John I Davies & Gill Norman report on recent developments in interstellar studies

Forthcoming books

Our readers will be interested in two books being published soon!

Stellar Engines
Advanced Spacecraft Propulsion through Extreme Aerospace Engineering Design
by Kelvin F Long

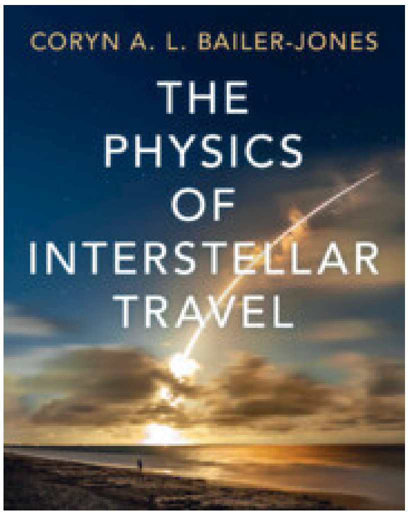
Publisher: Springer, April 2026
https://link.springer.com/book/9783032180612

This book considers the unique method of inertial confinement fusion as means for propelling a spacecraft on these sorts of missions, through interplanetary and interstellar space. This has involved combining the otherwise two separate fields of knowledge that is advanced propulsion theory and high temperature thermonuclear plasma physics.

The Physics of Interstellar Travel
by Coryn A L Bailer-Jones

Publisher: Cambridge University Press, May 2026
https://www.cambridge.org/core/books/physics-of-interstellar-travel/69C23CDCF164E2C71A65497F299EE38F

What is the physics behind getting a spacecraft to the nearest stars? What science can it do when it gets there? How can it send back data over enormous distances? Drawing on established physics, Coryn Bailer-Jones explores the various challenges of getting an uncrewed spacecraft to a nearby star within a human lifetime.



Estimating The Number of Intelligent Extraterrestrial Civilizations

Hristo Delev (MPHAC "Uni Hospital", Bulgaria) and Todorka L Dimitrova (University of Plovdiv "Paisii Hilendarski", Bulgaria) recently released *Estimating The Number of Intelligent Extraterrestrial Civilizations: A Probabilistic Approach to the Drake Equation* (see https://zenodo.org/records/17720863). Astrobiology seeks to address some of humanity's most profound questions: Are we alone in the Universe? What are the conditions necessary for life to emerge? One of the key theoretical tools in this pursuit is the Drake Equation, formulated in 1961, which provides a probabilistic framework for estimating the number of intelligent extraterrestrial civilizations in the Milky Way. In this paper, the authors revisit the Drake Equation using updated astronomical and biological data, along with simplified probabilistic assumptions. By applying current observational evidence of exoplanets, laboratory studies of prebiotic chemistry, and estimates of stellar and planetary habitability, they obtain a tentative value of ~72 civilizations capable of interstellar communication via radio astronomy. The result highlights the paradox first identified by Enrico Fermi - if intelligent life is so probable, why have we not yet detected it? They discuss possible resolutions to the Fermi Paradox, including distance, evolutionary differences, and the possibility of self-destruction. Finally, we outline future directions for astrobiology, observational astronomy, and SETI that may refine these estimates and potentially resolve one of the greatest scientific mysteries of our time.

The Fatal Absence of Extraterrestrial Intelligence and its Consequence for Humanity

Richard M Blaber has authored a paper examining the absence of Extraterrestrial Intelligence. The lack of any radio signals or other astronomical evidence supportive of the existence of intelligent extraterrestrial life possessed of technology of sufficient sophistication to bring itself to our attention here on Earth is not, per se, evidence of an absence of life, or even intelligent life, in the cosmos itself, but it does indicate that any such advanced societies, if they have come into existence at all, may be extremely rare and comparatively short-lived, destroyed by the very technology that might have brought them to our notice. This, it will be suggested, is the solution to Fermi's famous 'paradox', and the reason no SETI signals have been detected. The lessons we should learn are that life like that on our planet is very rare and precious, and we must not risk destroying it. View the paper here:
https://osf.io/preprints/socarxiv/uckfw_v1.

On Bayesian inference considerations and other issues concerning Drake's equation of Astrosociobiology

