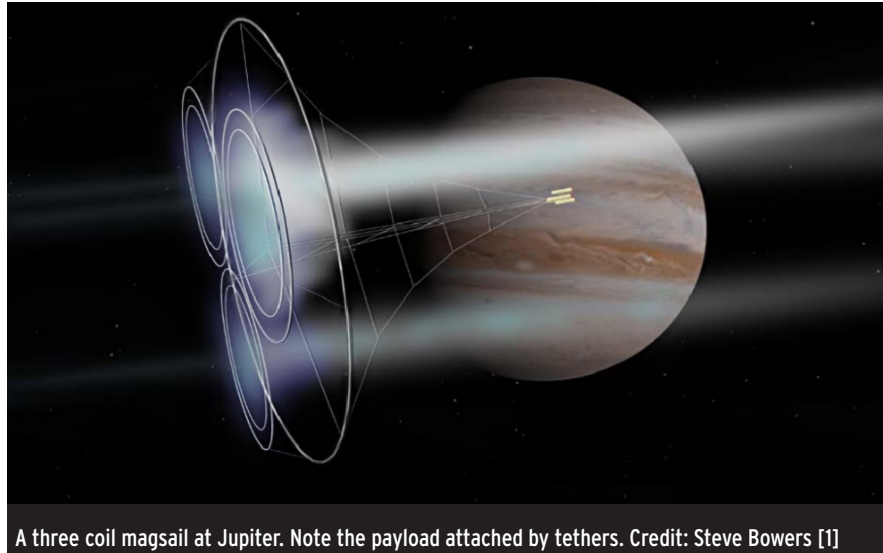
## Printing solar cells on the Moon

Our interstellar colleague, Gerald D Nordley, has drawn our attention to a significant breakthrough in lunar resource utilisation from Blue Origin, Jeff Bezos' launcher development company. They have succeeded in printing solar cells from printstock manufactured from lunar regolith simulant ([www.blueorigin.com/news/blue-chemist-powers-our-lunar-future](https://www.blueorigin.com/news/blue-chemist-powers-our-lunar-future)). He observes -

"Many scenarios for interstellar settlement, from getting the energy needed for beam-pushed propulsion, to living off the land when one gets there and getting back again are greatly enhanced, if not enabled, by robotic replication and the exponential growth it permits. Of course, making solar power satellites from lunar regolith could be a game-changer in many other things as well. This prototype cell represents a major step toward the kind of robotic production capacity needed for beam-rider starships traveling near the speed of light, and is happening years before many of us thought it would happen."

A Solar System economy is a vital foundation for really serious interstellar activity by our species and this development is a significant step in that direction.

