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Stellivore Extraterrestrials?
Binary Stars as Living Systems

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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”. We 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 testable with existing astrophysical data.

Keywords: SETI, Dysonian SETI, Astrobiology, High energy astrophysics, High energy astrobiology, Living systems theory, Stars: binaries: general, Stellivore

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 (Dyson 1960). Unfortunately, despite some searches, the results are negative (Jugaku, Noguchi, and Nishimura 1995; Carrigan Jr 2009; Wright et al. 2014). We thus 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 (Dyson 1966; Ćirković 2006; Bradbury, Ćirković, and Dvorsky 2011) 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 Sagan 1973, chap. 6; and Feinberg and Shapiro 1980 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 (Freitas Jr 1981). 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 (Kurzweil 2005, 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 (Chaisson 2001). 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.

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 (Nicolis and Prigogine 1977). 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 (Nicolis and Prigogine 1977, 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 (Aunger 2007). 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 (Sagan 1975, 145). *Living Systems Theory*, a subdiscipline of systems theory, shows that all living beings display 20 critical subsystems (J. G. Miller 1978; J. L. Miller 1990). 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 Miller's (1978) 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 A. A. Harrison (1997).

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.

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.

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 Ćirković 2015).

Kardashev Scale (in $erg.s^{-1}$)			Sentience Scale (in $bits.s^{-1}.kg^{-1}$)		Barrow Scale (in m)		
KI	– energy consumption at	~4 x 10^{19}	SQ -70	Minimum possible sentience quotient	BI	– manipulates objects of its own scale	~1
KII	– energy consumption at	~4 x 10^{33}	SQ -2	Information processing of a plant	BII	– manipulates genes	~10^{-7}
KIII	– energy consumption at	~4 x 10^{44}	SQ 13	Information processing of a human being	BIII	– manipulates molecules	~10^{-9}
			SQ 50	Maximum possible sentience quotient	BIV	– manipulates individual atoms	~10^{-11}
					BV	– manipulates atomic nuclei	~10^{-15}
					BVI	– manipulates elementary particles	~10^{-18}
					BΩ	– manipulates space-time's structure	~10^{-35}

Table 2: Three scales to classify civilizational development: by energy, sentience or ability to control small scales. Kardashev's (1964) types refer to energy consumption; Freitas' (1984) sentience scale refers to information processing capabilities, as the Sentience Quotient (SQ); Barrow's (1998, 133) types refer to a civilization's ability to manipulate smaller and smaller entities.

Extrapolating our exponential increase of energy consumption, Kardashev (1964) showed that this would lead our civilization to type KII in year ~5164 and to type KIII in ~7764. But we are still a ~KI civilization. What motivations could we have to evolve from type KI to type KII and harness the energy of the Sun? There are essentially two reasons. First, simply to meet our growing energy consumption needs. Indeed, the Sun is the obvious long-term resource to harness energy from, because it contains 99.8% of our solar system's mass-energy. Exploiting the energy of a star is an explorative engineering field known as *star lifting* or *stellar engineering* (Reeves 1985; Criswell 1985; Beech 2008). The second incentive is to engineer our Sun to avoid its red giant phase which will begin in ~5 billion years and will wipe out life on Earth. Various processes have been proposed for this purpose, resulting in an elimination of this red giant phase (Beech 2008).

Next to Kardashev's scale, which deals with matter-energy flows, we can add the *sentience scale*, dealing with information flows. Freitas (1984) introduced the sentience quotient and defined it as I/M, the ratio of the information processing rate I to the entity's mass M. The scale is benchmarked against the maximal amount of information that can be processed according to fundamental limits of quantum mechanics (Bremermann 1982). Freitas calculates an upper bound of 10^{50} $bits.s^{-1}.kg^{-1}$. Because of the large numbers involved, the sentience quotient focuses on orders of magnitudes, and is expressed through the logarithm of I/M. So in this case the result is +50. The lower bound is a system the mass of the universe (~10^{52} kg) able to manipulate just one bit, given the age of the universe (~10^{18} s). The resulting sentience quotient is -70. Freitas estimates that humans (and most living animals) cluster around a sentience quotient of +13, while plants are at -2.

Let us turn to the Barrow scale, which classifies civilizations by their ability to control smaller and smaller entities, as depicted in Table 2. This trend leads to major revolutions. Biotechnologies, nanotechnologies and information technologies are progressing at an accelerating pace and all stem from our abilities to control and manipulate small scale entities.

