TECHNOLOGICAL SIGNATURES OF SUPER CIVILIZATIONS:

GARGANTUAN STRUCTURES AND ENORMOUS ENERGIES OR "INVISIBILITY" DUE TO LOW ENERGY SOLUTIONS TO COMPLEX PROBLEMS AND QUANTUM ENGINEERING

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ABSTRACT: The evolution trajectory of technological civilizations envisioned by Kardashev suggests ever increasing amounts of energy being harvested by the civilizations resulting in creation of megastructures of an astronomical scale. However, the idea may itself reflect a relatively crude phase of our technological development, rather than a universal principle. An alternative vision is that of technological minimalism: achieving maximal outcomes with minimal energy expenditure. Instead of scaling energy consumption upwards without limit, an advanced civilization may optimize and miniaturize its processes. It might master engineering at the quantum scale, developing technologies that use only the smallest amounts of energy necessary to accomplish a given task. Advanced technological civilization may deliberately isolate its technological infrastructure from the natural world. From an interstellar distance, their planet could appear untouched to earthly observer, with a naturally thriving biosphere, devoid of industry or artificial interference.

KEYWORDS: Evolution of technological civilizations; Kardashev scale; Search for ETI; technological minimalism.

INTRODUCTION

Imagining the evolution of technological civilizations beyond the current stage of human civilization is a complex task, yet it is essential for guiding the search for advanced extraterrestrial intelligence (ETI). Most widely known is the Kardashev Scale, first introduced in 1964 by Soviet astrophysicist Nikolai Kardashev. It is a theoretical framework for assessing the technological development of a civilization based on its capacity to harness and utilize energy. Kardashev's model stems from the assumption that the fundamental laws of physics remain constant across time and space, and it extrapolates from the trajectory of human technological progress to speculate on the capabilities of advanced extraterrestrial civilizations. Kardashev categorized civilizations into three distinct types, each defined by the scale of energy they are able to control:

> Type I Civilization: This level represents a civilization capable of capturing and effectively using all of the energy resources available on its home planet. It would be able to harness energy from wind, solar, geothermal, and other terrestrial sources on a global scale.
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> Type II Civilization: A civilization at this stage would have the technological sophistication necessary to extract energy directly from its star. This concept is often associated with the theoretical construction of a Dyson sphere—a massive, hypothetical structure that encompasses a star to intercept and collect a significant portion of its radiated energy.
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> Type III Civilization: At the highest level of Kardashev's original scale, a civilization would be able to access and control energy on the scale of its entire galaxy. This includes energy derived from all stars, as well as potentially other cosmic phenomena such as black holes or interstellar matter.

The notion of a Dyson sphere (Dyson, 1960; Osmanov, 2015) plays a pivotal role in discussions about Type II civilizations. Originally conceived as a thought experiment, the Dyson sphere was proposed as a possible solution for meeting the immense energy demands of an advanced civilization once planetary resources become insufficient. Since only a small fraction of a star's energy output naturally reaches the surface of an orbiting planet, a structure surrounding the star could collect significantly more energy, thus vastly increasing the civilization's available power supply.

From an astrophysical standpoint, detecting such megastructures presents an intriguing possibility for identifying ETI. A Dyson sphere, or similar construct, would not only absorb a star's energy but also re-emit it as waste heat, likely in the form of infrared radiation (Dyson, 1960). If the emitted spectrum deviates significantly from what is expected based on the star's known properties—particularly if it shows signs of heavy elements not naturally produced by the star—it may signal the presence of artificial structures. This idea gained public attention in 2015, when the star KIC 8462852 (also known as Tabby's Star) exhibited irregular and extreme fluctuations in brightness (Boyajian et al., 2016). While some speculated that these anomalies could be indicative of a Dyson sphere or another form of alien megastructure, later studies attributed the dimming to natural causes, most likely interstellar dust (Boyajian et al., 2018). More recently, Suazo et al. (2024), identified other potential candidates that may exhibit signs consistent with Dyson-like structures. However, further analysis and observational data are required to confirm or refute these preliminary findings. Speculations on possible Kardashev's type II megastructures have also involved black holes (Hsiao et al., 2021; Baghram, 2025) and white dwarf stars (Zuckerman, 2022). There have been even proposals for searching Kardashev Type III civilizations (Chen and Garrett, 2021).

Nevertheless, one should ask whether an advanced intellect is necessarily driven to build ever-larger structures to harness increasingly vast amounts of energy, or whether more intelligent and refined alternatives exist.

