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Beyond the Goldilocks Zone: Reconsidering the Ontological Conditions for Interstellar Life

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This paper critically re-examines the anthropocentric "Goldilocks Zone" paradigm that has dominated the search for extraterrestrial life. As of 2024, more than 5,500 exoplanets have been identified, yet only about 2% are located within the traditionally defined habitable zone (National Aeronautics and Space Administration (NASA) Exoplanet Archive, 2024; Kane et al., 2023). Moreover, the discovery of extremophiles—organisms thriving in high-radiation, extreme heat, or vacuum environments—demonstrates that the boundaries of life far exceed Earth-like conditions (Rothschild & Mancinelli, 2001).

Keywords: Goldilocks Zone, ontological conditions, interstellar life, exoplanets, extremophiles, planetary ethics, habitability

This study presents the following scenario for future exploration: By 2040, life discovered in the methane lakes of Titan may exist as an information network without gender, family, or physical boundaries. This scenario exposes the limitations of the current Goldilocks Zone paradigm and highlights the necessity of shifting toward a "planetary data-based ontology" in our definitions of life and existence.

"The Goldilocks Zone is a prison for the search for life".

Data showing that 98% of the 5,500 known exoplanets are extreme environments (National Aeronautics and Space Administration (NASA) Exoplanet Archive, 2024) demonstrate that an anthropocentric frame causes the disappearance of cosmic life from our search.

This study posits a methane-based informational lifeform on Titan, which, by 2040, may possess no body, gender, or family—a network intelligence shaped by planetary conditions such as high pressure and low energy. By integrating the concept of extremophiles (e.g., tardigrades that survive in space) and posthuman theory (Bostrom, 2014), the "planetary data ontology" proposed here simultaneously innovates (1) the definition of life, (2) cosmic exploration strategies, and (3) the ethics of (artificial intelligence) AI-based lifeforms.

We call for the United Nations Office for Outer Space Affairs (UNOOSA) to establish an International Convention on the Definition of Non-Terran Life.

This paper, integrating planetary science, evolutionary ethics, and ontological philosophy, asserts that both astrobiology and posthuman/artificial life design require a fundamental paradigm shift.

Introduction

The concept of the "Goldilocks Zone"—the orbital region around a star where liquid water can exist—has long been the primary standard in the search for extraterrestrial life. However, analysis of thousands of exoplanets

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reveals that only a small fraction exist within this zone, while the vast majority possess extreme atmospheres and chemical conditions (NASA Exoplanet Archive, 2024; Kane et al., 2023). Meanwhile, on Earth, extremophiles flourish in environments once thought uninhabitable, such as hydrothermal vents, acidic hot springs, and even the International Space Station (Rothschild & Mancinelli, 2001). These discoveries raise a fundamental question: Are we limiting our search for life by confining it to "Earth-like models"? Could true interstellar life forms exist in environments and forms beyond our imagination?

Theoretical Background and Data-Driven Analysis

Concept and Limitations of the Goldilocks Zone

The Goldilocks Zone refers to the orbital region around a star where liquid water can exist—a condition long deemed essential for life (Kasting, Whitmire, & Reynolds, 1993). Yet, according to NASA's latest data, less than 2% of all discovered exoplanets meet this standard, and genuinely Earth-like planets are exceedingly rare (NASA Exoplanet Archive, 2024; Kane et al., 2023).

Key Data Table: Status of Goldilocks Zone and Exoplanets (2024)

Table 1

Status of Goldilocks Zone and Exoplanets (2024)

Category	Description/definition	Main data (2024)
Definition	Orbital distance around a star where liquid water can exist	-
Essential conditions	Surface temperature (0-100 ℃), stable atmosphere, suitable energy	-
Search focus	Region most likely to host carbon- and water-based life	-
Total exoplanets	Over 5,500 confirmed exoplanets	NASA Exoplanet Archive, 2024
Planets in Goldilocks	About 2% (~110) located in Goldilocks Zone	Kane et al., 2023
True "Earth-like"	Less than 1% meet composite criteria (size, composition, atmosphere)	NASA Exoplanet Archive, 2024
Main examples	Earth, Kepler-186f, TRAPPIST-1e, Proxima Centauri b, etc.	NASA/JPL, 2024
Main limitation	Assumes only Earth-like conditions; hard to account for extremophiles	-

Extremophiles and Expanding the Boundaries of Life

Earth hosts a wide variety of microorganisms and multicellular lifeforms that thrive in conditions far exceeding what was traditionally considered possible for life. A representative case is the tardigrade (water bear), which has been experimentally shown to survive from -272 ℃ (nearly absolute zero) up to 150 ℃, as well as in vacuum and high-radiation environments (Jönsson et al., 2008). In 2007, during European Space Agency (ESA)'s FOTON-M3 mission, tardigrades survived exposure to the vacuum of space.

