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RESEARCH ARTICLE

Where will they be: hidden implications of solutions to the Fermi paradox

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Abstract
Solutions to the Fermi paradox either deny the existence of extraterrestrials or offer alternative reasons to explain the non-occurrence of a first contact. While the latter, more optimistic approaches generally assume the existence of extraterrestrials, they simultaneously hint to limited future detectability. If solutions to the Fermi paradox are accepted as true, they must be evaluated in terms of how they affect the likelihood of success of future SETI efforts. Some solutions may lead to the so-called Fermi constraint: in order to explain why there has not been any contact so far, optimistic solutions to the Fermi paradox have to accept assumptions that, if the solution is assumed to be correct, indicate a very low probability of future contact. In other words: they are not here, and that is why they may never appear.

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Introduction

If there are other, much older civilisations in the Milky Way, and if these civilisations have engaged in interstellar space travel for a long time, where are they? This simple question, ascribed to Italian Nobel prize winner Enrico Fermi, is a rough summary of the so-called *Fermi paradox*.

Much has been written about the Fermi paradox. The most fundamental remarks are that it is neither a paradox nor originated from Fermi in the first place (Freitas, 1985; Gray 2015). Yet, Hart (1975) notably and pessimistically concluded that *them* not being here must mean that *they* do not exist. As SETI's most prominent mislabelled problem persists, several attempts have been made to explain the absence of extraterrestrials without denying their existence. We may call these approaches the *optimistic solutions*. They range from general criticism of the human search process (Freitas, 1985) to the idea that exponential expansion would not be a sustainable approach for extraterrestrial civilisations (Haqq-Misra and Baum, 2009). These and other optimistic solutions assume the general possibility of the existence of extraterrestrials and offer various reasons for why a first contact has not occurred yet.

This is opposed by the advocates of the pessimistic solution. Derived from the non-event of observation and some additional presumptions, the conclusion is that extraterrestrials do not exist

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(Hart, 1975; Tipler, 1980, 1981; Sandberg *et al*., 2018). Whether one postulates the existence of extraterrestrials or denies it, the Fermi paradox is one of the key arguments of SETI criticism. It is frequently employed to either call for a revisited search strategy or to abolish SETI altogether (Ćirković, 2013).

Hidden and future implications

There is no definitive solution to the Fermi paradox yet. However, when discussing the paradox, one fact unites the pessimists and the optimists: regardless of who will be proven correct, any solution to the Fermi paradox hints to a low or nonexistent chance for the future success of SETI.

Pessimists and optimists start from the same observation, a derivation from Hart's (1975) notorious *Fact A: There has been no contact between extraterrestrials and humanity that has been confirmed beyond doubt*. Every approach consequently offers a specific explanation *(B_{XY})* for *A*. B_{XY} for pessimists is simply that there are no extraterrestrials. If this is true and humanity is the only advanced civilisation in the galaxy, the case is clear: *A* will never change as there is nobody with whom humanity could establish contact. Due to the non-existence of extraterrestrials ($B_{\text{Non-existence}}$) *A* therefore leads to *C = There will be no contact between humanity and extraterrestrials* and $p_{\text{contact}} = 0$.

In the scenario where the optimists are right; extraterrestrials do exist, but various factors have prevented detection so far, things get a little more complicated. For optimists, B_{XY} can include a variety of reasons (Brin, 1983). These reasons can not only constitute an explanation for the non-occurrence of a first contact in retrospect but also contain limitations for establishing contact with extraterrestrials in the future. Overall, these limitations are more versatile and flexible than the one limitation given by the pessimists. If for example the failure of detection was simply a matter of employing the wrong search strategy and thus a methodological issue, the adaptation of proper methodology would significantly increase chances of future success. Nevertheless, if social, psychological, technological, or cultural factors discourage extraterrestrials from seeking contact with humanity, there is little to nothing human SETI researchers can do about it. Either way, *A* due to $B_{optimistic}$ leads to a weakened version of *C*: *C' = Future contact between extraterrestrials and humanity is very unlikely,* but may still be possible ($p_{\text{contact}} \geq 0$). Fig. 1 shows the internal structure of solutions to the Fermi paradox.

