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RESEARCH ARTICLE

The social science perspective on the Fermi paradox

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Abstract
The Fermi paradox points to the apparent contradiction between the idea that the emergence of life and civilization on Earth is an objective process following the general rules of Nature and that there are no visible signs of other civilizations beyond Earth. The Fermi paradox is widely discussed in astronomical, biological and other natural sciences but almost totally ignored by social sciences, even though more than half of known explanations deal with intentions and behaviours of extraterrestrial civilizations (ETCs) or social aspects of the evolution of technological civilizations. The article analyses the problem and possible solutions to the Fermi paradox from the perspective of social sciences. In this article I argue that the Fermi paradox is primarily a social science problem, and the most plausible solutions have to contain some form of social science explanations. Three types of explanations are discussed, namely, those related to ETCs' intentions, capacities and the consequences of their decisions and activities. I argue that attempts to explain the paradox by referring to specific goals and motives of ETCs are the least plausible. Arguments related to the capacities and consequences are more solid but do not convincingly solve the paradox. I conclude that the Fermi paradox is an important problem for social sciences whether ETCs exist or not, and it should attract greater attention from social scientists.

Contents

Introduction

The Fermi paradox, which, as some authors point out, is neither a paradox nor Fermi's (Gray, 2015, but see also Costa-Leite, 2023), denotes the fact that there are no visible manifestations of the activity of technologically advanced civilizations in the observable Universe, except for our own (Webb, 2015; Ćirković, 2018). The paradox arises from the fundamental scientific idea that life on Earth, as well as the emergence of intelligent life and modern civilization, is a natural process, and is not the result of an act of divine creation or another process beyond the scope of scientific concepts. If the Earth is not the centre of the world and an exception to the laws of the universe, then the emergence of life, including intelligent life, should not be a unique event and, given the enormous size of the universe, should be repeated with some frequency.

According to contemporary estimations, the universe has existed for 13.6 billion years, and there are more than 200 billion stars in our Galaxy alone, and the total number of galaxies is at least 500 billion (Webb, 2015, 332). The latest estimates of The National Aeronautics and Space Administration (NASA), against the backdrop of a rapid increase in the number of discovered exoplanets, are optimistic about the possible existence of trillions of Earth-like planets in our Galaxy (NASA, 2023), and there can be 5×10^{22} such planets in the entire observable universe (Webb, 2015, 332). The Solar System and the Earth have existed for 4.5 billion years, which means that there were many stars of previous generations even before the formation of the Sun. Humans as intelligent species appeared about 300 thousand years ago, and the first civilizations appeared approximately 5 thousand years ago. During its existence, a human civilization evolved from the emergence of writing and the first states to a civilization capable of manipulating matter at the atomic level and successfully exploring the nearest outer space. Taking into account the difference in timescales between the existence of human civilization and the rate of its progress, on the one hand, and the age of the universe, the lifespan of planets and stars, and the duration of biological evolution, on the other, suggests that if the emergence of intelligent life is a natural process, even if it is very rare, then many other civilizations should have appeared before mankind, and, given the possible rate of progress, they should have gone into space many millions of years ago. It is reasonable to assume that over such a long period they could spread far beyond their home planet, and the signs of their existence should be noticeable. However, so far, no reliable signs of the existence of other civilizations have been identified, despite the implementation in recent decades of several programmes to search for extraterrestrial intelligence (SETI) using astronomical observation tools. This situation requires a reasonable solution, and the 'Fermi paradox' has become a shorthand for a field of research and speculation that attempts to resolve this contradiction.

To date, several dozen possible explanations for the Fermi paradox are known (Webb, 2015), and more than half of them rely on assumptions and arguments which fall into the realm of the social sciences, that is, in one way or another they deal with the behaviour of the extraterrestrial civilizations (ETCs). In light of this, the absence of any systematic discussion of the paradox within the social sciences is surprising. Most of the discussions, including those related to the social aspects of the search for ETCs and the explanation of the paradox, are currently being conducted within the framework of astronomical, astronautical and biological disciplines. Only recently some enthusiasts have attempted to establish the study of the social aspects of space activity (both human and non-human) as a separate area of research, astro- and/or exosociology (Pass, 2006; Harrison, 2011; Anton and Schetsche, 2023). However, even the analysis of the social aspects of the space activity of mankind, despite its exceptional significance, remains on the periphery of the social sciences.