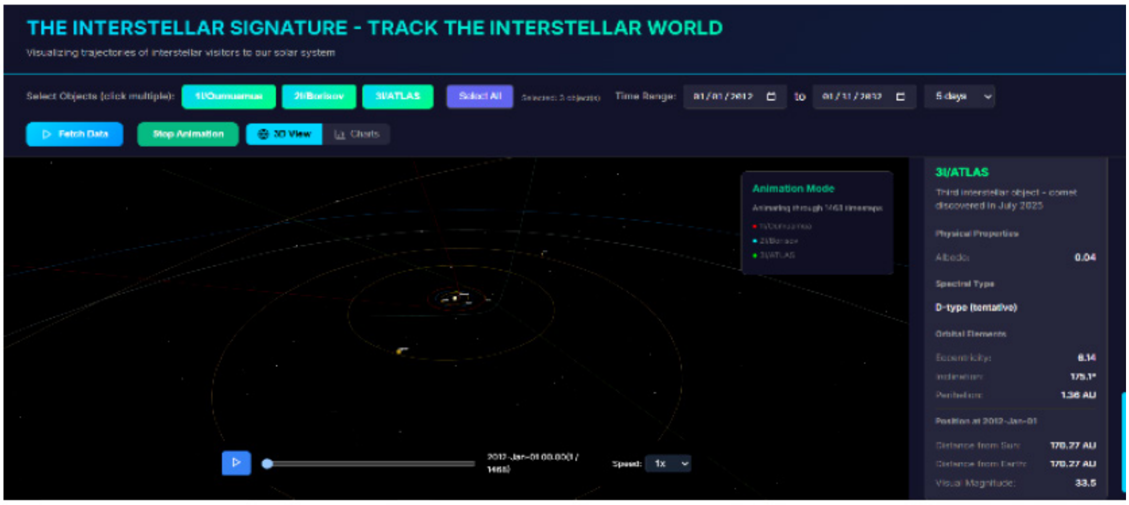
Orfeu Bertolami (Universidade do Porto, Portugal) published a paper on astrosociobiology – see https://arxiv.org/abs/2511.11582. Speculation about the existence of advanced forms of life in the Universe and in our galaxy, has been since forever a subject of fascination and discussion in fiction, as well as in astrophysics, biology and philosophy. The well-known Fermi's 1950s challenge, "Where are the aliens?" has acquired more substance with the realisation of the potentialities of radioastronomy, which led to the paradigmatic Drake's equation. The emergence of astrobiology, together with the discovery up to now of more than seven thousand exoplanets, has brought increasing support to the discussion about putative life cradles. However, after more than six decades, the only quantitative tool available to estimate how widespread is life and, in particular, advanced forms of life, is, besides direct searches, which so far provided no evidence, still Drake's equation. They review the current knowledge about this equation and present new arguments of multiple origin in order to evaluate one of its most critical terms, namely the one associated to the time span that a technological civilisation must search for detectable signs of the existence of life and for how long a search must be extended to bear fruits. They propose that this term should be replaced by a more specific one which involves critical parameters in the enterprise of gathering information, such as energy expenditure, searching area and entropy generation. These terms can be regarded as the capability that any cosmic civilisation must show in order to face the challenge of going beyond the climate and other crises that its development inevitably ensues. Their considerations suggest that a typical time span is about a couple of decades, meaning that a successful and systematic searching programme around about hundred stars might take around a few thousand years.

The Eschatian Hypothesis

The history of astronomical discovery shows that many of the most detectable phenomena, especially detection firsts, are not typical members of their broader class, but rather rare, extreme cases with disproportionately large observational signatures. A paper published in Research Notes of the American Astronomical Society by David Kipping (Columbia University, USA) proposes *the Eschatian Hypothesis*: that the first confirmed detection of an extraterrestrial technological civilization is most likely to be an atypical example, one that is unusually "loud" (ie, producing an anomalously strong technosignature), and plausibly in a transitory, unstable, or even terminal phase. Using a toy model, they derive conditions under which such loud civilizations dominate detections, finding for example that if a society is loud for only 10^{-6} of its lifetime, it must emit 1% of its total observable energy budget during that phase to outrun quieter populations. The hypothesis naturally motivates agnostic anomaly searches in wide-field, multi-channel, continuous surveys as a practical strategy for a first detection of extraterrestrial technology. See the paper here: https://arxiv.org/abs/2512.09970.
Paul Glister, in Centauri Dreams, reviews this paper here:
https://www.centauri-dreams.org/2025/12/17/new-uses-for-the-eschaton/.

A computational framework for interstellar tracking

In *The interstellar signature: A computational framework for open source interstellar tracking* (https://arxiv.org/abs/2512.07910), Pancha Narayan Sahu (independent student researcher, Nepal) presents a computational framework implemented through a web-based platform. Interstellar objects, such as 1I/'Oumuamua and 2I/Borisov, offer a unique window into the formation and evolution of other star systems, yet tracking and analyzing their trajectories remains largely restricted to specialized institutions. Interstellar and solar system datasets are often large, complex, and difficult to navigate, limiting their usability for developers, researchers, and enthusiasts. Interstellar Signature serves as a bridge between raw, unstructured astronomical data and an intuitive, developer-friendly interface. This framework integrates live astronomical data from public repositories and Application Programming Interfaces (APIs) with physics-based simulation techniques to model and visualize the motion of both solar system and interstellar objects in real time. The platform provides interactive visualizations, comparative analysis of interstellar and solar system objects, and modular tools that allow users to explore, modify, and extend the framework for their own research purposes.



Shows the 3D-view feature of the application.