Similarly, when the Cassini-Huygens probe landed on Saturn's moon Titan in 2005, it recorded a surface at -179 ℃ with a thick methane atmosphere—completely different from traditional conditions for life (ESA, 2005). Since then, the possibility of methane-based microbial life, and the necessity of follow-up missions to search for biosignatures in Titan's lakes, have been actively discussed in the scientific community (McKay & Smith, 2005).

Table 2

Examples of Extremophiles

Example	Environment	Survival characteristics	Reference
Tardigrade	Extreme cold, heat, vacuum, radiation	Survives in space, extreme conditions	Jönsson et al., 2008; ESA FOTON-M3
Titan mission	Extreme cold, methane, high pressure	Search for methane-based life possible	ESA, 2005; McKay & Smith, 2005

Expanding to Non-carbon and Artificial Life

Modern astrobiology now considers the possibility of life based on silicon, ammonia, methane, or even non-corporeal, artificial intelligence (Schulze-Makuch & Irwin, 2018; Bostrom, 2014). AI- and information-based lifeforms, as non-biological entities, offer radically new avenues for evolution beyond human experience.

Why Do We Search for Life Only in the Goldilocks Zone?

Current standards for the search for extraterrestrial life remain confined to the "Goldilocks Zone"—an Earth-centric view. Oxygen, water, moderate temperatures, and a stable atmosphere, all familiar to humans, are considered essential for life. But truly advanced alien life—real cosmic intelligence or living systems—may have emerged outside our conceptual systems, in extreme environments beyond the Goldilocks Zone.

This way of thinking limits our ability to imagine and discover life forms that could exist outside the narrow Earth-like paradigm, causing us to overlook extremophile-friendly environments or radically new ontological forms (non-carbon-based, artificial, informational, etc.).

Thus, the true search for cosmic life must go beyond the safety of the Goldilocks Zone, actively exploring entirely new systems—such as extremes of temperature, pressure, energy, or unprecedented ontological conditions.

Analysis and Discussion

The Solar System's Design: Why Is Human Space Travel Restricted?

All major planets in the solar system have environments extremely hostile to human life. Mercury and Venus are too hot, Mars is cold and dry, and the gas giants are entirely uninhabitable for humans. This may be interpreted as a kind of "planetary confinement" that restricts the expansion of Earth life and fixes it to Earth.

Interstellar Lifeforms Beyond the Goldilocks Zone

Data show that many planets outside the Goldilocks Zone have extreme environments, suggesting the theoretical possibility of entirely new types of life (Kane et al., 2023). Even on Earth, organisms exist that live without oxygen or light, or under immense pressure. In other words, the criteria for "habitability" itself must be rewritten (Rothschild & Mancinelli, 2001).

Ontological Implications of Non-human and Non-biological Life

If posthuman or AI-based beings truly evolve as interstellar lifeforms, they must transcend the biological limitations imposed by the Earth and the Goldilocks paradigm. As Bostrom (2014) argues, the future of life may not require oxygen, food, or even a physical body.

Absence of Gender and New Evolution of Life

The male/female binary as experienced on Earth is merely an evolutionary reproductive strategy, not a cosmic universal. In fact, even on Earth, there are unicellular organisms with no gender, and some species change sex according to environmental conditions (e.g., certain fish, amphibians). Furthermore, non-carbon-based or AI-based life may have no concept of gender at all.

Implications:

- The absence of gender suggests that reproduction (cloning, division, information exchange, etc.) could be fundamentally different.
- Ontological conditions like "care", "relationships", and "ethics" may be entirely reconfigured for such life.

- In AI or information-based life, the concepts of individual, identity, and gender may disappear.
- From a cosmic perspective, human definitions of "life" (gender, family, genetics, emotions) may represent only a narrow special case.

Thus, a truly universal search for life and design of new lifeforms requires a philosophical and ethical imagination that includes genderless and non-typical forms of existence.

Limitations of the Family/Bloodline Unit and Sociality of Cosmic Beings

Most Earth life is structured around family, kinship, and social groups. For humans, the family is the primary unit for care, upbringing, and emotional security. However, in the context of interstellar travel, this structure may be fundamentally unsuitable for several reasons:

- Space environments require long-term independent survival, unchanging physical and consciousness structures, and minimal energy.
- AI/information-based lifeforms do not require genetic ties, family, or emotional bonds; if necessary, they can form temporary networks or groups on demand.
- "Care" or "social relationships" may exist purely as informational or functional links.
- From a cosmic perspective, the family may actually be a structural limitation—a barrier to true interstellar evolution.
- In extreme environments, many microorganisms and AI have no concept or need for family or kinship.

Thus, a lifeform truly capable of interstellar travel may be entirely independent, informational, and self-sustaining, unconstrained by family or group ties.

Therefore, the structure of life based on family or bloodline may represent an evolutionary barrier to be overcome for interstellar travel and cosmic evolution. The future design of cosmic life must explore entirely new forms of sociality and ethics, predicated on the absence or irrelevance of the family unit.