Barrow estimates that we are currently a type ~BIV civilization that has just entered nanotechnology. We could estimate that lifeforms based on strong nuclear interactions hypothesized by Freitas are type ~BV and those based on weak nuclear interactions ~BVI. If we extrapolate the Barrow scale to its limits (type BΩ), we come to a civilization able to manipulate space-time, or what Freitas called gravitational beings. However, because gravitation is such a weak field, a lot of mass and density must be present to get significant effects. Such lifeforms would thus ultimately be tied with black holes, and scientists have indeed speculated on various ways an advanced civilization could extract energy from black holes (Penrose 1969; Frautschi 1982).

4 - Interacting Binary Stars as Extraterrestrial Life Candidates

Let us apply the Kardashev and Barrow scales to search for ETI. On the Kardashev scale, a type KII civilization would use the energy of its parent star. On the Barrow scale, small scales and high densities would attract intelligence, down to black hole organization (Vidal 2011; Smart 2012). Combining both the Kardashev and the Barrow scale, could a civilization harness with great efficiency the energy of a star, to run its organization at black hole –or lower– density? Such configurations actually already exist! Indeed, about 1000 binary star systems[2] composed of a dense body accreting gas from a companion star are known and studied by astrophysicists, such as cataclysmic variables, and X-ray binaries which include X-ray pulsars and microquasars (see e.g. Warner 1995; Frank, King, and Raine 2002).

Traditional astrophysics sees such white dwarfs (WDs), neutron stars (NSs) or black holes (BHs) as the stellar graveyard, because such dense bodies are theorized to be the remains of dead stars. However, some of these supposedly dead bodies display a perplexing variety of behavior more characteristic of the living world.

2 This crude estimate is based on the following figures:

- **Cataclysmic variables**: **472** are known in 2003 (Ritter and Kolb 2003) but not all cataclysmic variables are ETI candidates.
- **X-ray binaries**: There are about **400** of them. Some are white dwarfs, others are neutron stars or black holes, and may thus overlap with other catalogs, (see e.g. Caballero and Wilms 2012).
- **Pulsars**: About 1805 pulsars are known (Antoniadis 2015, 13). But most of them are single. The millisecond pulsar population is much smaller, about 10% of this figure, so 180 (Becker, Bernhardt, and Jessner 2013). About 80% of millisecond pulsars are in binaries, so it totals to **144**.
- **Microquasars** (i.e. binary system with a black hole primary). About **2 0** are known, see: https://en.wikipedia.org/wiki/List_of_black_holes#Stellar_black_holes_and_candidates

Let us visit the binary zoo with thermodynamic criteria in mind. Kopal (1955) classified binaries in three types: *detached binaries, contact binaries,* and *semi-detached binaries*. Broadly speaking, *detached binaries* are like two stones, they do not exchange matter-energy and do not influence each other. *Contact binaries* often evolve to a *common envelope* event, where stars exchange matter unstably and rapidly until the system reaches an equilibrium. The dynamics is similar to a wild forest fire. However, in *semi-detached binaries*, the energy flow exists, it is irregular but does not appear out of control. Their activity might shroud a metabolism.

There are three main ways semi-detached binaries can interact (Eggleton 2006). They can interact via a *conservative process*, where the overall mass of the binary system is conserved. They are not good ETI candidates because no entropy is expelled in a sink out of the system. In *rapid non-conservative processes*, mass is rapidly expelled out of the system, such as in type Ia supernovae, triggered when a WD accretes more matter than it can support, and explodes. They are also not promising ETI candidates because the duration is short and the end point is the total destruction of the system. The third category are the *slow non-conservative processes*, where mass is expelled out of the system, but in a slow way. They are promising because all the conditions of a metabolism are put together. There is an energy gradient between the star and the dense body, and such binaries display an irregular energy flow coming from their companion star. Furthermore, they dissipate entropy in the form of regular cataclysms (in WDs) or jets (in NSs and BHs).

An objection is that not only living systems are out of equilibrium, but also dissipative self-organized systems such as chemical clocks. This is why we must ask if there is an *energy flow control* which allows the regulation of metabolic processes. If we turn to cataclysmic variables, microquasars and some X-ray binaries, their accretion pattern is varying, a fundamentally puzzling property challenging to explain (Mészáros 2010, 101). This could be interpreted as an active energy flow control.

