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Philosophical and Scientific Implications of Astrobiology and Palaeontology in the Light of Hypothesising the Existence of Intelligent Pre-human Civilisations on Earth: Empiricist, Rationalist, and Positivist Approaches

Implicaciones filosóficas y científicas de la astrobiología y la paleontología a la luz de las hipótesis sobre la existencia de civilizaciones pre-humanas inteligentes en la Tierra: enfoques empiristas, racionalistas y positivistas

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Abstract

In this paper, the scientific and philosophical implications of the theory that suggests the existence of an intelligent civilisation on Earth prior to mankind is discussed. All available scientific evidence which would constrain such theory is brought into discussion. Therefore, we first review the Drake Equation regarding this hypothesis. We summarily appraise the Shadow Biosphere within the scope of the theory. Subsequently, we thoroughly analyse important geochemical and sedimentological constraints of the proposal, mainly in the context of some *Fossillagerstätten*. This leads us to discuss the philosophical implications this theory may have for the fields of Astrobiology and Palaeontology, analysing them under empiricist, rationalist, and positivist approaches. We contextually examine the concepts of technological species, intelligence, and industrialisation, taking into account the scope of the theory. Furthermore, we debate on the validity of this hypothesis, considering all constraints it presents regarding the analysed concepts. Finally, we propose to appraise the hypothesis under an epistemological/positivist point of view.

Keywords: Philosophy of Astrobiology, Pre-Human civilisations, Silurian Hypothesis, Drake Equation, Shadow Biosphere, Technological Species.

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Resumen

En este artículo se discuten las implicaciones científicas y filosóficas de la teoría que sugiere la existencia de una civilización inteligente en la Tierra anterior a la humanidad. Se considera toda la evidencia científica disponible que constriñe tal teoría. Por lo tanto, primero revisamos la Ecuación de Drake con respecto a esta hipótesis. Evaluamos sumariamente la Biósfera Sombra dentro del alcance de la teoría. Posteriormente, analizamos a fondo importantes limitaciones geoquímicas y sedimentológicas de la propuesta, principalmente en el contexto de algunos Fossillagerstätten. Esto nos lleva a discutir las implicaciones filosóficas que esta teoría puede tener para los campos de la Astrobiología y la Paleontología, para así analizarlas bajo enfoques empiristas, racionalistas y positivistas. Examinamos contextualmente los conceptos de especie tecnológica, inteligencia e industrialización, teniendo en cuenta el alcance de la teoría. Además, debatimos la validez de esta hipótesis y consideramos todas las limitaciones que presenta con respecto a los conceptos analizados. Finalmente, proponemos valorar la hipótesis bajo un punto de vista epistemológico/positivista.

Palabras claves:
Filosofía de la astrobiología, civilizaciones pre-humanas, hipótesis silúrica, ecuación de Drake, biosfera Sombra, especies tecnológicas.

1. Statements and Declarations

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2. Introduction

Astrobiology has been defined as "the study of the origins, evolution, distribution, and future of life in the universe" (NASA, 2021). This area is, by itself, interdisciplinary as it encompasses approaches from different fields, which include biology, chemistry, astronomy, geology, selenology, and so on. Some important approaches of Astrobiology are trying to discern what physical properties allow our Universe to support life, how life begins and evolves, and where else in our Universe life might have arisen (Plaxco and Gross, 2021). In this sense, astrobiological works also include subjects like the search for life/life-like signals and the study of prebiotic chemistry on Mars and other extraterrestrial bodies in the solar system, in addition to the study of radio signals from the Universe.

According to Chon-Torres (2018), it is essential to address the scope of astrobiology well beyond classical scientific specialisations. A reason for this could be that astrobiology may hold the answer to a natural matter of curiosity within mankind, regarding our uniqueness in the Universe. Consequently, a further field for astrobiological studies is the research into the origin and evolution of life on our planet, including, of course, the possibility of the existence of intelligent life forms prior to humans, a topic which has awoken the interest of many sectors in the society. Not only astrobiologists have poured their efforts into answering this question: biologists, chemists, social scientists and recently philosophers (*e.g.* Scott, 1996; Jakosky, 2000; Fry, 2015; Sandalinas and Balaguer-Rosa, 2018) have also approached this issue. This could imply that astrobiology could also be engaged under a philosophical perspective, rather than under a scientific mindset. In any case, it must be stated that both views can be equally dealt with, without leaving one or the other behind.