In social sciences, questions related to the possible existence of ETCs remain tabooed and ignored, leading to important gaps in our understanding of life beyond Earth. In this article, I argue that, with some exceptions regarding the possible existence of ETCs, the resolution of the Fermi Paradox is principally a social science problem rather than astrophysical or biological, i.e. is somehow or other related to the social aspects of ETCs. The article attempts to review the existing and possible explanations to the Fermi paradox from the broadly defined social science perspective.

The problem with large numbers and small probabilities

One of the most obvious problems that arise when trying to scientifically discuss the problems of ETCs is the lack of a subject for comparative analysis: we only know one civilization and it seems that we simply do not have facts for any reasonable conclusions. Attempts to analyse the problem of ETCs inevitably contain a good share of speculations and assumptions, and this is true for every aspect of the problem: physical, technological, biological and social. A large number of hypothetical judgements and assumptions is one of the distinguishing features of this area of research, causing reasonable criticism. For example, Webb, commenting on one scientific paper published in the journal *Acta Astronautica*, calculated that on average, each page of a 10-page article contains about 7.5 hypothetical judgements (Webb, 2015, 206).

Despite this, the amount of empirical knowledge that can be used to study the problem of ETCs may be not as small as it seems at first glance. Although human civilization is the only one we know, it is still a civilization, existing in the Universe, and as such it provides us some information about the evolution of intelligent life. Information regarding temporal and spatial activities of human civilization, the amount of energy and technologies it operates, is an important source of reasonable assumptions underlying scenarios of ETC's possible evolution and development trajectories, underlying many solutions of the Fermi paradox. However important and useful such types of evidence, two facts directly underlying the paradox are incomparably more important. The first is the fact of our own existence, the fact of the existence of a technologically advanced, intelligent species whose representatives can understand the paradox. The second fact is the paradox itself, or rather, the absence of any clear evidence of the existence of other technologically advanced civilizations.

It is widely recognized that the Fermi paradox is all about large numbers and estimations of probabilities. On the one hand, there are large numbers that describe the enormous spatial and temporal scale of the Universe, which provide a lot of opportunities for Nature to do the same thing as with Earth. On the other, there are important arguments that the origin of intelligent life requires a combination of many independent factors. Since the beginning of the discussions on SETI and the Fermi paradox, scientists speculated about the probability of such an event by developing equations with several independent factors (da Silva, 2022). The most famous is the Drake equation[1].

Such equations, although very popular and formally logical, make little sense, mainly due to the lack of reliable estimations for several crucial parameters. However, they point to the general logic of the argumentation underlying the resolution of the Fermi paradox by concluding the uniqueness of human civilization. Most solutions associated with the conclusion that ETCs do not exist are based on the low probability of different factors, which are important for life on Earth (Ward and Brownlee, 2003)[2]. The low probabilities associated with the emergence of life on Earth, look like convincing evidence that the emergence of human civilization is indeed an extremely unlikely event. Webb himself, after reviewing 74 possible answers to the Fermi paradox, eventually formulates his own, 75th solution, which also stresses how unlikely is the combination of factors necessary for the emergence of a technological civilization (Webb, 2015, 332–337).

Webb argues that if the emergence of civilization depends on a set of independent low-probability events and a successful combination of factors, then the rules of combinatorics can come into play, which operate with a fundamentally different order of numbers so that all the billions of galaxies and trillions of planets become irrelevant. Webb suggests that to correctly describe those coincidences and combinations of factors that led to the emergence of human civilization, unthinkably large numbers, such as Graham's number, may be required, numbers that simply cannot be described in the

[1]The so-called Drake formula, often used in discussions on SETI, determines the number of communicating civilizations in a galaxy (N) as a function of seven factors:1

$$N = R \times f_{\mathrm{p}} \times n_{\mathrm{e}} \times f_{\mathrm{l}} \times f_{\mathrm{i}} \times f_{\mathrm{c}} \times L \tag{1}$$

Here, the first three terms refer to, respectively, the rate of star formation, the proportion of stars that have planets and the proportion of planets that have environments suitable for life. The next two are the proportion of such planets, where life emerged, and from them the proportion of planets on which intelligence emerged. Finally, the last two factors describe the proportion of planets on which intelligent species have created a technologically advanced civilization (f_{c}), and the period L, during which such a civilization is ready for interstellar communication. Note that the evaluation of the last two factors is the responsibility of the social sciences. Other equations follow the same logic but with different sets of parameters (da Silva, 2022).