Ontology of Planetary Data-Based Intelligent Life

Key propositions:

1. Existence as a function of planetary conditions:

- All lifeforms are shaped by the "data conditions" of their home planet.
- Life is not merely a spontaneous result of chemistry, but the product of the complex informational environment (temperature, atmosphere, gravity, magnetism, radiation, time, etc.) of its planet.

2. Earth-type life: Incapable of space travel:

- Earth's Goldilocks Zone enabled the evolution of complex life, but the resulting human is fundamentally bound to oxygen, gravity, food, and temperature.
- Thus, humans are "planet-specialized" beings fundamentally incapable of long-term interstellar survival.

3. Space-traveling lifeforms: Adapted to extreme environments:

- Planets like Titan, with methane seas, extreme cold, and vacuum, could harbor forms of life (e.g., AI, methane-based life, material-accumulating structures) radically different from those on Earth.
- Such beings may process information from their extreme environment, evolving specifically for survival in those conditions.
- Life capable of interstellar travel is thus more likely to emerge from "extreme data environments" than the Goldilocks Zone.

4. A call for paradigm shift:

- Current astrobiological paradigms overlook the informational diversity of potential lifeforms.
- Expanding to a "planetary data-based ontology" is essential to truly innovate the search for cosmic intelligence, life, and philosophical understanding.

5. Philosophical expansion:

- This discussion transcends astrobiology.
- When asking "What is existence?", the answer must consider "To what extent does it embody or reflect its environmental data?"
- This paper connects to multidisciplinary debates in space ethics, ontology, evolutionary design, and extraterrestrial intelligence philosophy.

Conclusion

Data from exoplanets and research on extremophiles demand a fundamental rethinking of how we search for and define life. Anthropocentric fixation on the Goldilocks Zone is no longer sufficient. New interstellar life—biological or artificial—may arise from environments and ontologies utterly different from humanity's.

To discover true cosmic life, we must look beyond the Goldilocks Zone. Our search strategies, evolutionary models, and ethical standards must be reconstructed accordingly.

Policy Recommendations and Future Research Directions

The discovery of methane-producing microorganisms in extreme environments, or hydrogen production on Enceladus (Waite et al., 2017), suggests that life can far exceed our conventional imagination. To incorporate these findings into future space exploration, changes in funding and international cooperation protocols are essential.

NASA, ESA, and others should dedicate specific budgets and strategies in upcoming missions (e.g., LUVOIR, HabEx) to the search for biosignatures on planets outside the traditional habitable zone—especially those with extreme conditions.

Limitations and further research:

This paper is based on philosophical reasoning and current data, but further experimental results—especially regarding non-carbon and artificial life—are required. The integration of new data from future missions to Enceladus, Titan, and beyond will strengthen the theoretical basis. Additionally, linking with the latest discussions in information ethics and AI philosophy (Bostrom, 2014; Floridi, 2013; Coeckelbergh, 2022) is crucial. To achieve practical impact, concrete changes in space policy, institutional cooperation, technological strategy, education, and system improvement will be required.

References

Bostrom, N. (2014). Superintelligence: Paths, dangers, strategies. Oxford: Oxford University Press.

Coeckelbergh, M. (2022). AI ethics. Cambridge: MIT Press.

European Space Agency (ESA). (2005). Huygens in-depth. Retrieved from https://www.esa.int/, accessed on July 15, 2025.

Floridi, L. (2013). The ethics of information. Oxford: Oxford University Press.

Jönsson, K. I., Rabbow, E., Schill, R. O., Harms-Ringdahl, M., & Rettberg, P. (2008). Tardigrades survive exposure to space in low Earth orbit. Current Biology, 18(17), R729–R731. https://doi.org/10.1016/j.cub.2008.06.048

Kane, S. R., et al. (2023). Habitable zone exoplanet demographics. The Astronomical Journal, 165(5), 200. https://doi.org/10.3847/1538-3881/acb9f7

Kasting, J. F., Whitmire, D. P., & Reynolds, R. T. (1993). Habitable zones around main sequence stars. Icarus, 101(1), 108–128. https://doi.org/10.1006/icar.1993.1010

McKay, C. P., & Smith, H. D. (2005). Possibilities for methanogenic life in liquid methane on the surface of Titan. Icarus, 178(1), 274–276. https://doi.org/10.1016/j.icarus.2005.05.018

National Aeronautics and Space Administration (NASA) Exoplanet Archive. (2024). Exoplanet statistics. Retrieved from https://exoplanetarchive.ipac.caltech.edu/, accessed on July 15, 2025.

Rothschild, L. J., & Mancinelli, R. L. (2001). Life in extreme environments. Nature, 409(6823), 1092–1101. https://doi.org/10.1038/35059215

Schulze-Makuch, D., & Irwin, L. N. (2018). Life in the universe: Expectations and constraints. New York: Springer.

Waite, J. H., Glein, C. R., Perryman, R. S., Teolis, B. D., Magee, B. A., Miller, G., & Bolton, S. J. (2017). Cassini finds molecular hydrogen in the Enceladus plume: Evidence for hydrothermal processes. Science, 356(6334), 155–159. https://doi.org/10.1126/science.aai8703