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Stellivore extraterrestrials? Binary stars as living systems

Clément Vidal

Center Leo Apostel, Evolution, Complexity and Cognition research group, Vrije Universiteit Brussel (Free University of Brussels), Krijgskundestraat 33, 1160 Brussels, Belgium

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ABSTRACT

We lack signs of extraterrestrial intelligence (ETI) despite decades of observation in the whole electromagnetic spectrum. Could evidence be buried in existing data? To recognize ETI, we first propose criteria discerning life from non-life based on thermodynamics and living systems theory. Then we extrapolate civilizational development to both *external* and *internal* growth. Taken together, these two trends lead to an argument that some existing binary stars might actually be ETI. Since these hypothetical beings feed actively on stars, we call them "stellivores". I present an independent thermodynamic argument for their existence, with a metabolic interpretation of interacting binary stars. The jury is still out, but the hypothesis is empirically testable with existing astrophysical data.

1. Introduction

In 1960, Freeman Dyson proposed to search for extraterrestrial intelligence (ETI) by looking for infrared radiation emitted by an artificial biosphere covering a star [14]. Unfortunately, despite some searches, the results are negative [26,7,51]. Overall, we lack proof or even indication of ETI, a fundamental gap in our knowledge of the universe. Here I show that building on and extending Dyson's method leads to a new ETI interpretation of known interacting binary stars. The jury is still out, but the hypothesis is testable with existing empirical data.

The Dysonian SETI approach [15,5,9] opens new research agendas as it discards many implicit assumptions. Here in particular, I *do not* assume that putative ETIs necessarily use oxygen or carbon; that they live on a planet around a sun like-star or thrive on temperatures or magnetic fields we know are suitable for life on Earth (see [42], chap. 6; and [18] for debunking of such terrestrial chauvinisms). I also make no assumption about their communicative intent, nor that we should limit the search to our galaxy only.

Free of these assumptions, we can start to think systematically about life-as-we-don't-know it [21]. A common denominator to definitions of life is that it requires a *metabolism*, a manipulation of matter-energy by a force. But which force? Freitas systematically analyzed four possible metabolisms respectively based on the four fundamental physical interactions: *strong nuclear*, *electromagnetic*, *weak nuclear*, and *gravitational*.

Starting with such universal metabolic considerations, it follows that the substrate on which life or complex systems are based needs not to be unique. For example, our computers' substrate has already changed five times since their invention, from electromechanical calculators to today's integrated circuits ([30], chap. 3). In all cases, computers metabolize in a primitive way because they use energy to manipulate logical gates and dissipate heat. The lesson is that in astrobiology, as in computer engineering, what matters is not matter itself, but the ability to manipulate matter-energy and information.

How do we recognize ETI? To do so, we must establish criteria for distinguishing life from non-life. Let us further inquire into *thermodynamics* and *living systems theory*, because these frameworks are universal in the sense that they are independent of a particular material substrate.

2. Criteria for distinguishing life from non-life

The thermodynamic view of the universe can be quantified in order to describe 13.8 billion years of cosmic evolution [8]. Chaisson developed an empirical metric based on the rate of energy which flows through a system of a given mass (its unit is therefore erg s^{-1} g^{-1}). It uses only the fundamental concepts of energy, time and mass and successfully applies to describe the rise of complexity in physical, biological and cultural systems. Given such a billion-years applicability, we can reasonably hope that it would also apply to advanced extraterrestrials.

E-mail address: contact@clemvidal.com
URL: http://www.clemvidal.com

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We can distinguish three kinds of increasingly complex thermodynamic structures. First are *equilibrium structures* which are the subject-matter of classical thermodynamics, when applied to liquids or crystals. Then come *dissipative structures* which are in a nonequilibrium state and self-organize [37]. A famous example is the Belousov-Zhabotinsky chemical reaction, in which the concentration oscillates periodically, leading to the formation of non-trivial patterns. However, since the system remains closed to mass transfer, it finally reaches a state of equilibrium ([37], 340). The third kind of thermodynamic structures are *living structures*, which sustain a non trivial behavior and stay in nonequilibrium. They are best modelled as *open systems,* meaning that a flow of energy goes through them.

An additional thermodynamic criterion is the *control* of that energy flow, which is a necessary condition for the growth, maintenance, evolution and reproduction of complex systems [1]. For example, a stone processes virtually no flow of matter-energy, and most scientists will agree that it is dead. On the opposite side, a wild forest fire grows and uses a lot of energy, but is uncontrolled. Living systems are in between these two extreme examples, controlling their energy flow.