[2]Such factors, most of which are described by Webb (2015) in the relevant scenarios, include a narrow Habitability Zone (the distance from the star that allows the planet to support liquid water); the presence of a satellite (the Moon), exactly the size that is optimal for life; the exceptional stability of planetary conditions over billions of years; the optimal number of cataclysms that promote speciation, but do not lead to the sterilization of the planet; a successful combination of chemical elements that allow life to arise; optimal geological activity; the formation of the first self-replicating molecules and cells from simple organic compounds; the emergence of eukaryotes; the emergence of intelligence and consciousness (in the human sense) only once in the entire evolution, against the backdrop of tens of billions of other species that do not have such intelligence; billions of years of evolution themselves.

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standard decimal system using all the matter in the entire universe. This, according to Webb, is the answer to Fermi's paradox: the emergence of intelligent life is just too unlikely.

My conclusion is exactly the opposite: if this argumentation is correct, then the situation is even more strange and puzzling. This argumentation reminds a wonderful essay by S. Lem, a Polish sci-fi writer and great thinker, 'On the impossibility of life', in which he pointed to the problems with the reverse computation of the probability of actually occurring events. Taking almost any event and tracing back to the previous facts and events, which made it possible, and trying to figure out the probability of these facts and events, we very soon come to such extremely low probabilities that we will have to conclude that this event just couldn't happen. It happened, however. The problem with such backward computation of probabilities of the emergence of ETCs is the same.

Let's conservatively consider planets as the only possible home for life. Let P be the total number of planets, which exist or existed in the observable universe since the Big Bang for a significant amount of time, say 1 billion years. We don't know this number, although recent astronomical progress allows us to be very optimistic about their existence. At the time I wrote this paper, NASA's catalogue included around 5.6 thousand detected exoplanets (https://exoplanets.nasa.gov/discovery/exoplanet-catalog/), and, no doubt, this number will continue to grow rapidly. NASA assumes our Galaxy can contain trillions of exoplanets, which is more than even the very optimistic accounts made by authors one or two decades ago. Extrapolating these estimations, and taking into account the number of galaxies in the universe (there are at least hundreds of billions of them), we can get a reasonable estimation of P as something around 10^{22}–10^{23}. This seems an enormous number, but, as Webb argues, if the emergence of civilizations depends on a specific combination of factors, with probabilities described by the Graham number or the like, then all these large numbers are totally irrelevant.

Further, let p_c be the probability of the emergence of technologically advanced civilization. It is determined by a number of partly or completely independent variables (a, b, c, …, n), which may refer to the number of stars in the universe, the average number of planets around the stars, the width of the habitable zone, availability of chemical substances necessary for life, probability of amino acids combining to form a protein, easiness of transforming prokaryotes to eukaryotes, stability of the environment, the existence of a moon of optimal size, optimal rate and impact of mass extinction events, environmental conditions favourable to the brain size growth, etc. – whatever we might consider as a critical step or the necessary condition for intelligent life. The question is: how probable is that

$$p_c \cong 1/P? \tag{2}$$

How probable is it that the specific combination of factors necessary for the emergence of a technologically advanced civilization has a probability, which equals, or is very close, to $1/P$, *whatever P* is? How plausible is that two independent variables described by such enormous numbers, so perfectly fit to each other? In other words: how plausible is the situation that the combination of factors necessary for the existence of civilization has probability, which allows one and only one civilization to exist – our own? As Milan Ćirković argues, even if we find another civilization and there will be two civilizations in the universe, this doesn't change the situation too much in terms of the Fermi paradox (Ćirković, 2018, 37).