To sum up, we now have enough concepts to define more precisely a putative ETI in a binary system: it is an extraterrestrial civilization using stellar energy (type KII on Kardashev's scale), in the configuration of a slow non-conservative transient accreting binary (thermodynamic criteria), with the dense primary (Barrow scale) being either a white dwarf, neutron star or black hole. For convenience, I call such a hypothetical civilization *stellivore*[3], defined simply as “a civilization that feeds actively on stars”.

An important strategy to understand living systems is to look at their waste products. If we apply this to WDs, we can study the novae ejectas which are expelled during novae. It is quite puzzling that the composition of novae ejecta displays heavy-elements abundance, ruling out the possibility that it is simply the accreted matter which is ejected (Gehrz et al. 1998). The alternative ETI interpretation is that the accreted material is used to perform work and novae are actually waste products ejected as heavy elements.

How could work be performed under strong magnetic fields surrounding WDs? In fact, strong magnetic fields open up new ways of organizing matter, as the discovery of a third mechanism for chemical bonding in strong magnetic fields shows (Lange et al. 2012). This new *paramagnetic bond* adds to the *covalent bond* and the *ionic bond* and plays a role in the magnetized atmospheres of WDs.

3 In my (2014) book, I first coined the word “starivore” (a hybrid word from English *star*; and latin *vorus*) because of its proximity with the word “carnivore”. I now changed to *stellivore* (from latin *stella* and *vorus*).

Let us now illustrate some of the living subsystems which could be at play in candidate known binary stars (Table 3).

MATTER + ENERGY + INFORMATION	
2. Boundary	*White dwarfs* have atmospheres (hydrogen and helium layers), which regulate the energetic outflow of the star. *Neutron stars* have outer and inner crusts. *Black holes* in rotation have an ergosphere and an event horizon, which delimit boundaries for radiation or light to escape or not.
MATTER + ENERGY	
3. Ingestor	Binaries display many different types of accretion methods. Magnetic white dwarfs have accretion following fields lines. Other accretion types include Roche-lobe overflow, tidal friction, gravitational radiation, stellar winds, magnetic braking, accretion disc, and accretion disc with a strong magnetic field (accretion curtain).
5. Converter	Conversion of energy extracted from the secondary. In white dwarfs, the material extruded (nova ejecta) has a different chemical composition from the accreted material.
8. Extruder	In *white dwarfs*, recurrent novas, or classical novas. In *neutron stars* and *black holes*, the relativistic jets. Their composition remains a matter of debate.
9. Motor	Some binaries also move at high speed through the galaxy (e.g. the extremely low-mass *white dwarf* J0755+4906, the *neutron star* IGR J1104-6103 or the *black hole* XTE J1118+480).
INFORMATION	
14. Timer	Our galaxy contains binary millisecond pulsars, that can be used as a timing reference and galactic navigation system.

Table 3: Tentative living systems interpretation of candidate binary systems, from a high energy astrobiological perspective. Six critical living subsystems are suggested to apply to interacting binaries composed of a primary white dwarf, neutron star, or black hole.

This metabolic interpretation raises the objection that we did not take into account Miller's ten *informational* critical subsystems, despite that information processing is essential to the living. Could we search for information processing from hypothetical stellivores? This brings us to pulsars, especially to binary millisecond pulsars which are in a stellivore configuration. The artificiality of pulsars has repeatedly been suspected, not only at the time of their discovery but also later (e.g. by Carl Sagan in Dyson et al. 1973). We suggest that binary millisecond pulsars could be an informational subsystem, fulfilling the *timer* function. Millisecond pulsars constitute excellent timekeeping devices as they are comparable to atomic clocks in stability (Hartnett and Luiten 2011). Observing at least four pulsars at the same time allows them to be used as a galactic navigation system known in space science as X-ray pulsar-based Navigation and timing (XNAV) (Downs 1974; Sheikh 2005). What is remarkable is that the system is accurate down to 10 meters, on a galactic scale (Song et al. 2015)! Such accuracy is comparable to global navigation satellite systems we have on Earth. Finally, the NANOGrav project is currently using pulsar signals to attempt to measure gravitational waves (The NANOGRav Collaboration et al. 2015). Not all pulsars are in binary systems, but it is worth noting that 80% of millisecond pulsars are in binary systems, while less that 1% of normal (non-millisecond) pulsars have a companion (Lorimer and Kramer 2005, 27).