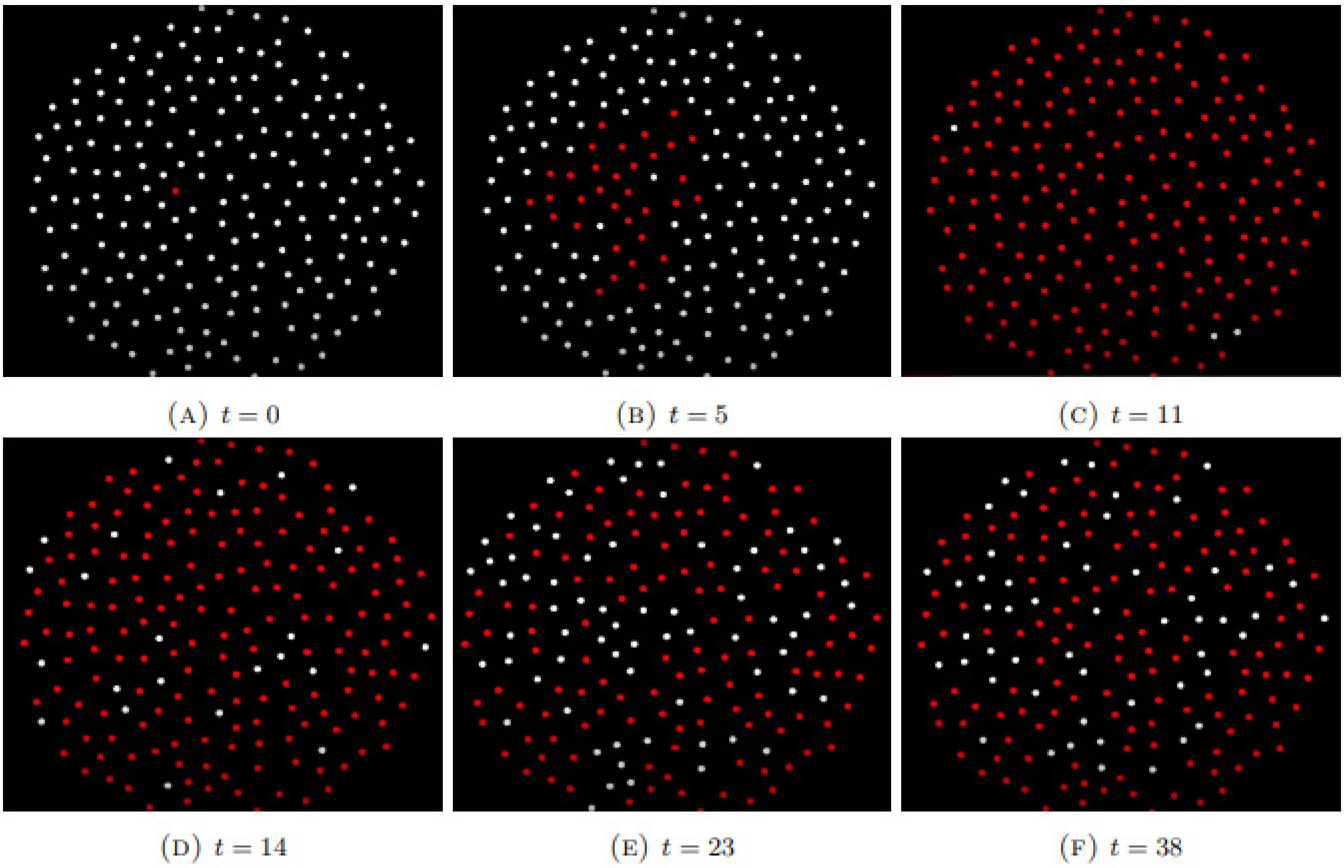
Credit (graphic and caption): Sahu, Figure 1

Shows the graph view of the application.

Credit (graphic and caption): Sahu, Figure 2

Exploring Fermi's Paradox using an intragalactic colonization model

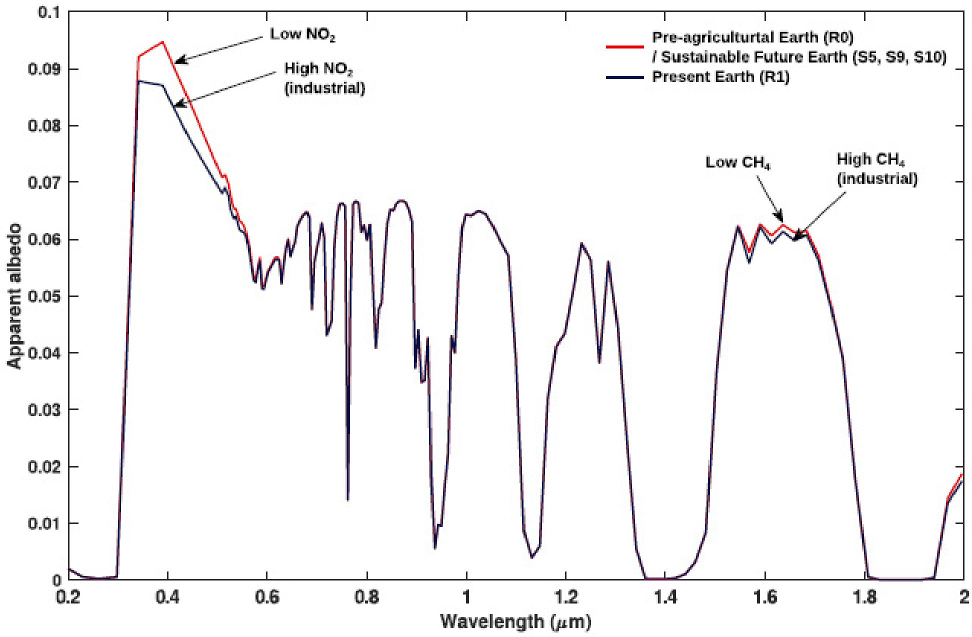
Gregory Roudenko (University of Florida, USA) & Yurrian Pierre-Boyer (Florida International University, USA) explore Fermi's Paradox via a system of differential equations and using simulations of dispersal and interactions between competing interplanetary civilizations. To quantify the resources and potentials of these worlds, three different state variables representing population, environment, and technology, are used. When encounters occur between two different civilizations, the deterministic Lanchester Battle Model is used to determine the outcome of the conflict. They use the Unity engine to simulate the possible outcomes of colonization by different types of civilizations to further investigate Fermi's question. When growth rates of population, technology and nature are out of balance, planetary civilizations can collapse. If the balance is adequate, then some civilizations can develop into dominating ones; nevertheless, they leave large spatial gaps in the distribution of their colonies. The unexpected result is that small civilizations can be left in existence by dominating civilizations in a galaxy due to those large gaps. Their results provide some insights into the validity of various solutions to Fermi's Paradox.
See https://arxiv.org/pdf/2411.00061 for the paper.