3. Civilisations Prior to Human

During the last decade, a popular trend within astrobiology has dealt with the prospect of an ancient "civilisation" that may have dwelled on Earth prior to mankind. Wright (2018) discussed the origins and potential locations for technological signatures of prior technological species "indigenous" to the Solar System. According to him, a possibility exists that these species might have arisen either on ancient Earth or on another body from our system. In case this body was Venus, the onset of its global greenhouse conditions may have erased all possible evidence from its surface. As for our planet, the author attributes the loss of possible evidence of technological species to plate tectonics and erosion, in case such species lived Gyr ago. He concluded that possible evidence could be eventually found on the Moon or Mars.

Schmidt and Frank (2018) recently concluded that the existence of an intelligent civilisation on Earth prior to humans could have been geochemically and statistically possible. These authors reviewed geochemical and sedimentological signals throughout the geological record prior to human existence and concluded that they generally exhibited similarities with man-originated signals. Their "Silurian Hypothesis" states that the existence of an "industrial civilisation" in Earth prior to humans could be both mathematically and geologically possible (Schmidt and Frank, 2018). These assumptions were based on the Drake Equation (Drake, 1961, 1965) and on comparisons with the fingerprint that mankind has caused during the Anthropocene.

Recently, Lingam and Loeb (2019), despite not dealing explicitly with pre-human civilisations, showed mathematically that terminal speeds approaching the speed of light might be achievable under idealised circumstances, provided advanced materials and manoeuvring techniques were available. This would imply extended possibilities of travelling massively through space.

Nevertheless, all these arguments can neither be sufficiently supported by the Drake Equation, by any astrophysical demonstration, nor even by any geochemical/sedimentological evidence, as both the Drake equation and the discussed geochemical, sedimentological and astrophysical traits present several approaches, not necessarily related to the Anthropocene. Furthermore, Schmidt and Frank (2018) state that they "strongly doubt that any previous civilisation existed before our own" (p. 148), whereas Lingam and Loeb (2020) assert that their own analysis "did not take numerous engineering constraints into account" (p. 14). Moreover, Carroll-Nellenback *et al*. (2019) emphasised the ambiguity of some geochemical signals in the geological record for being considered as possible evidence of a pre-human civilisation.

In the following pages, theories dealing with technological species prior to humans on Earth will be scientifically evaluated, based on the analysis of the Drake equation, on the revision of determined geochemical and sedimentological features in famous localities, and on important industrialisation-related concepts. In the end, we propose a philosophical approach in the light of the always-standing question regarding our uniqueness in the universe.

4. The Drake Equation

The Drake Equation (Drake, 1961, 1965) intends to depict the probability for "intelligent" (*a.o.* active and communicative) extraterrestrial civilisations in our galaxy, to exist. The formula of this equation is the following:

$$N = R^* \cdot fP \cdot ne \cdot fl \cdot fi \cdot fc \cdot fL$$

where:

N = number of civilisations in our galaxy with possibility of communication

R^* = the average rate of star formation in the Milky Way

fP = the fraction of such stars which have planets

ne = the average number of planets which could potentially harbour life, per star which has planets

fl = the fraction of planets which could harbour life that eventually develop life

fi = the fraction of life-harbouring planets which develop intelligent life

fc = the fraction of civilisations which develop a technology that produces detectable signals of their existence into space

fL = the time span for which such civilisations produce detectable signals into space.

Drake (1961, 1965) originally proposed the subsequent solution, assigning the following values:

$R^* = 10$; $fP = 0.5$; $ne = 2$; $fl = 1$; $fi = 0.01$; $fc = 0.01$; $fL = 10{,}000$, therefore $N = 10$ possible detectable civilisations.