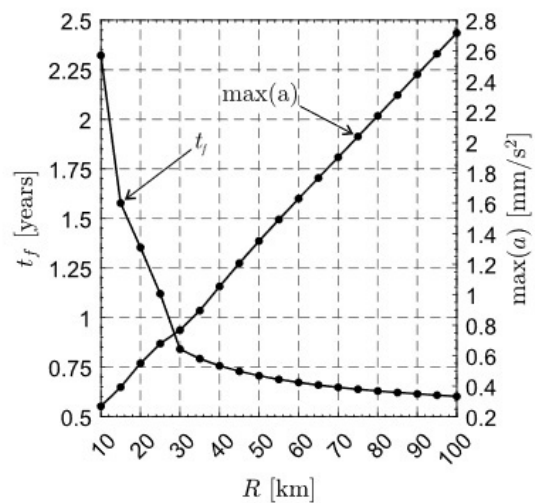




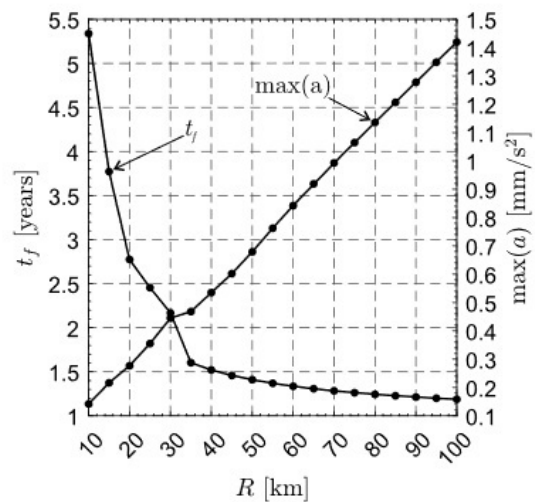
## Pushing against the solar wind

In *Refined MagSail thrust model for preliminary mission design and trajectory optimization*, Bassetto et al [1] by a team including Nikolaos Perakis of i4is, has produced a refined model of magnetic sailing. A MagSail uses thrust against charged particles of solar wind to generate thrust using only electrical energy and thus requiring no propellant. This could enable intra-solar system transport driven entirely by energy from solar panels or nuclear reactions. It is not a candidate for long duration thrust in an interstellar role but it does have potential application in decelerating a lightweight interstellar probe such as implied by Breakthrough Starshot (widely covered earlier issues of Principium) and early i4is studies Project Dragonfly (see Principium Issue 11 November 2015 and subsequent issues) and Project Andromeda (see Principium Issue 14 August 2016 and subsequent issues).

The authors present a single-loop Assail thrust model based on the numerical and experimental results obtained in the last decade. They present results for Earth-Mars and Earth-Venus transfers for a range of magsail radii. They suggest that "the proposed thrust model can be easily implemented in a simulation code for trajectory optimization and, in this sense, it represents an effective tool for preliminary mission analysis."



(a) Earth-Venus transfer.



(b) Earth-Mars transfer.

Fig. 11. Variation of  $t_f$  [journey time] and  $\max(a)$  [acceleration] with  $R$  [magsail radius] when  $f = 0.8$ .

Credit (image and caption): Bassetto et al, Fig 1

[1] Steve Bowers is a member of the Orion's Arm Universe Project, [orionsarm.com/](http://orionsarm.com/)

[2] Marco Bassetto, Alessandro A Quarta and Giovanni Mengali (all University of Pisa) and Nikolaos Perakis (Technical University of Munich and Initiative for Interstellar Studies). *Aerospace Science and Technology*, Volume 133, February 2023, 108113. [www.sciencedirect.com/science/article/abs/pii/S127096382300010X](https://www.sciencedirect.com/science/article/abs/pii/S127096382300010X), full text via [lnkd.in/d7Zgxp2](https://lnkd.in/d7Zgxp2)





## i4is at the Royal Institution

This will be our fourth i4is Summer School at the Royal Institution of Great Britain, Faraday's old place! This year the Royal Institution has invited us to extend our Skateboards to Starships summer schools to two younger age groups, ages 7-8 and 9-11. Reserve at -

***Skateboards to Starships (ages 12-14) Tue 15 Aug 11.00-15.00***

***[www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-12-14](http://www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-12-14)***

***Skateboards to Starships (ages 7-8) Wed 16 Aug 11.00-13.15***

***[www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-7-8](http://www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-7-8)***

***Skateboards to Starships (ages 9-11) Wed 16 Aug 14.15-16.30***

***[www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-9-11](http://www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-9-11)***

***Skateboards to Starships (ages 15-18) Thu 17 Aug 11.00-15.00***

***[www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-15-18](http://www.rigb.org/whats-on/holiday-workshops-skateboards-starships-ages-15-18)***

More about past summer schools in *News Feature: The Third i4is Summer School at the Royal Institution* - in Principium 39 November 2022 ([i4is.org/wp-content/uploads/2022/11/News-Feature-%E2%80%93-The-Third-i4is-Summer-School-at-the-Royal-Institution-Principium39-2211291202opt-3.pdf](http://i4is.org/wp-content/uploads/2022/11/News-Feature-%E2%80%93-The-Third-i4is-Summer-School-at-the-Royal-Institution-Principium39-2211291202opt-3.pdf)).