Evolution of one civilization (with $R_0 = 4$) that first occupies almost the entire galaxy but then declines to a certain level, as shown in Figure 6(C), and leaves spatial pockets, possibly for smaller civilizations to co-exist. Credit (graphic and caption): Roudenko and Pierre-Boyer, Figure 7

Strategies for Observing Technosignatures

A letter was recently published in The Astrophysical Journal entitled *Projections of Earth's Technosphere: Strategies for Observing Technosignatures on Terrestrial Exoplanets* by Jacob Haqq-Misra (Blue Marble Space Institute of Science, USA) et al. The search for technosignatures - remotely detectable evidence of extraterrestrial technology - draws upon examples from the recent history of Earth as well as projections of Earth's technosphere. Facilities like the Habitable Worlds Observatory (HWO) will significantly advance the feasibility of characterizing the atmospheres of habitable exoplanets at visible and near-infrared wavelengths, while other future mission concepts could extend this search to mid-infrared wavelengths. The authors draw upon a recently developed set of ten self-consistent scenarios for future Earth technospheres as analogs for extraterrestrial technospheres, which they use to outline a stepwise technosignature search strategy, beginning with HWO and followed by other missions. They find that HWO could reveal elevated abundances of a CO_2 + NO_2 pair on planets with combustion and other large-scale industry, which could be observable in up to eight of the ten scenarios. Follow-up radio observations could reveal narrowband directed transmissions, as occur in two of the scenarios. Further study involving direct detections at mid-infrared wavelengths with the Large Interferometer for Exoplanets could reveal spectral features from industry, such as the combinations of CO_2 + CFC-11/12 in four scenarios and CO_2 + CFC-11/12 + CF_4 in one scenario; two of these also include the N_2O + CH_4 + NH_3 triple from large-scale agriculture. See https://iopscience.iop.org/article/10.3847/2041-8213/ae23c6.



Albedo spectra of pre-agricultural Earth (red line) and present-day Earth (dark line) observed 10 pc away at nominal HWO wavelengths. The noticeable difference between the spectra in the 0.3–0.6 μm region arises from the significant production of NO2 pollution from industrial activity, as well as large-scale agriculture, on present-day Earth. The authors assume an isoprofile abundance for the NO_2 gas concentration, which overestimates the absorption feature for the present-day Earth. The small difference between the spectra near 1.6 μm is due to the excess production of CH_4 from human activity (including agriculture, combustion, and decomposition of landfill waste). Scenarios S5, S9, and S10 are spectrally identical to pre-agricultural Earth (R0). Credit (graphic and caption): Haqq-Misra et al, Figure 1

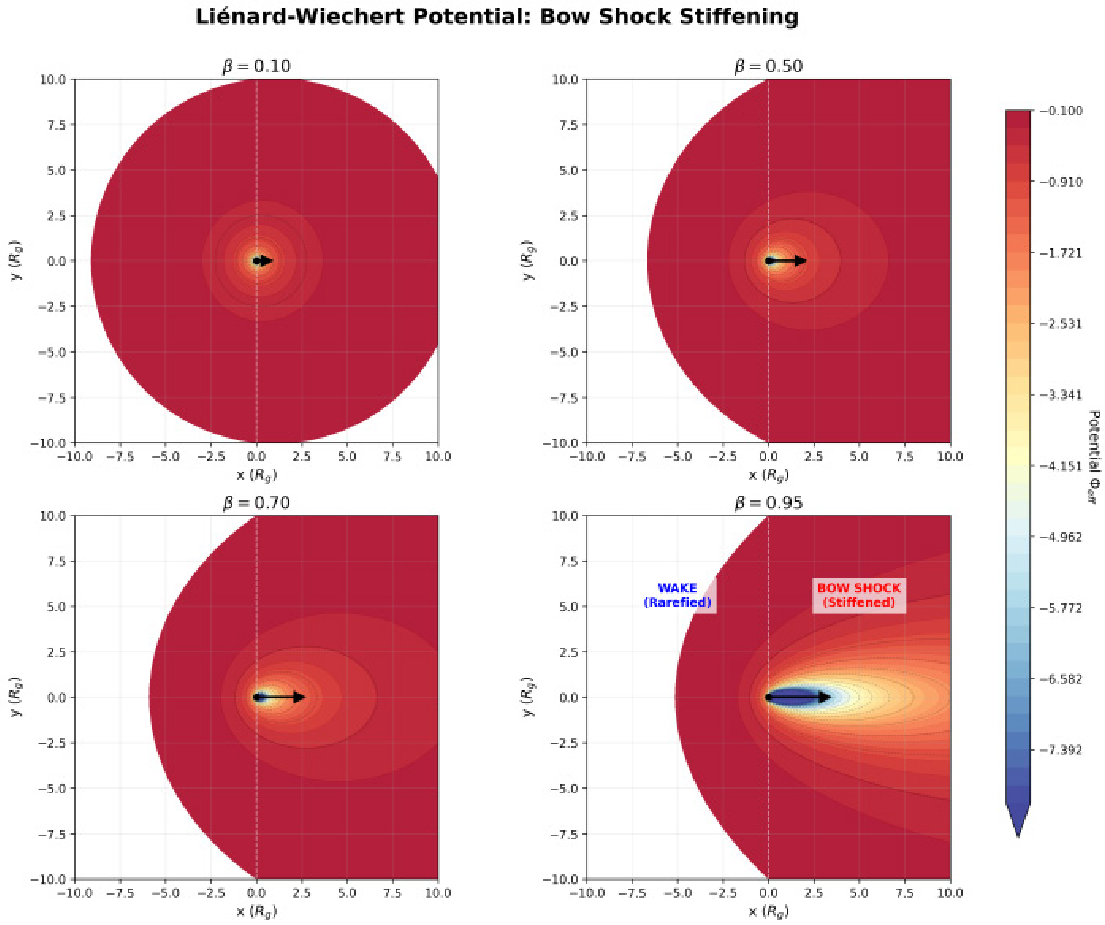
Photon Dynamics and Collision Risks in Relativistic Spaceflight: A Comparative Study of Methods and Implications