Schmidt and Frank (2018) provided a thorough discussion of how this equation may help explain the high probability of appearance of multiple industrialised civilisations during the lifetime of a planet. They grounded their premise in the fact that many stars harbour planets, and that these planets may be found in the habitable zone of those stars. They further remarked on the existing debate concerning how many times intelligence has evolved "in terms of other" (not human) species, such as dolphins, chimpanzees, octopi, and crows. Furthermore, these authors referred the constraints to the equation reviewed by Frank and Sullivan (2016), who proposed a lower limit on the probability that one or even more "technological species" have evolved in the history of the observable Universe. The discussion on the Drake Equation has been thoroughly revised elsewhere (*e.g.* Maccone, 2010; Prantzos, 2013), and it becomes extensive due to how variables may change substantially, depending on the considerations and on the type of calculus used to solve it (Schwartz, 2016). However, several variables have been underestimated, such as the still-lacking technology for detecting rocky Earth-like exoplanets (Schneider, 2017), the shield-effect and volatile-provider function portrayed by Jupiter and Saturn (Grazier 2016), the long-time known Earth axis- stabilisation effect owed to the Moon (Laskar *et al.*, 1993), and the thermostat-effect played by plate tectonics on Earth (Ward and Brownlee, 2003). In any case, an important factor that should be of interest for assessing the Drake Equation is fL, which is the fraction of a planetary lifetime graced by a technical civilisation. In one of the last appraisals of the Drake Equation, Schmidt and Frank (2018) only mentioned its parameters, but they do not explore a calculated probability or argument about fL. For the age of the Earth ~4.5×10^9 years, and to our current knowledge, only one civilisation has developed industry. This has happened extensively only for the last few decades. Therefore, the probability of fL is less than 1×10^{-8} (Maccone, 2012). Substituting this value in the original Drake Equation, and with the remaining original values that Drake proposed, the value of possible detectable civilisations would be $N = 1 \times 10^{-11}$. This value is much lower than the one originally provided by Drake (1961, 1965), thus reducing the possibility of existence of any such non-human intelligent civilisation prior to humans on Earth. However, recent models (Prantzos, 2020) suggest that some modifications into the Drake equation may help to make the Fermi paradox easier to solve, while other authors (*e.g.* Gertz, 2021)

argue it is time to reformulate Drake. In any case, and following Ward and Brownlee (2003), conditions on our planet for harbouring life are extremely unlikely, which would support the estimation made by Maccone (2012).

5. The "Shadow Biosphere" and its philosophical implications

The debate around the possible parallel evolutionary history of the origin and further evolution from organisms other than the Last Universal Common Ancestor (LUCA) has been alive since the last two decades (Benner *et al.*, 2004; Cleland and Copley, 2006). The existence of such organisms is, however, conjectural until now, as there is no ascertainable evidence for them. Regarding the hypothetical microbial descendants of an alternative origin of life constituting the "shadow biosphere" (Cleland and Copley, 2006; Cleland, 2007), there cannot exist anything but speculations. Spatially constrained, sulphur-deprived and/or extreme fluctuating thermal settings (between hot and cold) could be potential environments for searching for such kinds of organisms (Benner *et al.*, 2004). However, Cleland (2007) stated that modern technologies could not detect such (microbes) "if they existed". In a more recent work, Davies *et al.* (2009) proposed the term "weird life," umbrellaing all possible members of this shadow biosphere, emphasising that such elements may have not been discovered to date. As Davies *et al.* (2009) stressed, it would not be easy to identify " 'weird' terrestrial life for what it represents against the 'noisy' backdrop of familiar life". This further reinforces the necessary philosophical background of astrobiology since the main interests in finding signals of such a shadow biosphere might be, as for most astrobiological questions, philosophical as well as scientific in nature, ultimately aiming to answer the questions "what are we?" "where do we come from?" and "where do we go?" (*e.g.* Tamames, 2018). This is similar to the way in which Cleland and Chyba (2007) address the quest for a universal definition of "life," for they present their arguments in a logical way without postulating any of them as highly-plausible without evidence.

6. Scientific Constraints of Hypothesising a Pre-Human Civilisation on Earth

The incompleteness of the geological and the fossil record has been a known matter since long (*e.g.* Darwin, 1859; Twitchett, 2001; Lieberman, 2002; Benton, 2009), even in spite of the onset of Punctuated Equilibrium (Eldredge and Gould, 1972; Gould, 1972; Gould and Eldredge, 1977) as an alternative theory for explaining its shortcomings. In this regard, although some species can be over-represented, such as some dinosaurs, their fossil record may be disproportionally scarce (Marshall *et al.*, 2021). It has also been suggested that species which experience high rates of extinction may not be represented in the fossil record at all (Benton *et al.*, 2011, 2013; Dirzo *et al.*, 2014; Plotnick *et al.*, 2016), which significantly adds to its incompleteness.