Take, for instance, the simple explanation that extraterrestrials do not want contact with humanity. This solution simultaneously limits future detectability. We can, of course, assume that the motivation of extraterrestrials may be dynamic, i.e. open for change so that they may be motivated to contact us in the future. This assumption weakens the initial claim as it cannot explain why the motivation of every extraterrestrial in the galaxy has been seemingly consistent over the past decades of human SETI efforts (cf. Hart, 1975).

This example demonstrates how any singular explanation of the Fermi paradox must be saturated in the sense that it must explain the absence of extraterrestrials for every given time period in which no first contact has happened. This means that optimistic solutions must be able to explain the failure of SETI in general as well as regarding specific periods of human SETI efforts. Therefore any solution to the Fermi paradox must first explain why extraterrestrials are not physically present on Earth, given its young age and the possibility of older civilisations on other planets (compare the reasoning of Hart (1975), Tipler (1980), and Morris (2011) on this issue). After accounting for this, any solution to the Fermi paradox must then explain why humanity has not made contact in six decades of SETI. It is evident that some optimistic solutions cannot account for both aspects on their own. When we explain the absence of extraterrestrial signals with humans employing the wrong search strategy for them, this does not logically resolve the issue of their physical absence in the past. This demonstrates that several restrictive aspects must be taken into account in order to form a solution to the Fermi paradox.

While the pessimistic solution to the Fermi paradox (they do not exist) is sufficient alone, optimistic solutions may be more versatile and may not apply to every hypothetical extraterrestrial civilisation. Conversely, one solution may explain the absence of several civilisations, for instance the consideration

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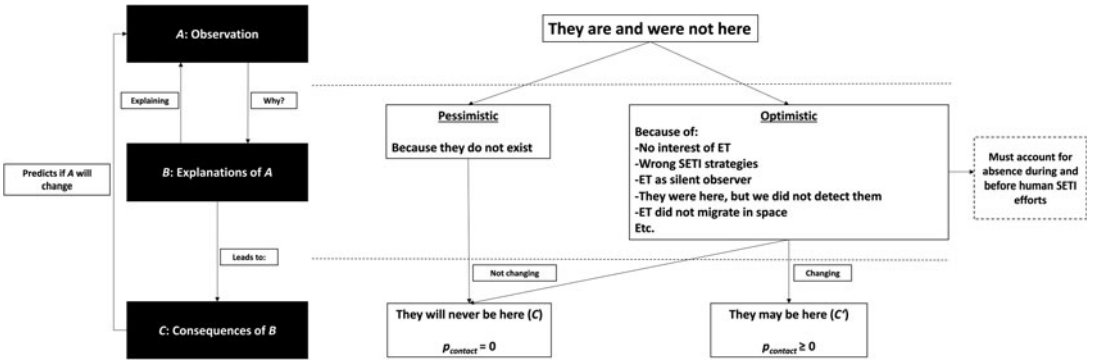

Fig. 1. *The internal structure of solutions to the Fermi paradox.*

of the effort and technological advancement needed for space travel and interstellar communication (Ashkenazi, 1995; Döbler, 2020).

Optimistic solutions assume the existence of extraterrestrials but simultaneously contain limiting factors for future detectability of the extraterrestrials in question. Therefore, solutions to the Fermi paradox without denying the existence of extraterrestrials may lead what we may call *Fermi constraint*: *In order to explain why there has not been any contact so far, optimistic solutions to the Fermi paradox have to accept assumptions that, if the solution is assumed to be correct, indicate a very low probability of future contact.* In other words: They are not here, and that is why they may never appear.

Applying the parameters of any optimistic solution to the Fermi paradox results in a prediction not all too different to those solutions that claim humanity is the only advanced species in the galaxy. Depending on how the question 'Where are they?' is answered, the chance of future contact either approximates or equals zero. The degree of this approximation depends on the parameters of the respective solution. Any solution that cites dynamic factors such as sociological and psychological ones, will have a hard time sufficiently justifying the past absence of extraterrestrials by itself. While dynamic solutions place fewer constraints on the probability of future contact than stable solutions, the latter can explain past absence more reliably, but at the same time impose greater limitations on the likelihood of success of future SETI efforts. Table 1 shows the difference between dynamic and stable solutions.