Kevin Li presents a dissertation for a BSc in Physics at the University of Hong Kong, entitled *In Photon Dynamics and Collision Risks in Relativistic Spaceflight: A Comparative Study of Methods and Implications*. See https://arxiv.org/abs/2512.08447. Relativistic spaceflight, travelling at velocities approaching the speed of light, has been attractive to scientists and futurists alike since it poses both a possibility for interstellar travel as well as a massive technical challenge. When the spacecraft has reached a relatively high speed, the physical laws governing its motions diverge significantly from the Newtonian mechanics, which can be perfectly applied at a lower speed context. The dissertation discusses the challenges associated with relativistic spaceflight, focusing on the collision with other interstellar particles and the interactions with the cosmic microwave background radiation.

Causal Gravity Assists

Daniel Sandner (Independent Researcher, 100 Scientific Visions Initiative) presents *Causal Gravity Assists: Relativistic Energy Harvesting and Interstellar Propulsion via the Liénard-Wiechert Vacuum Wake*. Standard gravitational assists (slingshots) are limited by the orbital velocity of planetary bodies, making them insufficient for relativistic interstellar travel. They propose a novel propulsion mechanism, the Causal Drive, based on Causal Latency Theory (CLT). Due to the finite speed of information updates (c), massive bodies moving through the vacuum create a "Causal Wake" - an anisotropic deformation of the gravitational potential characterized by a steep "Bow Shock" and a rarefied "Wake." They demonstrate via numerical simulation that a spacecraft approaching a relativistic source from the direction of motion can extract linear momentum from the source via a Gravitational Fermi Acceleration mechanism. Unlike standard assists, the coupling efficiency increases with the source velocity; as $\beta \to 1$, the wake "stiffens" into an effective potential wall, allowing for near-elastic reflection. They validate this model against astrophysical anomalies, showing that the trajectory of 'Oumuamua and the recently discovered 3I/ATLAS (C/2025 N1) match the kinematic signature of "Wake Surfing." See the paper here: https://zenodo.org/records/18042720.

Figure 1: Liénard-Wiechert Potential: Bow Shock Stiffening. 2D equipotential contours of the vacuum field. Top Left (β = 0.1): The field is nearly symmetric (Newtonian). Bottom Right (β = 0.95): The field exhibits extreme compression in the direction of motion. The bunching of equipotential lines in the Bow Shock region represents a divergent gravitational force (high impedance), effectively creating a solid wall off which a probe can bounce. Conversely, the Wake region is rarefied, minimizing drag upon exit.
Credit (graphic and caption): Sandner, Figure 1



From the Search for Extraterrestrial Life to Interstellar Civilizations

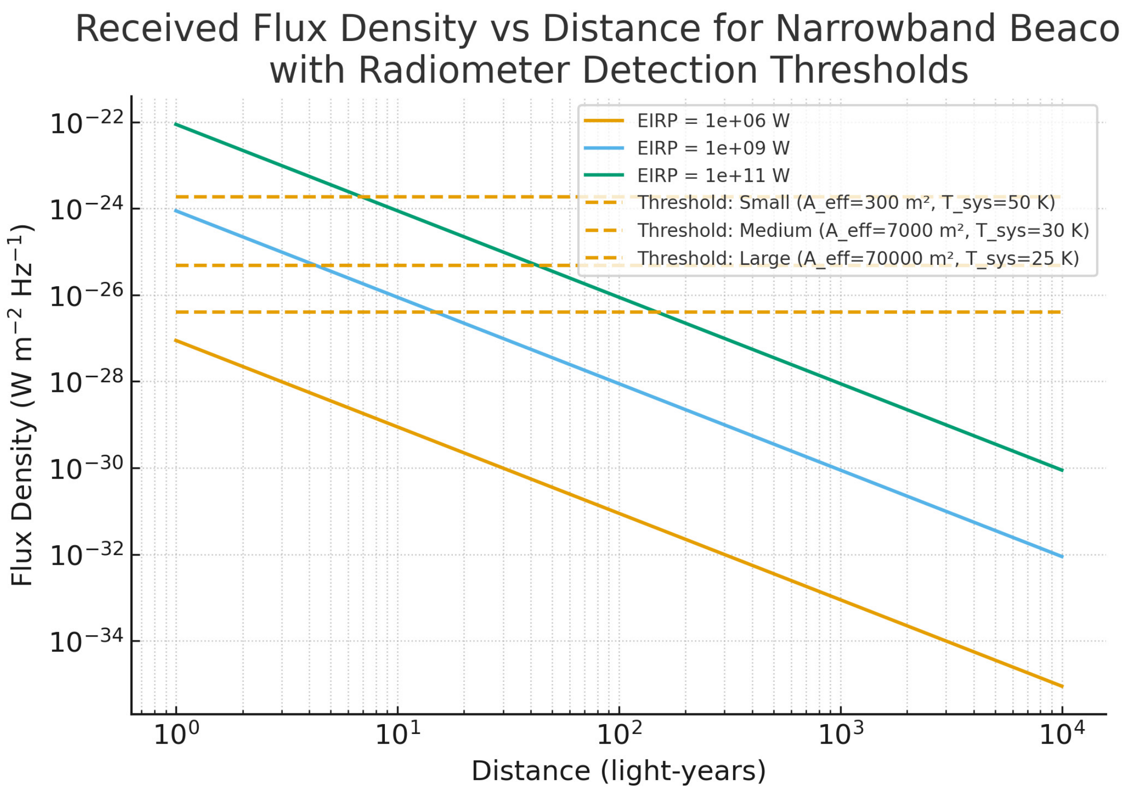
A recent paper by Horiike, Hiroshi (Shanghai University, China) introduces a *Stepwise Logical Analysis of Astrobiological and Technological Uncertainties*. The search for extraterrestrial life has transitioned from speculative philosophy to an observationally driven scientific endeavour. However, the inference chain connecting abiotic conditions to detectable interstellar civilizations remains conceptually fragile. This paper presents a structured Bayesian analysis of the logical progression from habitability to technology. By integrating exoplanet statistics, evolutionary bottlenecks (such as the eukaryotic transition and the "oxygen bottleneck"), and civilization scaling models, they argue that each step introduces compounding uncertainties. They conclude that while microbial life may be common, the emergence of detectable technological societies is constrained by significant stochastic filters, necessitating epistemic humility in future SETI/technosignature searches. View the paper here https://zenodo.org/records/18321628.