I see this probability as completely implausible. If the combination of necessary factors is described by Graham numbers or other enormous numbers – when our existence is simply impossible, is it possible that all the factors proposed to be important for our existence, jointly produce probability close to $1/10^{22}$ – or any other estimate of relevant objects? This seems to be extremely implausible. Either p_c is significantly less than $1/P$, and in this case, we just couldn't exist, or this number is significantly larger, and in this case, we can reasonably suppose that other civilizations exist or existed.

Assuming that $p_c > 1/P$, there is only one solution of the Fermi Paradox, which doesn't require social science explanations. It is possible if the probability is such, that the closest ETC can emerge far enough to be beyond the maximum theoretical range of signalling potentially detectable currently

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on Earth:

$$1/P < p_c < 1/N_d \quad (3)$$

where N_d is the number of planets ever existed within discoverability radius r_d, i.e. the maximum theoretical radius of ETC discoverability from Earth. This radius shows how far ETC can be to have a theoretical possibility to send a signal detectable on Earth here and now. It depends on time, when life became in principle possible in the Universe, and the speed of light, which is the maximum known speed of communication. This variable ignores the putative duration of ETCs' life cycle, so that a technological civilization emerged 10^9 years ago on the distance 10^9 light years, is equivalent to a civilization emerged a few centuries ago at the nearest star, with the correction coefficient $t < 1$ indicating the theoretical minimum of time necessary to develop energetic and technological capacity necessary to send an omnidirectional electromagnetic signal sufficiently strong to pass through the given distance.

Formula (2) means that rareness of civilizations must be such that *under no circumstances* they *could* communicate, even indirectly, with Earth until now. For example, if the other technologically advanced civilization emerged somewhere in the Universe 1 Gyr ago, than it should be $\sim 10^9$ light years (multiplied by t) from us to solve the paradox without any references to 'social' explanations, e.g. arguments explaining why such a civilization didn't develop capacity and/or didn't decide to send electromagnetic signals manifesting its presence in the Universe. A non-sociological explanation may be due to earliness of intelligent life in the Universe (Hanson *et al*., 2021). In all other cases, including one that ETC might appear, say, with the 1 per 1 Gyr rate in our own Galaxy (da Silva, 2022), any resolution of the paradox requires explanations associated with factors related to intentions and actions of such species, and therefore are problems of the social sciences.

Social science explanations of the paradox: intentions, capabilities and consequences

From the very beginning of the discussions about ETCs and the absence of visible manifestations of their existence, one of the most common types of explanations was 'sociological' explanations. In a 1975 article in an astronomical journal, Hart suggested that if ETCs exist, then four types of explanations can be proposed to explain the fact of their absence, one of which he called 'sociological' (Hart, 1975, 129). It relates to the unwillingness (for one reason or another) of other civilizations to make contact with earthlings, lack of interest, motivation, organizational and political conditions. Likewise, 'sociological' explanations for the paradox have been regularly invoked in other publications, the vast majority of which are published on astronomical or astrobiological outlets. More than half of the solutions described by Webb in his book are sociological or, broadly, social science arguments. It is noteworthy that sociological explanations for such a large and challenging problem are discussed by anyone, but not by social scientists. Recent attempts of developing astro- and exosociology (Pass, 2006; Harrison, 2011; Anton and Schetsche, 2023) remain marginalized in the social sciences.

The explanation of the Fermi paradox from the point of view of broadly understood social sciences can be approached from at least three different perspectives: from the point of view of the content of motivation, goals and intentions of ETCs; from the point of view of the social structures that underlie the ability of ETCs to operate in the Cosmos, ensuring its presence and manifestations on a significant scale; from the point of view of the consequences of ETCs' actions, activities or internal characteristics.

Social science explanations: goals and motivations

Reconstructing human intentions is one of the most challenging tasks for social sciences, and dealing with the intentions of aliens should be much more problematic. Yet, explanations based on the attribution of certain motives (stable dispositions), goals (specific future conditions achieved by actions) or intentions (readiness for such an action) to ETCs resulting in the absence of their visible

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manifestations, are widespread in the discussions on the Fermi paradox. Webb and other authors give many specific explanations of this kind (Webb, 2015). Perhaps they live a contemplative lifestyle and are not interested in space exploration. Perhaps they are too advanced and we are not interesting for them. Perhaps they are afraid of attracting attention from aggressive races. Perhaps they do not want to interfere in the development of primitive societies and therefore make sure that we do not notice them. Perhaps they have too alien ideas, motives and interests that manifest themselves in actions that we simply cannot recognize. Perhaps they are listening to the signals, but not sending them because it is too expensive. And so on.