In one of the most recent publications on the plausibility of existence of a pre-human civilisation, Schmidt and Frank (2018) state that "for all the dinosaurs that ever lived, there are only a few thousand complete specimens" (p. 143). This agrees with the statement of Marshall *et al.* (2021). Furthermore, Schmidt and Frank (2018) assume that a species "as short-lived as *Homo sapiens* might not be represented in the fossil record, at all" (p. 145). These authors give an interesting approach about the inverse relationship between sustainability and the embedment of a geological signal for humanity, and concluded that the more sustainable a civilisation is, its geological/ecological footprint is lessened. This issue has been almost universally accepted (*e.g.* Moffatt, 2000; Athira and Subha, 2013; Piciu, 2013). However, this may lead to stating—without scientific evidence—that a sustainable civilisation could have developed on Earth without leaving any signal in the geological record (Schmidt and Frank, 2018) and therefore remaining undiscovered, which implies nothing but a sophism that may confuse readers. On the contrary, we propose that such theories should only be addressed under a philosophical approach, under a plain "what-if" perspective, and not stating them as verifiable or ascertainable facts.

In addition, Schmidt and Frank (2018) widely discuss how human activity has altered stable isotopy together with radioactive patterns and products in the planet, as well as the impact of production and deposition of plastics and synthetics on the footprint during the Anthropocene. However, they clearly do not state a scientific relation between their dissertation on these topics and the possibility of existence of an industrial civilisation prior to mankind. They compare, for example, the negative $\delta^{13}C$ excursions during the onset and elapse of the Oceanic Anoxic Events (OAEs in the Jurassic–Cretaceous) and the Palaeocene-Eocene Thermal Maximum (PETM, in the Palaeocene-Eocene boundary) with phenomena occurring in the Anthropocene. They scientifically review the causes of these events in both geological prehistoric times and in the Anthropocene and draw attention to the incompleteness of the geological and the fossil record. According to them, this would be the cause for which a pre-Holocene civilisation, or its footprint, would not be fossilised. The authors, despite not being "convinced of the correctness of their proposed hypothesis" (p. 145), constantly expose arguments defending its plausibility—as it would be expected in any published manuscript, after all. Therefore, we stress on the importance of assessing this matter—just like the Shadow Biosphere—from a philosophical view.

The coevality of negative $\delta^{13}C$ excursions and events such as the OAEs and the PETM has been widely documented in the literature, as the authors remark and

provide bibliography for (Galazzo *et al.*, 2014; Mutterlose *et al.*, 2014; Naafs *et al.*, 2016). In the case of the PETM, possible sources of the $\delta^{13}C$ excursion would include volcanically-driven thermal combustion of organic-rich sediment, dissociation of seafloor methane hydrates and desiccation and oxidation of soil/sediment organics (Zachos *et al.*, 2007). For the isotopic excursions during OAEs, there is plenty of evidence to support many sources (*e.g.* Erbacher *et al.*, 2005; Li *et al.*, 2016; Zhang *et al.*, 2016); yet, none of "industrial" nature. Finally, Foster *et al*. (2018) disregarded the Silurian hypothesis, centering in several ascertainable causes for the study of hyperthermal events.

Certainly, the fact that a hypothetical future civilisation can find remnant materials from human activity on Earth such as processed metals, concrete, polymers, etc., is extremely interesting; however, it is still just an idea that undoubtedly gives rise to interesting discussions.

7. Philosophical Implications of the Quest for Pre-Human Civilisations on Earth

We are almost sure we may never be able to find any evidence of a pre-human civilisation on Earth, given the incompleteness of the geologic/fossil record, and assuming completely sustainable practices for such civilisation(s). However, we think we should avoid falling into an extreme of Popperian falsification, which would be founded on a premise like "If we cannot rule out the possibility of existence of pre-human civilisations on Earth, therefore their existence remains probable." This is an interesting exercise of thought and rhetoric, which should fall also in the terrain of logic and philosophy, not only of science. Authors like Haqq-Misra and Kopparapu (2012) conclude in a paper on the search of NTA (non-terrestrial artifacts) that the discovery of extraterrestrial technology "would certainly be one of the most significant findings in human history," and that "it would give us some certainty that life—and intelligence—has developed elsewhere" (p. 11). This is precisely the way in which we suggest such topics related to a strobiology should be addressed.