All revenue from the Summer Schools goes to the Royal Institution minus modest expenses.

## ◀ 1I/'Oumuamua: reasoning from a single instance

In *Statistical implications of the  $n = 1$  observation of 1I/'Oumuamua*, Eirik Grude Flekkøy (University of Oslo) and Renaud Toussaint (University of Strasbourg) [1] "obtain the exact statistical distribution of expected detection rates that may be obtained from the detection of 'Oumuamua which currently belongs to a class of objects that is only observed once in our Solar system". They apply the Poisson distribution, Bayes theorem and Shannon's information theory. They state that probability depends on the estimates of detection rates that existed prior to the 'Oumuamua observation but unless the constraints given by these model-based estimates are within an order of magnitude of the actual detection rate, they have a negligible effect on the probability of making a second observation so their results are generalised to the expected future case where more than one observation exists.

Their main purpose is to obtain the exact distribution  $P_n(\lambda)$  for the expected observation rate  $\lambda$  after  $n \geq 1$  observations are made so that the correct a priori assumption is identified, and thus obtain the expected recurrence time of objects similar to 'Oumuamua by the Vera C Rubin Observatory/Large Synoptic Survey Telescope (LSST) programme. They point out that "It is important to distinguish between a priori assumptions based on model-dependent estimates and a priori knowledge, as only the latter may be used as hard constraints in the  $P(\lambda)$  distribution". They nevertheless conclude that "Another observation similar to that of 'Oumuamua is expected within 5 yr at a confidence limit of 90 per cent." - with the underlying assumption that the LSST is operating.

## Two answers to - Where is everybody?

A couple of new clues on the old Fermi question. In *Beyond Mediocrity: How Common is Life?* ([arxiv.org/abs/2305.05395](https://arxiv.org/abs/2305.05395)) Amedeo Balbi, Università di Roma and a friend and colleague of i4is, Manasvi Lingam, Florida Institute of Technology, are sceptical.

But in *Could AI be the Great Filter? What Astrobiology can Teach the Intelligence Community about Anthropogenic Risks* ([arxiv.org/abs/2305.05653](https://arxiv.org/abs/2305.05653)) Mark M Bailey suggests that the hypothesised Great Filter, extinguishing intelligence before it reaches the stars, may come upon us through the further development of forms of artificial intelligence,

Balbi and Lingam suggest that appealing uncritically to some version of the "Principle of Mediocrity" - namely, the supposed typicality of what transpired on Earth - is problematic on empirical or logical grounds. They adopt a Bayesian [2] statistical approach to put on rigorous footing the inference of lower bounds for the probability of abiogenesis (biology arising from a non biological source), based on current and future evidence. They conclude that if habitable worlds are uncommon, for an agnostic prior, a deterministic scenario for the origin of life might be favoured over one where abiogenesis is a fluke event. We certainly can't build much on the single instance we know, ourselves, as we also see in the uniqueness of 1I/'Oumuamua as an ISO.

Bailey is more pessimistic still. He also uses the toolkit of Thomas Bayes to point out that the probability of finding evidence for a globally catastrophic event having occurred (*a posteriori* evidence) will never be more than the *a priori* probability of that event occurring. The implication is that we underestimate the probability of any global catastrophic event occurring that could wipe humanity off the face of the planet. He worries especially about recent AI developments.

Bailey is Chair of the Cyber Intelligence and Data Science Department at National Intelligence University and Co-Director of the Data Science Intelligence Center. This is therefore the view of what an old colleague used to call "the Paranoia Brigade" - which is not to disparage them - the colleague was himself an established member of the "Brigade".