For the most part, such explanations are a kind of 'folk sociology' and are an example of naive anthropomorphism. But the problem is not that such explanations extrapolate possible human motives to the entire universe. On the contrary, the problem is that such explanations *de facto* exclude the only kind of empirical evidence available to us as a reference point, deliberately abandoning the scientific method. If we look at the problem of ETCs from the point of view of motivation and intentional action, then the main conclusion from human experience available to us is the irreducible and significant variety of goals and motives, and even more importantly, the variety of strategies and modes of action arising from contextual differences even when the motives are similar. All of the above-mentioned types of explanations take one of the possible motives that could underlie human behaviour, and in some incomprehensible way extrapolate it to all possible intelligent species at all periods of the existence of the universe. The fantastic implausibility of such an assumption of the universal uniformity of the motivation of all ETCs is quite obvious and was noted even by authors who do not belong to the social sciences.

The diversity of motives and goals, both between and within civilizations, associated with differences in knowledge, available resources and other factors, is one of few assumptions regarding ETCs, about which we can be reasonably sure. This means that if there were many ETCs in the universe, then *at least* some of them would be sufficiently active and motivated to space exploration, communication and/or colonization. However, there are aspects of the motivation problem that seem more relevant to the explanation of the Fermi paradox. These are the problem of coordination and the problem of stability of motives and goals.

The problem of coordination arises as a consequence of the existence of many individual actors with their own goals and motives (let's conservatively assume that ETCs' social organization is based on many interacting individuals). In case an action can be performed by an individual actor, the diversity of motives in a population practically guarantees that some possible action will be performed by at least someone. However, if an individual actor cannot perform such an action (e.g. send a signal into space), then its implementation requires coordination of the motives of many actors. Complex tasks and endeavours may require coordination of the efforts of the majority of the entire population.

The second problem is related to the stability of motivation. Space exploration and the implementation of complex projects aimed at communication with other civilizations, colonization, the creation of large astroengineering structures, etc., require not only an appropriate motive and purpose but also the readiness and persistence to pursue them for a long time, probably significantly exceeding the individual lifespan. Taking into account the huge periods necessary for interstellar travel and communication, the stability of motivation seems to be a particularly important condition for the possibility of detecting ETCs or their technosignatures.

In both cases, the problem of motivation is closely related to the second type of sociological explanation – the possibilities of civilization. The desire to participate in space exploration and communication with other civilizations has no practical meaning without real opportunities to do so.

Social science explanations: capacity

Discussions about the Fermi paradox primarily focus on the material aspects of the ETCs' capabilities and resources which are important for interstellar travel or other large-scale activity. These are communication technologies, space flights (from engines to life support systems), energy, geoengineering, etc.

The technological level of civilization is not only a necessary condition for space exploration, colonization or interstellar communications, but it also determines the list of possible technosignatures – manifestations of technological activity that indicate the existence of a highly developed civilization (Pass, 2019; Romanovskaya, 2022). The presence of technosignatures is an important aspect of the problem since they potentially make it possible to detect traces of the existence of civilizations from a distance and regardless of their motivation. Modern human civilization, by the very fact of its daily functioning, creates such technosignatures in the form of specific electromagnetic radiation, traces of substances that are not found in Nature, spacecraft and large-scale artificial structures on the surface of the planet[3]. Several researchers classify hypothetical ETCs according to the level of technology, consumption and sources of energy (da Silva, 2022). For example, the well-known classification of Kardashev distinguishes three types of space civilizations, depending on what scale of energy they can operate with the energy of their planet, the energy of their star and the energy of their galaxy[4]. Some authors expand this classification with additional, even higher levels (Ćirković, 2015). The meaning of such hypothetical classifications is that higher levels of technological development should manifest themselves in technosignatures which are themselves signs of a space civilization and do not require reconstruction of ETCs' motives.