Fry (2015) emphasised on the Copernican and Darwinian points of view regarding the origin and evolution of life. According to her, the Copernican approach rejects the claim that our planet was uniquely chosen for life and considers the possible existence of biogenic conditions on other planets. This may be considered highly possible, taking into account the high number of "earth-like" exoplanets (Lineweaver and Chopra, 2012; McKay, 2014). In this regard, Covone *et al.* (2021) performed some models on the feasibility of photosynthesis on terrestrial exoplanets. However, they concluded that none of these could be comparable to Earth in terms of useful photon flux, which is needed to trigger an efficient photosynthesis. Therefore, the possibility of existence of other life forms in the Universe other than the terrestrial ones, remains speculative until we find evidence for the contrary. We could endlessly write on the important and transcendental efforts that hundreds of scientists and philosophers have performed aiming at dissertating on the origin and evolution of life on Earth, and on the existence of life on other worlds. However, as Jakosky (2000) points out, there has been little discussion on why we, as a society, are so engaged in solving this matter. He further remarks that the desire to know and understand the distribution of life in the universe may be linked to our intrinsic nature of comprehending "the nature of the world around us" (Jakosky, 2000. p. 661) as well as the interactions between us and that world. This has obvious epistemological implications. We think knowledge itself should not be only defined under an empiricist view, as this approach makes no distinction between truth and falsehood (Biggam, 2001): we rather believe that it should be approached under a more integrative (*i.e.* empiricist-rationalist-positivist) point of view, when it comes to science. As Engels (2014) pointed out, the main task of natural sciences is to study all particularities, causes and effects of every phenomenon. Complementarily, Lenin (2010) stressed the importance of discarding all "metaphysical" (*i.e.*, unverifiable) concepts within natural sciences.

In any case, science is not synonymous with possessing the truth (Pérez-Villamar, 2015). Science should thus be rather related with the constant search for truth under a critical scope as we propose the search for intelligent life elsewhere or at other times should be.

8. Palaeontology and Astrobiology under Empiricist, Rationalist and Positivist Approaches

We will discuss here some ways in which palaeontology and astrobiology, (*i.e.*, both sciences addressed in this paper), could be approached.

Major scientific theories have been posed based on strong evidence. Despite many of these theories being initially based on empiricism—at least for what we can discern—a major problem arises. In empiricist disciplines, such as palaeontology, it is difficult to assume a "natural order" or a "logic" for things. This has been a widely discussed problem since the 18th century, when incipient evolutionism entered the scene; for example, the debate between Cuvier and Lamarck on transformism vs catastrophism (Jenkins, 2016). Palaeontological evidence, assuming the absence of geological-stratigraphic alterations, means the existence of an ancient way of life at a particular time. It is almost universally accepted that, to this day, the presence of a dinosaur fossil places us in some point between the Mesozoic Era, concretely from approximately 230 to 66 mm yy ago (De Almeida-Marsola and Cardoso-Langer, 2021); the presence of Mammaliaformes (mammals and mammal-like forms), from somewhere during the

Late Triassic to the present (Luo *et al.*, 2002); and that of the hominins (human-related hominids), from about 5-7 mya to date (Harcourt-Smith, 2010). To date, this evidence supports theories which cannot assert anything other than that the aforementioned taxa existed/exist from that moment on. However, this empiricist way of thinking—which we do not criticise—can lead us to a dangerous terrain, that of "what if...".

Now, approaching the problem from a perspective beyond empiricism (*i.e.* a Cartesian/rationalist perspective), it is often asserted that the most important leap in intelligence on our planet is correlated with the increase in cranial volume in hominids (Beran *et al.*, 1999) and with the concomitant appearance of tools, beginning with the Lomekwian industry (3.3 million years ago; Harmand *et al.*, 2015) and in constant transformation since then. Even though each of these events suppose irrefutable evidence in the development of the achievement of intelligence—under an empiricist approach—it is not until a rationalist perspective is addressed that these isolated facts take shape and are constituted as a theory. However, no older evidence has been found for intelligence on our planet than the Lomekwian tool industry. This does not mean that it does not exist—as Schmidt and Frank (2018) rightly say. In turn, assuming the existence of such pre-human intelligent life does not imply a clash between rationalism and empiricism.

But this mere assumption lacks scientific arguments; that is, its epistemological basis is neither empiricist nor rationalist, since such assumption is merely that: an assumption. It is not about the presence of a feather, which could be related to flight or thermal regulation, nor is it an amniotic egg, which implies independence from the aquatic environment. It is only an assumption that, when it reaches the public, it can be interpreted under a series of conjectures without foundation. Under this perspective, it is concluded that palaeontology can be considered a science with an empiricist-rationalist approach.