[1] MNRAS 523 [doi.org/10.1093/mnras/slad049](https://doi.org/10.1093/mnras/slad049) Advance Access publication 2023 April

[2] The idea of probabilities based on prior evidence. For example the vaccine-sceptical idea that more people than the general population died after vaccination but the jab was given preferentially to those with other health problems - the prior probability of them dying was already higher than the general population [en.wikipedia.org/wiki/Bayes%27\\_theorem](https://en.wikipedia.org/wiki/Bayes%27_theorem)

## Transmitter rate of extragalactic civilizations

In *Upper limits on transmitter rate of extragalactic civilizations placed by Breakthrough Listen observations* ([arxiv.org/abs/2304.02756](https://arxiv.org/abs/2304.02756)), another investigation sponsored by Breakthrough Listen, researchers from National Chung Hsing University and National Tsing Hua University, Taiwan, The Australian National University and National Astronomical Observatory of Japan have used results from the Green Bank (USA) and Parkes (Australia) telescopes to constrain the possible existence of highly advanced civilisations in the observable universe. This continues the work begun by Professor Mike Garrett (University of Manchester) and colleagues for example in a paper *SETI radio surveys of the distant Universe* presented at the 69th International Astronautical Congress, Bremen 2018. Their research suggests that the existence of KII-type civilisations [1] are extremely limited, and the search for radio transmissions should continue.

## Human 2.0 to the stars?

What might we need to do ourselves to get to the stars? Papers identified by the indispensable Interstellar Research Group (IRG) alert service aspect of this question.

In *The final frontier: what is distinctive about the bioethics of space missions? The cases of human enhancement and human reproduction* [2] Konrad Szocik (Yale University) and Michael J Reiss (University of Information Technology and Management in Rzeszow, Poland) examine the bioethical issues that arise from long-duration space missions, asking what there is that is distinctive about such missions. Longer term self-sustaining space settlements may require

human enhancement and reproduction in space. Is space bioethics analogous to the extremes of military bioethics? They cite a number of ethical philosophers including Derek Parfitt (see his book, *Reasons and Persons*) and Joseph Rotblat (a nuclear weapons scientist who turned to both ethics and biomechanics). They discuss radical human enhancement interestingly and at some length but don't mention Tsiolkovsky who opposed the reaction of cultural critics like John Ruskin (1819 - 1900) lamenting the artificiality of industrial civilisation "In ethereal space this artificiality will simply be extended to the very limit, but then man too will find himself in conditions that are most favourable for him" [3]. They also explore the rationale for space missions as a significant factor in space bioethics.

And in *Bioethical Issues in Human Modification for Protection against the Effects of Space Radiation*, Szocik (as above) and Martin Braddock (Mansfield and Sutton Astronomical Society, UK) [4] examine the possible justification of human enhancement as a measure against the currently intractable problem of space radiation, principally galactic cosmic radiation (GCR). They use a hypothetical scenario of a long duration mission with long term effects of GCR still largely unknown. They consider scientific, commercial, motivations for missions, tourism and settlement as motivations. As in the other Szocik paper, the military analogy is seen as relevant but differences are clear.

[1] Kardashev scale 2, defined as using all the available power of their home star, about 2 billion times as much as our own early Kardashev type 1 civilisation

[2] Monash Bioethics Review (2022) <https://link.springer.com/article/10.1007/s40592-022-00164-6>

[3] see *Tsiolkovsky - Interstellar Pioneer* in *Principium* 20 February 2018.

[4] Space Policy 2022, [www.sciencedirect.com/science/article/pii/S0265964622000315](https://www.sciencedirect.com/science/article/pii/S0265964622000315)