The Temporal Observability Filter Hypothesis

In *The Temporal Observability Filter Hypothesis (TOFH): A Physically-Constrained, Bayesian Framework for the Observational Invisibility of Technological Civilizations*, Daud Zia (independent researcher, UK) offers a physically constrained, probabilistic solution to the Fermi Paradox, in the form of The Temporal Observability Filter Hypothesis (TOFH).

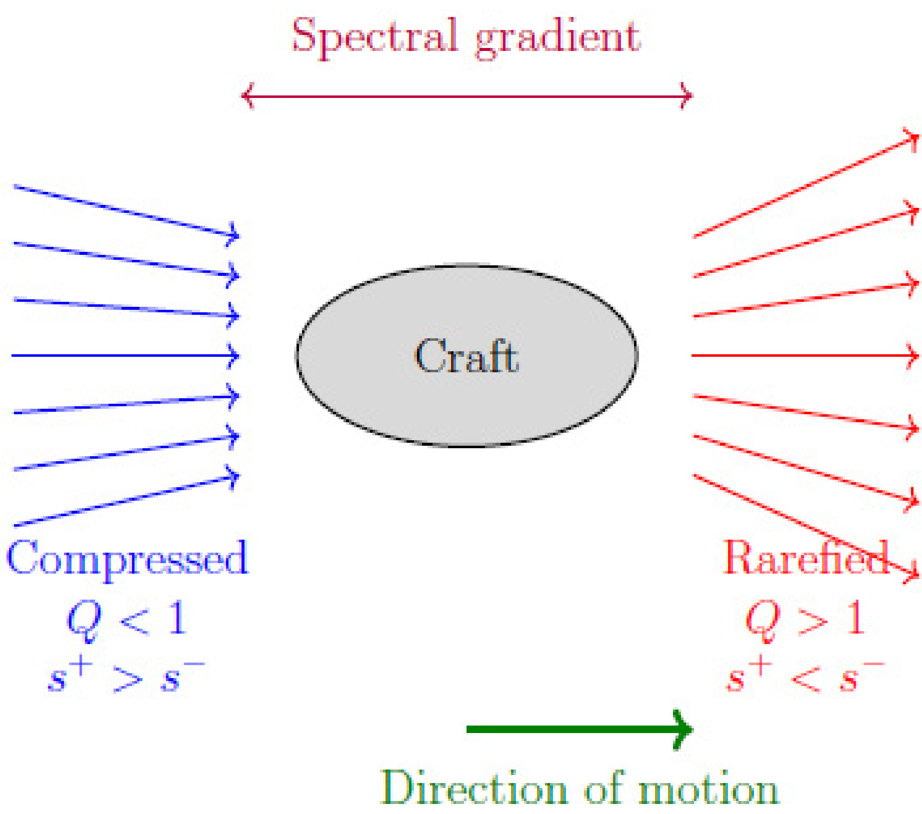
Rather than attributing cosmic silence to rarity, intent, or catastrophe, TOFH argues that most civilizations remain undetectable due to four compounding effects: cosmological look-back time, angular resolution limits, radiometric attenuation, and Bayesian suppression of belief under uncertainty. They derive the TOFH constant as a necessary condition for detectability, unifying diffraction, photon statistics, and Bayesian inference into a single inequality. Simulations of signal decay and telescope sensitivity confirm that even megawatt transmitters fall below detectability beyond ~ 100-125 light-years, consistent with TOFH predictions. The framework reframes SETI expectations around observability volume rather than inherent absence, making specific, falsifiable predictions testable by current and next-generation instruments. See the paper:
https://www.academia.edu/143709470/The_Temporal_Observability_Filter_Hypothesis_TOFH_A_Physically_Constrained_Bayesian_Framework_for_the_Observational_Invisibility_of_Technological_Civilizations.

Received flux density vs distance for narrowband transmitters with equivalent isotropic radiated power (EIRP) of 1 MW, 1 GW, and 100 GW. Dashed lines mark radiometer detection thresholds for small, medium, and large telescope classes, assuming $n_p = 2$, $B = 1$ Hz, $\tau = 300$ s, and required SNR = 10.
Credit (graphic and caption): Zia, Figure 2



DUST-Based Propulsion Systems

In *DUST-Based Propulsion Systems: Theoretical Framework for Advanced Spacecraft*, Dino Ducci (DUSTLabs Research Institute, University of South Africa) presents a theoretical framework for spacecraft propulsion systems based on manipulation of the underlying spectral lattice structure described by Ducci Unified Spectral Theory (DUST). Unlike conventional propulsion requiring reaction mass, DUST-based systems achieve motion by directly modulating local spacetime geometry through spectral field manipulation. They derive the fundamental principles, engineering requirements, and observable signatures of such systems, demonstrating how mastery of spectral physics enables capabilities consistent with reported UAP (Unidentified Aerial Phenomena) characteristics: instantaneous acceleration, inertial dampening, gravitational field manipulation, and trans-medium travel. This analysis assumes an advanced civilization has developed practical technology to manipulate the prime-periodic hexagonal lattice at macroscopic scales. See the paper here: https://www.academia.edu/145764039/DUST_Based_Propulsion_Systems_Theoretical_Framework_for_Advanced_Spacecraft.