For its part, in the case of Astrobiology and the fields that it comprises, something similar can be proposed. One of the branches of Astrobiology is precisely responsible for studying the possibility of intelligent life on other planets, and even the possibility of intelligent life on our own planet before our existence (Wright, 2018). However, this view could be opposed for the following reasons.

Until now, there is not a single piece of evidence that supports in a reliable and irrefutable way that there has been intelligent life on our planet, prior to the hominin lineage. Thus, there is no room for an empiricist approach to this issue, nor is there room for any rationalist explanation which could relate some phenomena or artefacts—possibly attributable to one or several intelligent civilisations prior to humanity and native to Earth—with intelligence itself. Up to now, it has not been possible to unquestionably associate such phenomena with intelligence—such as the "WOW" sound (Paris, 2017)—nor can those mentioned by Schmidt and Frank (2018) be recognised as alleged evidence of pre-human intelligent life. Finally, a positivist explanation is the least plausible to explain this type of phenomenon, since this school is based on scientific evidence (Riley, 2007; Popa *et al.*, 2015) and, therefore, should not even give rise to this type of possibilities. Our claim is clearly not about a theory which is widely accepted by the scientific community as String Theory has been since 1974 (Scherk and Schwarz, 1974), which essentially proposes that space-time has many more dimensions than we can perceive. Obviously, this would be impossible to prove both empirically and rationalistically, as well as addressing a positivist point of view (*e.g.* Dawid, 2013). However, this theory has been, for many specialists, mathematically provable since its inception. Likewise, it has been fundamental within the fields of Theoretical Physics and, specifically, Quantum Gravity (Ziaeepour, 2022). Instead, we argue that the Silurian hypothesis should perhaps be discussed under a transdisciplinary scope.

Back to String Theory, we must stress that it is not as controversial, as is Darwin's Theory of Evolution (Darwin, 1859), which is also demonstrable. The main argument of the critique against the Theory of Evolution, very similar to what happens with String Theory, is that it cannot be empirically provable and is even objectionable, arguing that it is not possible to verify how organisms have evolved (Johnson, 1991). However, in this sense, Lenski and Travisano (1995) reported the changes that occurred in 10,000 generations of bacteria after 1500 days of culture, which they named "experimental palaeontology," thus demonstrating in an empirical, rationalist and positivist manner that evolution is an unquestionable fact.

We only try to propose that any theory that is raised as scientific within a branch coming from the intersection between the physical-mathematical sciences with the chemical-biological sciences—such as astrobiology—should keep an empiricist, rationalist, or positivist perspective, since these are de facto the most followed approaches in this type of sciences. We do not aim to demerit any approach that arises within a science belonging to the aforementioned fields and that does not follow an empirical/rationalist/positivist perspective. Very interesting proposals can arise from these points of view. But, as long as there is no proof that scientifically supports these approaches, or at least while a methodology that could verify them is not proposed, they should not be classified as part of a scientific theory or hypothesis. They should simply be catalogued as ideas, or as mere approaches.

It is important to indicate that we do not intend to establish positivism as the only and absolute way to approach the study of natural sciences. Some time ago, Alam Anis (1978), as well as more recently Popa *et al.* (2015) , have emphasised the criticism of positivism in this field of science. The main claims of these

authors are that, under an "extreme" positivist perspective, experience is subjugated by the "hard" practice of science, leaving no room for other approaches.

Instead, we maintain that positivism should be impregnated with, and oriented towards, a tendency to take knowledge and contributions from different currents of science itself, as occurs in transdisciplinarity, which is the essence of the study of complex systems (Popa *et al.,* 2015). Perhaps this could be a way to address the main question of this text.

Finally, as Kerr and Gelfert (2014) state, when the "extendedness" of science is applied to scientific evidence, the premises proposed within it acquire greater relevance and credibility.

9. Technological Species, Intelligence and Industrialisation

In this section, we address three important concepts within astrobiology: technological species, intelligence, and industrialisation.

First, the "technological species" concept will be discussed. According to Stern (2016), the concept "technological species" refers to an interbreeding group of organisms depending on technology for its success. Creatures on exoplanets capable of communicating with humans must thus be technological species, in case they exist.

To date, no scientific proof of communication with humans from any other civilisation other than humans has been recorded. Recently, in order to elucidate the origin of the famous "Wow!" signal from 1977—which has been for a long time falsely considered to be a "proof" of possible alien life by many sectors of the society, a more scientific explanation was presented. Paris (2017) recently concluded that the source for such signal was a comet: the 266P/Christensen, since its spectra matched the frequency of the signal at 1420 MHz.