Let us apply Chaisson's metric to binaries, to see how well they score. We can first calculate the theoretical maximum energy rate density that a binary could achieve. A crude estimate comes from the *Eddington limit* for luminosity (e.g. Frank, King, and Raine 2002, 3). If a system were to accrete at a rate above this limit, the radiation creates outward pressure preventing accretion of more material. This accretion rate is ~1.3 x 10^{38} ($M/M_{\odot}$) erg.s^{-1}, that can be translated to a theoretical maximum free energy rate density of ~6.54 x 10^4 erg.s^{-1}.g^{-1}. Now, how do actual binary WDs, NSs and BHs score? Surprisingly, their luminosity can break this limit. They are amongst the few systems which display *super-Eddington* luminosity (see e.g. Bachetti et al. 2014). Those values of energy rate densities are thus *extremely high,* since other astrophysical systems such as the Sun has a value ~2 and planets have ~10^2. Higher values are otherwise known only for complex system such as a human body (~2 x 10^4; (Chaisson 2001, 138)).

An objection against these suspiciously high values is that binaries display unstable states, indicative of destructiveness and not of constructive complexity. Indeed, supernovae, which are definitely destructive processes also do display high values (>>10^6; (Chaisson 2001, 157)). However, novae or jets are not supernovae, and associated binaries systems are not at all destroyed and generally not even disturbed by such events. The case of *recurrent novae* is particularly clear: even though these systems undergo impressive cataclysms, this happens recurrently.

5 - Discussion

Assuming the argument presented here is correct, what could be the origin of stellivores? I can propose three options: the *power station*, the *separate path*, or the *developmental path*. In the first case, we assume that intelligent life harnesses the already existing energetic gradient occurring in interacting binary stars. The situation would be similar to humans noticing a waterfall and later building hydroelectric power stations to harness this gravitational energy. This *power station* interpretation suffers from complications. Where is the intelligent life precisely? In a nearby planet? If so, how is the energy transferred?

The *separate path* interpretation assumes that there are many pathways to life, not only organic chemistry as we know it on Earth. Such a non-organic form of life may thus be advanced or not compared to us, it would just be different, and happened to have self-organized at a stellar scale.

The *developmental path* interpretation suggests that stellivores evolved and developed from lifeforms which started on an Earth-like planet. From our point of view, it might seem nearly impossible to transform into such a form of life. However, we should not forget that we are very young in the galaxy, and putative other lifeforms are on average 1 to 2 billion years our senior (Norris 2000; Lineweaver, Fenner, and Gibson 2004)!

Given such time, here is one speculative scenario which could lead life on Earth into such a high-energy configuration. We continue to climb the Kardashev scale and use more and more energy. In parallel, our technologies function on smaller and smaller scales, and we climb the Barrow scale. Those small and dense technologies demand more and more energy. Once we cover the Earth with solar panels—having understood that all other energy sources are not sustainable in the long term—we still want more energy. An obvious way to get more energy is to get closer to the Sun. This might be done by changing the orbit of the Earth (Korycansky, Laughlin, and Adams 2001). The higher temperatures progressively require to change the physical substrate of life from organic chemistry, to a heat-resistant postbiological substrate. After a certain time, the energy passively received is still not enough to meet our ever growing energy needs. Stellar engineers set up the first active accretion from the Sun. We have become stellivores.

Interestingly, reducing the mass of the Sun is also a way to prolong its lifetime (Beech 2008). In such a scenario, not only do we consume massively more energy, but this consumption also delays the predictable red-giant phase of the Sun.

This scenario needs not to be correct in all its details. Yet, from what we know about cosmic evolution, the developmental path option makes most sense. Indeed, a characteristic of biological complexification is to lead to high-energy, far-from-equilibrium systems (Pross 2005, 153–154). It would thus seems most efficient and economical that the primary (WD, NS or BH) is the living structure, while the companion star is its energy source. The separate path would be at odds from what we know about cosmic evolution, because it would organize and complexify directly in high energies. The power station interpretation holds to the assumption that biology should stay as we know it, and complicates needlessly the energy transfer.

6 - Conclusion

We showed with two independent lines of arguments that some binary stars are good ETI candidates. First, by extrapolating general energetic and scale-density trends of civilizational development; second, with a metabolic and living systems interpretation of some existing binary stars in accretion. The stellivore hypothesis invites us to look back at a chapter of high energy astrophysics with a fresh high energy astrobiological perspective. Contrary to many ETI speculations, this hypothesis is ready to be tested because binary astrophysics is a well established empirical science. More detailed propositions to test this hypothesis can be found in (Vidal 2014, chap. 9).