Spectral gradient propulsion. The craft engineers asymmetric spectral field distribution, creating effective spacetime slope it can "fall" along.
Credit (graphic and caption): Ducci, Figure 1

Stellar engines and Dyson bubbles can be stable

A recent paper by Colin R McInnes (James Watt School of Engineering, University of Glasgow, UK) was published in Monthly Notices of the Royal Astronomical Society (https://academic.oup.com/mnras/advance-article/doi/10.1093/mnras/stag100/8426277).
A range of speculative space ventures envisage the use of ultra-large structures for the collection and reflection of light. Given the length-scale of such structures they cannot be considered as point masses for the calculation of gravitational and radiation pressure forces. Using a simplified model it will be demonstrated that ultra-large reflectors in static equilibrium levitating above a central star (so-called stellar engines) are always unstable if the reflector comprises a uniform disk. However, if the reflector has a non-uniform mass distribution, specifically a ring supporting a reflector, a stellar engine can in principle be passively stable. Moreover, while it can be shown that static swarms of reflectors levitating above a central star (so-called Dyson bubbles) are unstable, in principle they can become passively self-stabilising if arranged about the star as a dense cloud. While such ventures are clearly speculative, understanding the orbital dynamics of ultra-large structures, and in particular the conditions for passive stability, can provide insights into the properties of potential technosignatures in search for extra-terrestrial intelligence studies.

Technological Singularity despite Decentralized Consumption

In *Technological Singularity despite Decentralized Consumption (TSDC) and Its Implications for Extraterrestrial Civilization Exploration*, Minjun Kim (independent researcher) has proposed a novel theoretical framework which challenges the conventional notion that advanced civilizations require exponentially increasing energy consumption. Instead, it suggests that future high-level civilizations will reduce total energy usage by focusing on precision, efficiency, and ultra-refined technologies. They develop a mathematical model illustrating the growth of intelligence density under decentralized consumption constraints. Furthermore, they explore how this framework informs methods for detecting extraterrestrial civilizations, emphasizing the significance of low-energy, highly efficient technological signatures rather than traditional megastructure or energy-intensive signals. This approach broadens the scope of astrobiological search strategies and highlights the need for sensitive detection tools tailored to subtle technosignatures. View the paper here: https://www.academia.edu/129756369/Technological_Singularity_despite_Decentralized_Consumption_TSDC_and_Its_Implications_for_Extraterrestrial_Civilization_Exploration?sm=b&rhid=37397469293.

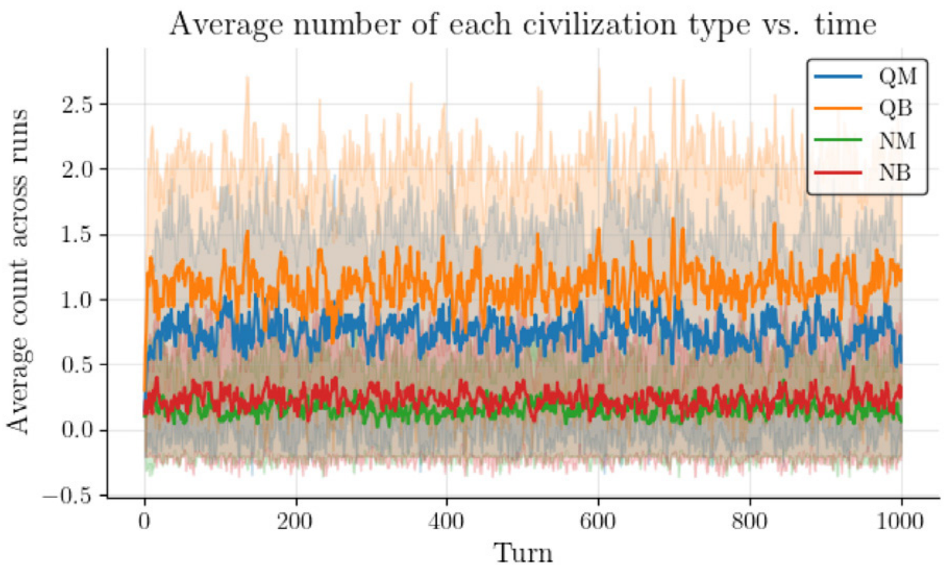
A Photonic Sail of Utmost Simplicity: The Ribbon

Gyula Greschik (TentGuild Eng Co) and Charles R West (Gossamer Space Systems LLC) recently published this paper on solar sails. The structural overheads and mechanical challenges that severely limit the prevailing approach to solar sail engineering are overcome for diffractive sails with the simple ribbon architecture: a film strip in an inherently stable tilted orientation, with the payload at its rear end. Missions with spiral solar trajectories or orbit cranking such as Sun polar observer platforms will profoundly benefit from the consequent thrust efficiency and dramatically simplified design. The concept is introduced and some of the key aspects of its feasibility and expected performance are reviewed and assessed. Request the paper here:
https://www.researchgate.net/publication/400234308_A_Photonic_Sail_of_Utmost_Simplicitiy_The_Ribbon.