TECHNOLOGICAL CONTEXT OF ADVANCED ETI AND ENERGETIC SIGNATURES

Contrary to Kardashev's framework for the progression of technological civilizations, it may be premature—even futile—to project future solutions using only our current technological imagination. To us, it seems natural to extrapolate our path forward: more energy, bigger systems, broader control over physical matter. Yet that very assumption may mirror the naivety of a Stone Age mind attempting to conceptualize the inner workings of a nuclear submarine. We must acknowledge the limitations of our present understanding. The theories, paradigms, and perhaps even the mathematics that underpin future technological revolutions may not yet exist.

Many futurists envision that advanced interstellar civilizations must harness enormous amounts of energy, employing stellar-scale megastructures like Dyson spheres to fuel their growth (Nicholls, 1983). But this idea may itself reflect a relatively crude phase of technological development (Namboodiripad and Nimal, 2021), rather than a universal principle. An alternative vision—one that may be more aligned with advanced intelligence—is that of technological minimalism: achieving maximal outcomes with minimal energy expenditure.

Instead of scaling energy consumption upwards without limit, an advanced civilization may optimize and miniaturize its processes. It might master engineering at the quantum scale (Zong et al., 2023), developing technologies that use only the smallest amounts of energy necessary to accomplish a given task. Such a civilization would likely transition away from mega-scale constructions toward computation, manipulation, and information processing in forms that are almost invisible to our current observational tools. Nanotechnology (Malik et al., 2023) and beyond may form the infrastructure of such a civilization. They might evolve not through building bigger, but through building smarter—reducing entropy and minimizing waste.

However, there may be one exception to this paradigm of minimalism: interstellar transportation (Matloff and Gerrish, 2023). Moving matter across astronomical distances likely imposes a fundamental energetic cost that cannot be bypassed through cleverness alone. Overcoming the constraints of space-time—whether through relativistic ships, wormholes, or other yet-unknown mechanisms—may remain the only domain in which advanced civilizations must still "burn fuel," so to speak. Therefore, if we are to detect extraterrestrial intelligence through energetic signatures, it may be most promising to focus on the traces of interstellar travel rather than planetary-scale energy consumption.

ECOLOGICAL CONTEXT OF ADVANCED ETI AND INTERSTELLAR CIVILIZATIONS

In parallel to technological evolution, we must consider the ecological orientation of an advanced intelligence. Human history is rife with examples of domination and exploitation of nature, but there is no guarantee that this trend reflects also a universal trajectory for more advanced intelligent life. In fact, it is conceivable—perhaps even likely—that truly advanced civilizations adopt a fundamentally different stance: one of respect, restraint, and preservation toward their planetary ecosystems.

As civilizations mature, they may come to realize that reshaping nature to fit their needs is not only destructive but also intellectually unsatisfying. The advanced mind may no longer find meaning in controlling its environment but rather in understanding it. Natural ecosystems may be valued not for their utility but for their beauty, complexity, and role as living data (Sarkar, 2005). The civilization may come to view their biosphere much like we now view ancient artifacts or endangered species: not to be altered, but to be studied, admired, and protected.

Such a civilization may deliberately isolate its technological infrastructure from the natural world. Its artificial systems—energy harvesting, computation, and manufacturing—could operate in closed environments. This vision implies that the ecological footprint of advanced civilizations might be nearly undetectable. From an interstellar distance, their planet could appear untouched to earthly observer, with a naturally thriving biosphere, devoid of industry or artificial interference.

Such a civilization may also find its inspiration not in conquest, but in scientific reflection and artistic interpretation of the cosmos. Its trajectory might resemble a spiritual or philosophical journey as much as a technological one. The very drive to explore the stars could stem from curiosity and creativity, rather than necessity or expansionism. In this context, the search for extraterrestrial intelligence must expand beyond thermodynamic footprints and look for more nuanced indicators—patterns, anomalies, and contradictions within natural systems that defy purely natural explanation.

CONCLUSION: RETHINKING THE KARDASHEV PARADIGM

The Kardashev Scale, while historically important and intellectually provocative, may reflect more about our current mindset than the actual path of intelligent evolution. Its underlying assumption—that energy consumption must scale indefinitely alongside technological progress—may be a projection of our industrial infancy rather than a law of the cosmos. A truly advanced civilization may evolve toward greater efficiency, subtlety, and harmony with its environment. Its most profound technologies may be invisible to us—not because they are hidden, but because they operate on scales and principles we are not yet equipped to detect. Interstellar travel may remain the only domain where brute energy still plays a dominant role, and thus our best bet in detecting extraterrestrial civilizations might lie in looking not for Dyson spheres, but for the faint, improbable echoes of movement between the stars.

In the end, the absence of clear signals from the stars may not reflect a quiet universe. It may instead reflect a quiet intelligence—one that speaks not through explosions of energy, but through the elegance of restraint.

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