Another term that will be discussed is "intelligence." It can be interpreted from different perspectives in biological sciences. Intelligence has evolved relying on factors such as brain evolution, genetics and behaviour (Marino and Colvin, 2015; Marino and Merskin, 2019). On the other hand, from a social perspective, it has been defined as the "...capability to forecast change in time to do something about it" (Breakspear, 2013). This capability involves foresight and insight and is intended to identify imminent change, which may be positive or negative, thus representing opportunity or threat. Neither biological nor social approaches have been explicitly addressed by any technological-species theorist (*e.g.* Schmidt and Frank, 2018); and, according to both biological and social perspectives and to all available evidence, this phenomenon has only developed on Earth.

We would like to pinpoint a final remark regarding the definition of "industrialisation". According to some authors (Mahmood *et al.*, 2020, Franck and Galor, 2021), industrialisation implies the transition from an agriculture-based society to an industry-based one. In other words, a society that bases its economy on the transformation of raw materials into adequate products using inanimate sources of energy for satisfying the necessities of its members (*e.g.* Nightingale, 1978; Biernacki, 2001; O'Brien, 2001; Belvedere *et al.*, 2013; Liao *et al.*, 2018). An evident consequence of industrialisation is the production of waste, which inevitably goes to the environment (Izvercian and Ivascu, 2015), and is related to human (*i.e.*, "intelligent") activity (Moraru *et al.*, 2010).

Schmidt and Frank (2018) implied, for example, that some (nuclear?) "catastrophes" may have caused the fallout of hypothetical non-human synthetically produced materials. However, they do not provide evidence for such catastrophes. Natural "fission reactors" can occur naturally (Gauthier-Lafaye *et al.*, 1996; Hidaka, 2007) and certain conditions in such settings may be similar to those found in modern pressurised water reactors (Gauthier-Lafaye *et al.*, 1996). However, there is no scientific evidence for any catastrophes attributable to these natural "nuclear reactors." To our knowledge, being industrialised is a requisite for such catastrophes to happen, and ours is the only civilisation who has been capable of industrialisation. To date, there is no scientific evidence of any sort of industrial civilisation on Earth before humans, therefore we further emphasise in giving the necessary philosophical implications to one of the main questions in astrobiology.

10. Conclusion

Raising the possibility that an industrial civilisation prior to humans has dwelled on Earth might lead to unconstrained speculation and to fall into the terrains of science fiction (Schmidt and Frank, 2018; Wright, 2018). This has already happened, even in scientific resources. Hippke (2020) even suggested that such events "might have happened a long time ago" (p. 1). As expected, this conjecture has also permeated non-scientific media (*e.g.* Ancient Astronaut Archive, 2018; Whitwam, 2018). For this reason, we stress the importance of stating the philosophical implications of certain topics in astrobiology, particularly those regarding if there was an "intelligent civilisation" thriving on Earth prior to mankind, by addressing them under a rather positivist approach.

Concerning the Drake Equation, the problem seems to be that the discussion by Schmidt and Frank is not strictly focused on the implications it has for the probability of a planet to develop "intelligent" (industry-capable) life. They name many concepts in this regard, and yet their conclusion seems to be unfocused, thus generating confusion and leading to misinterpretation all along their manuscript. In fact, the Drake Equation is not but a proposal which aims to solve an important matter on our loneliness in space, as well as a possible way to address the Fermi paradox.

Papers like those from Wright (2018) and from Schmidt and Frank (2018) certainly represent an interesting exercise of thought, which opens debate on how to formulate hypotheses on this topic. However, by not giving proper emphasis upon any particular matter, or by not clearly establishing that their hypothesis is just an assumption, evident problems take place. Controversial misinterpretations may arise, and hence information on the topic is generally misconceived. This is the risk of formulating hypotheses lacking enough scientific basis, as well as of using language as an instrument of persuasion. This usually leads to postulating unclear ideas. All this can drive any member of the society (either belonging or not to the scientific community) to believe in theories without a robust and clear scientific background.

We thus reinforce our proposal of sharing certain questions and matters within the field of astrobiology to the scope of philosophy, particularly under a positivist point of view; that is, formulating theories only with ascertainable evidence. This would contribute to answering the question of Persson (2013): "Is there a place for philosophy in modern astrobiology?" (p. 29).

Of course, there is.

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