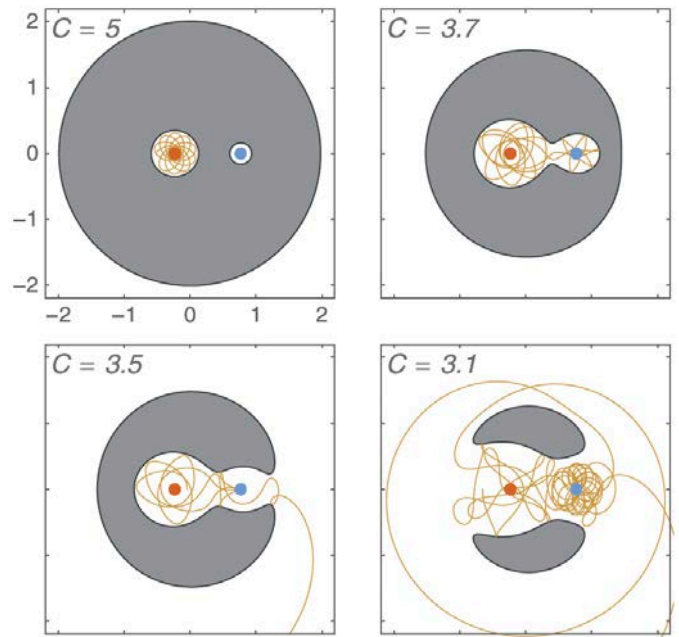


## Planetary PinBall

Once in a while we come across a science fiction story which prefigures some science. In the twin 1950s stories, *The Man from Nowhere* and *Rogue Planet*, the central character, Dan Dare, and some of his regular companions are asked to save a peaceful planet from a malign planet which comes close to it over very long periods.

A recent piece by Sean Raymond, an American astrophysicist now living in Bordeaux, in his blog entry *Star-hoppers: planets bouncing between binary stars* [1], PlanetPlanet ([planetplanet.net](http://planetplanet.net)) refers to an odd astrodynamical situation where a planet can migrate between two star systems. In this blog entry Raymond also cites an animation from the same source, see **exoplanets bouncing: 250 au binary, Solar mass stars**.

In the two Dan Dare stories the character Lero, of the exoplanet Cryptos, crashes into the Mato Grosso jungle from his starship, which ditches in the Tuscarora Deep. He explains that his planet is periodically subjugated by the dictatorship of the exoplanet Phantos when the two planets come close together every 10,000 years. The Crypts are pacifists and are incapable of resisting this.



Examples of planet orbits in a circular, coplanar binary star system (the stars are the large red and blue dots, with the red dot being a Sun-like star and the blue dot being about 30% as massive), for different values of the Jacobi constant  $C$  (which roughly corresponds to the orbital energy) [2]. Bouncing between stars happens when  $C=3.7$ .  
Image credit: Moeckel & Veras, 2012 [3]  
Caption credit: Sean Raymond



[1] [planetplanet.net/2022/02/24/star-hoppers-planets-bouncing-between-binary-stars/](http://planetplanet.net/2022/02/24/star-hoppers-planets-bouncing-between-binary-stars/)

[2] [en.wikipedia.org/wiki/Jacobi\\_integral](https://en.wikipedia.org/wiki/Jacobi_integral)

[3] Dimitri Veras is an astrophysicist at Warwick University, UK, researching the contents of planetary systems (including our own solar system) in a wide variety of contexts, across both time and space. [warwick.ac.uk/fac/sci/physics/research/astro/people/veras/](http://warwick.ac.uk/fac/sci/physics/research/astro/people/veras/)



Earth engineers help Lero to salvage and rebuild his starship. Dan and co return in it with Lero ...  
....and save the day (of course).



The stories contain other SF ideas such as a ruling "god", Orak, which controls the Phants and instructs them to eat food which keeps them aggressive. Their "god" turns out to be an artificial intelligence built from transistors (in the early 50s a character saying "They never wear out." was not implausible). The Crypts have food which makes them peaceful and the two species turn out to be less different than they appear. The images from the *Eagle* are by Frank Hampson and Don Harley as published in the Dragon's Dream books. The publisher is sadly "dormant" according to Companies House, the UK regulator.



**If Sean Raymond and his sources are correct we may well find such "pinball planets" - but**  
what are the chances of life on them?