Percival Lowell elaborated a theory that canals on Mars were artificial. In 1895, the issue of natural or artificial canals was clearly formulated. Yet, during two decades, science was unable to confirm or infirm the theory (Dick 1996, 78). Let us hope that we will do better and take less time to assess the stellivore hypothesis.

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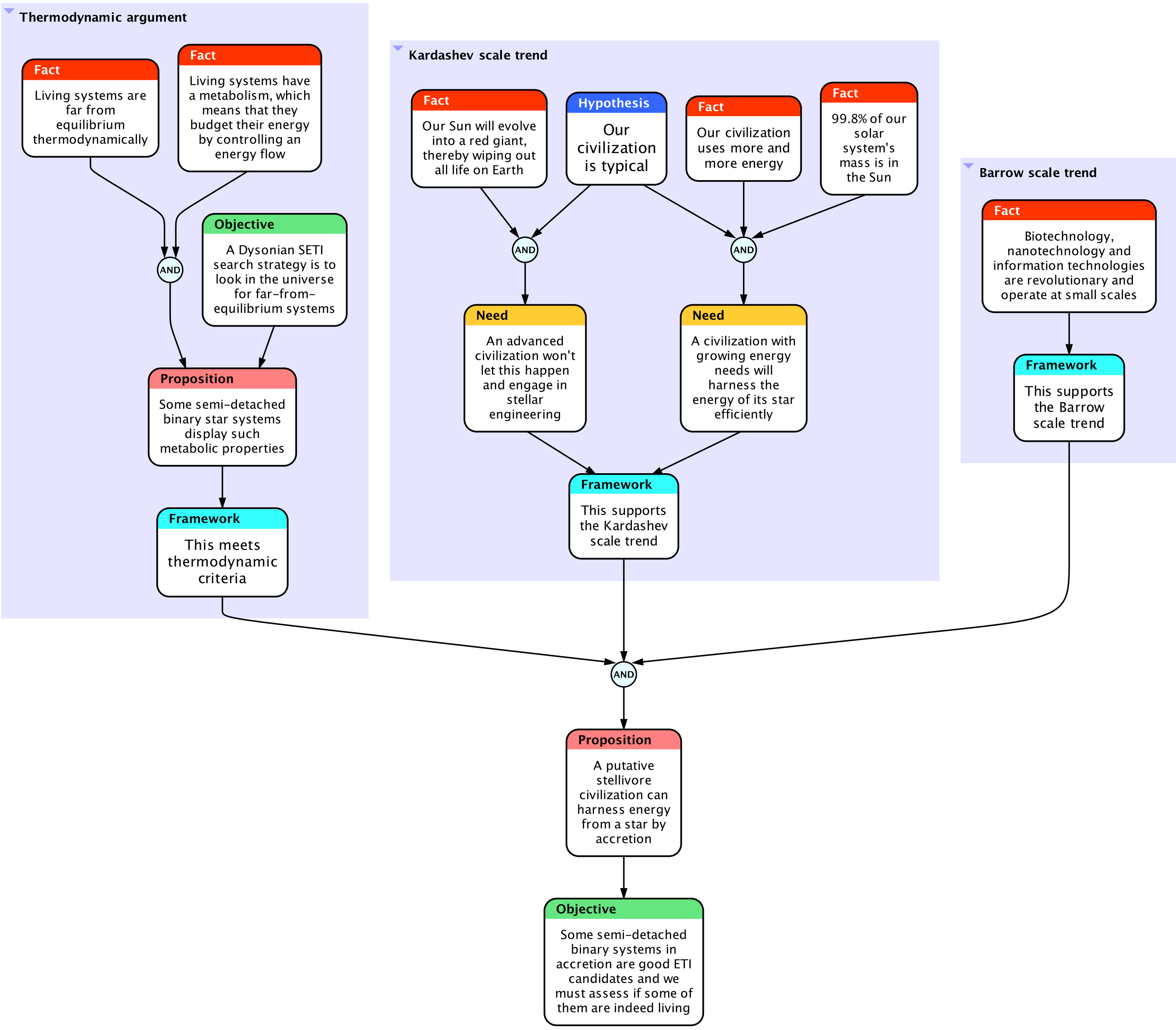
Argumentative Map



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