Thermodynamic criteria are insufficient, since a refrigerator or a candle also do satisfy them. So, thermodynamic criteria are necessary but not sufficient to recognize extraterrestrials ([43], 145). *Living Systems Theory*, a subdiscipline of systems theory, shows that all living beings display 20 critical subsystems [35, 36]. The critical subsystems are divided in three broad categories. First, one subsystem, the reproducer, processes both *matter-energy and information*; second, nine subsystems process *matter-energy* and third, ten remaining subsystems process *information* (see Table 1).

James Grier's [35] 1100-page book is an impressive theoretical exposition and application of this general theory of the living to many different kinds of living systems at different levels, from cells, organs, organisms, groups, organizations, and societies to the supranational organization of civilized life. This *magnum opus* is a very useful guide to thinking in general terms about extraterrestrial life. As a matter of fact, it has been applied in the context of astrobiology by Harrison [24].

3. Scales for civilizational development

Now that we have thermodynamic and living systems criteria, we need "candidate" ETIs to apply them to. A typical strategy to find advanced ETI is to extrapolate general trends of our own development. Although it is admittedly Earth-centric, we have to start somewhere, and we have just one option: life on Earth.

We distinguish three scales for civilizational development (Table 2). Importantly these extrapolations make a minimum of assumptions because energy, information processing and scale are arguably universal physical concepts (see also [10]).

Extrapolating our exponential increase of energy consumption, Kardashev [27] showed that this would lead our civilization to type

Table 1
Miller distinguishes 20 subsystems that all living systems have, which can be divided into three broad categories: First, subsystems that process both matter-energy and information; second, subsystems that process matter-energy; and third, subsystems that process information.

Living subsystem	Description
	MATTER + ENERGY + INFORMATION
1. Reproducer	The subsystem that is capable of giving rise to other systems similar to the one it is in.
2. Boundary	The subsystem at the perimeter of a system that holds together the components making up the system, protects them from environmental stresses, and excludes or permits entry to various sorts of matter-energy and information.
	MATTER + ENERGY
3. Ingestor	The subsystem that brings matter-energy across the system boundary from the environment.
4. Distributor	The subsystem that carries inputs from outside the system or outputs from its subsystems around the system to each component.
5. Converter	The subsystem that changes certain inputs to the system into forms more useful for the special processes of that particular system.
6. Producer	The subsystem that forms stable associations that endure for significant periods among matter-energy inputs to the system or outputs from its converter, the materials synthesized being for growth, damage repair, or replacement of components of the system, or for providing energy for moving or constituting the system's outputs of products or information markers to its suprasystem.
7. Matter-energy storage	The subsystem that retains in the system, for different periods of time, deposits of various sorts of matter-energy.
8. Extruder	The subsystem that transmits matter-energy out of the system in the forms of products or wastes.
9. Motor	The subsystem that moves the system or parts of it in relation to part or all of its environment or moves components of its environment in relation to each other.
10. Supporter	The subsystem that maintains the proper spatial relationships among components of the system, so that they can interact without weighting each other down or crowding each other.
	INFORMATION
11. Input transducer	The sensory subsystem that brings markers bearing information into the system and changes them to other matter-energy forms suitable for transmission within it.
12. Internal transducer	The sensory subsystem that receives, from subsystems or components within the system, markers bearing information about significant alterations in those subsystems or components, changing them to other matter-energy forms of a sort that can be transmitted within it.
13. Channel and net	The subsystem composed of a single route in physical space, or multiple interconnected routes, by which markers bearing information are transmitted to all parts of the system.
14. Timer	The subsystem which transmits to the decider information about time-related states of the environment or of components of the system. This information signals the decider of the system or deciders of subsystems to start, stop, alter the rate, or advance or delay the phase of one or more of the system's processes, thus coordinating them in time.
15. Decoder	The subsystem that alters the code of information input to it through the input transducer or internal transducer into a "private" code that can be used internally by the system.
16. Associator	The subsystem that carries out the first stage of the learning process, forming enduring associations among items of information in the system.
17. Memory	The subsystem that carries out the second stage of the learning process, storing various sorts of information in the system for different periods of time.
18. Decider	The executive subsystem that receives information inputs from all other subsystems and transmits to them information outputs that control the entire system.
19. Encoder	The subsystem that alters the code of information input to it from other information processing subsystems, from a "private" code used internally by the system into a "public" code that can be interpreted by other systems in its environment.
20. Output transducer	The subsystem that puts out markers bearing information from the system, changing markers within the system into other matter-energy forms that can be transmitted over channels in the system's environment.