Given the myriad of solutions that assume the existence of extraterrestrials, determining the exact chance of future contact is impossible. One can, however, examine how one specific explanation may or may not impact the success probability of future SETI efforts. This task must be fulfilled with great care, sophisticated statistical models, and interdisciplinary effort and is thus beyond the scope of this paper. Yet, the explanation for the retroactive absence of extraterrestrials, 'They are not here because of B_{XY},' implies the prospective prediction: 'They may never come because of B_{XY}.'

Adjusting search strategies

Any solution to the Fermi paradox accepted to be true has consequences for the assumed likelihood of success of future SETI efforts. This is where we see the paradoxical nature of solutions to the Fermi paradox. Generally, optimistic solutions are meant to justify SETI efforts: They posit that extraterrestrials exist, even though it may be hard to contact them. But at the same time, optimistic solutions thwart the original premise because of their hidden implications. Optimistic solutions should therefore be careful not to inadvertently undermine their justification for SETI projects.

Any quantitative measure of how likely future contact depends on the specific solution. Factors beyond human control may be more restrictive than others, such as the suitability of search strategies or the suitability of technical search capabilities. In a solution where the former factors outweigh the latter, humanity is reduced to a passive observer whose capability for interstellar

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Table 1. *Dynamic and stable optimistic solutions to the Fermi paradox*

Type	Dynamic	Stable
Solution	Motivation of extraterrestrials	Long distances
	Technological development	Huge rareness of extraterrestrial civilisations
	Wrong human search strategy	Self-destruction of civilisations
P_{contact}	Reduced but may change	Very unlikely
Explanatory power of past absence	Weak	Strong

Note. Different types of solutions may be in place for different civilisations. Civilisations may be influenced by more than one solution.

contact is more in the hands of others than in ours. A wrong approach to SETI, given it is identified as such, grants humanity more capacity to act and is more permissive regarding the possibility of establishing contact on our own. Yet, it still depends on the principal motivation of the other to be contacted.

Nevertheless, certain loopholes exist. The recent SETI focus on detection by a variety of technosignatures allows for remote detection even without a deliberately sent signal (Frank *et al*., 2017; Sheikh, 2020). Other exceptions may be the explanation 'Messages or space ships are already on their way.' But generally speaking, specific optimistic solutions to the Fermi paradox require adjusting search strategies to cope with the constraints these solutions impose on the contact probability.

Conclusion

The considerations presented here are not intended to undermine the SETI enterprise. Instead, the goal is to put things into perspective and encourage an open debate about the hidden implications of different solutions to the Fermi paradox and about necessary adjustments to search strategies. Even though we do not know whether extraterrestrial life exists, how we think about it will determine how we search for it.

Furthermore, it is necessary to think about extraterrestrials as independent from human detection (Döbler, 2020; Döbler and Raab, 2021). In order to detect them remotely, their technological development must be so advanced that they can be detected with humanity's technological capabilities. But this is no inevitable consequence of their development. They may never be detectable. Either way, this would not change their ontological status as factually existing, independently of our knowledge of them.

One function of scientific theories is the explanation to explain current phenomena in the world. These explanations can be validated by trying to predict future phenomena. Once we accept a certain theory, such as one explaining the previous absence of extraterrestrials, we submit ourselves to certain beliefs and hypotheses with all their predicted consequences. The problem is that we cannot validate which solution of the Fermi paradox is true, since almost all of them more or less lead to the same prediction: They will not come.

Arthur C. Clarke once famously said, 'Two possibilities exist: either we are alone in the Universe or we are not. Both are equally terrifying.' Considering the Fermi paradox, our ability to determine which possibility we should be afraid of is constrained by the same problem: Assuming we believe to know why they are not here, would we ever know that our explanation is correct?

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