A framework for the Dark Forest Hypothesis

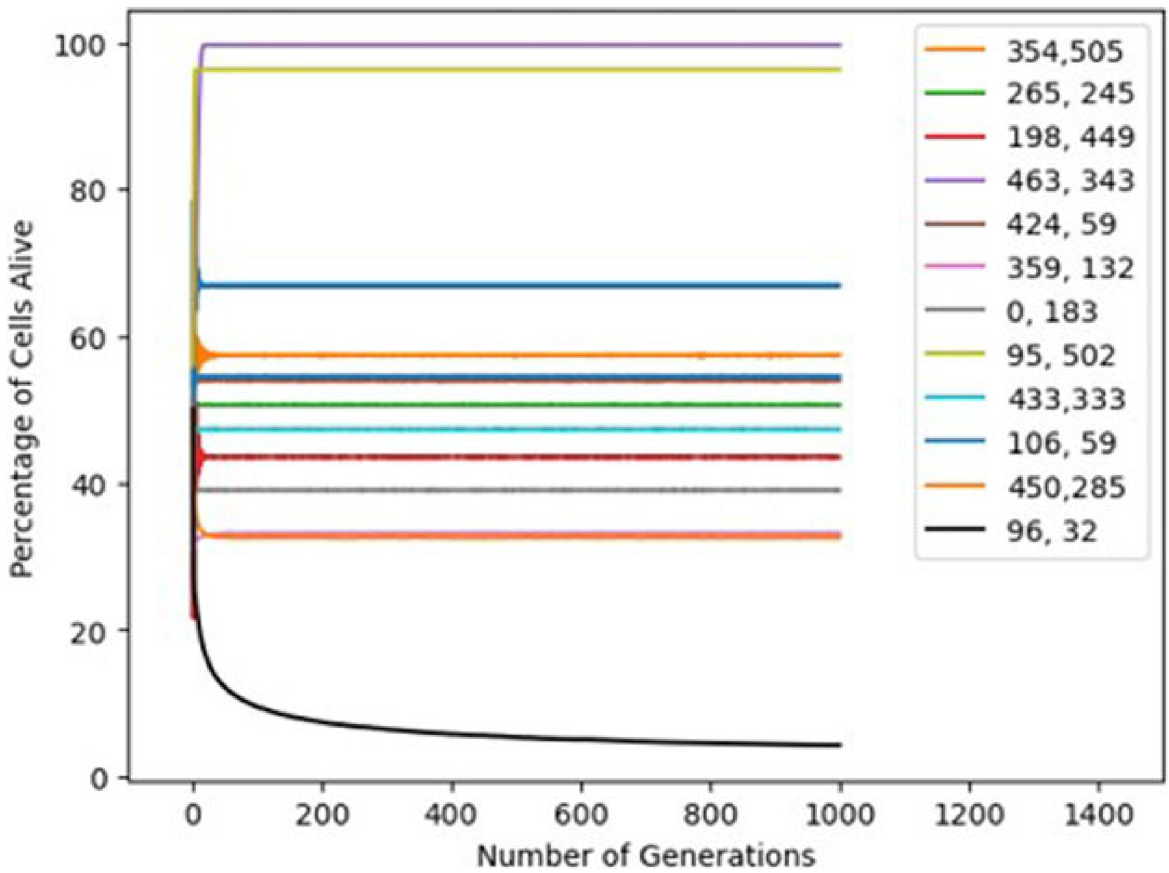
C A Bonin (independent scholar, Brazil) has published *A stochastic framework for the dark forest hypothesis: Modeling silence and survival in the cosmos.* They introduce a stochastic model inspired by the Dark Forest Hypothesis to investigate probabilistic dynamics between civilizations in the cosmos. Each agent is characterized by broadcasting behaviour, strategic intent, and technological level. Interactions are governed by a simple probabilistic rule set, enabling both analytical insights and simulation-based exploration. They show that civilizations adopting a quiet strategy dominate long-term survival, and that the presence of even a single malevolent actor can drastically reduce the success of noisy civilizations. Their results offer a formal basis for the hypothesis that cosmic silence may not be puzzling, but rather a strategic necessity. The model characterizes four fundamental types of civilizations: Quiet Malevolent (QM), Quiet Benevolent (QB), Noisy Malevolent (NM) and Noisy Benevolent (NB). See
https://www.sciencedirect.com/science/article/abs/pii/S3050517825000814.

Average number of each type of civilization as function of time under certain conditions. Credit (graphic and caption): Bonin, Figure 3



Conway's Game of Life

James McCrum (University of St Andrews, UK) and Terence P Kee (University of Leeds, UK) present *Conway's Game of Life as an Analogue to a Habitable World: Livingness beyond the Biological*. Conway's Game of Life (CGOL) is a cellular automaton noted for its rich, complex, and emergent behaviour, which seems qualitatively 'lifelike'. It exists within a wider space of different rulesets of cellular automata, none of which have been found to display behaviours that seem as rich as Conway's selected example. They present here a set of three quantitative tests for 'lifelike' behaviour, based on the critical brain theory, Shannon's theory of information entropy and integrated information theory, all of which are successfully able to select Conway's Game of Life as an outlier within this set, which is a non-biological analogue to the selection of a habitable planet or universe amongst a wider space of similar settings that cannot support the same kinds of living systems.
See the paper here:
https://www.cambridge.org/core/journals/proceedings-of-the-international-astronomical-union/article/conways-game-of-life-as-an-analogue-to-a-habitable-world-livingness-beyond-the-biological/8034B0A26CDC682C4BCFD563E781E521.



A set of different rulesets are allowed to evolve from soup to ash. The lowest line is CGOL, which is clearly again moving towards a lower entropy equilibrium than its counterparts.
Credit (graphic and caption): McCrum and Kee, Figure 4