From the social science perspective, the content and level of technologies necessary for space activity as well as their feasibility, are of little importance. What matters is a much more important and usually ignored or only superficially mentioned question about the social structures that support such technologies, their emergence, development, dissemination and practical use. First of all, a technologically advanced society requires structures supporting the creation, accumulation and application of objective knowledge, that is, science, as well as its systematic conversation into technologies, i.e. an innovation economy. Science as a social institution is not limited to individual cognitive activity, rationality or the development of specific methods. It requires several social conditions: specific roles and organizations, including those necessary for the transfer of accumulated knowledge to new generations, scientific ethos and the readiness of the whole society to allocate resources for research (Merton, 1972). Some explanations of the Fermi paradox point to the fact that science as a special social institution is not a universal attribute of human societies, and in its modern form appeared relatively recently (Webb, 2015, 319–321). The same can be said about the innovation economy based on the introduction of new scientific knowledge into production technologies. The corresponding social organization began to take shape in full scale only in the second half of the 20th century, with the rise of postindustrial society (Bell, 1973), and the development of science and technology was relatively independent of each other until recently (Weingart, 1978).

The use of such arguments to explain the Fermi paradox is not very convincing. Even recognizing that the emergence of specific forms of social organization requires a combination of relatively independent factors, as was suggested by M. Weber regarding the emergence of modern Western capitalism (Weber, 2001), it is impossible to deny the fact of technological progress that accompanied the development of human civilization, across societies and historical periods. There are good reasons to

[3]A few examples of human technosignatures worth mentioning. Even ancient civilizations had a fundamental opportunity for limited interplanetary communication. Megalithic constructions such as Egyptian pyramids can be seen from other planets in the Solar System (with our current technologies), so they could be used to send information (see Note 5). The presence of human civilization in the form of radio signals is even more impressive and the first TV signals are more 80 hundred light years from the Sun, although as very weak radio waves. Human artefacts are present or have visited several space bodies (Moon, Mars, Venus, asteroids, etc.) as well as different points in the Solar System. Of special importance is the fact that formally, human civilization is already an interstellar civilization. Two space missions, Voyager 1 and Voyager 2, sent by NASA more than 45 years ago, are currently beyond the heliopause (119 a.u.), which is the outer limit of the Solar System, and reached (as of August 2023) the distance of 160.8 a.u. and 134.1 a.u. from the Sun, respectively, still sending signals (https://voyager.jpl.nasa.gov/mission/status).

[4]Currently, human civilization consumed 439 EJ in 2021 (IEA, 2022, 281), and is classified as type 0.8, i.e. slightly below the type I civilization, which can consume all the energy available at the home planet (Ćirković, 2015, 12).

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suppose that intelligent life, organized as social and political communities, will, sooner or later, invent science or any other core institution necessary for rapid technological development[5].

More importantly, even if the emergence of experimental science requires a combination of different conditions and therefore contains an element of historical chance, its reproduction and adaptation in various social, political and cultural systems turns out to be a much simpler task. Although there are important differences in the ability of societies to support research and innovation, to some extent any society with a minimally efficient economy can maintain institutions of science and innovation. It is also significant that different types of cultures and political systems can maintain a high level of scientific and innovative development. The Soviet Union and the USA differed significantly in the form of political organization, but they were equally successful at the initial stage of space exploration, including efforts in SETI. Now countries like USA and Japan, Sweden and Israel, the UK and Germany, South Korea and China are equally successful in science and innovation, even though they are very different in terms of national culture, as can be seen from any large comparative project in the study of cultures (e.g. Hofstede *et al*., 2010).

Experimental science and innovative economics are not the only components of the social conditions necessary for space activities. At least in the initial stages of development, space exploration seems to require a large concentration of resources and effort. Managing them is a complex task in its own right, requiring not only the political commitment to allocate these resources but also the organizational structures that can ensure the implementation of large-scale projects. In terms of institutional development, what matters for space exploration is not simply the emergence of science but the emergence of Big Science (de Solla Price, 1963).

In human history, space exploration has become and remains one of the areas that stimulate the development of unique organizational and managerial models, particularly project management. Contemporary project management, as a system of purposeful actions and standardized tools, began to develop in the second half of the 20th century (Kwak, 2005; Garel, 2013). The Apollo project was one of the first examples of scientifically based project management, contributing to establishing it as a new field of management science.

The development of contemporary project management was largely due to Second World War and the subsequent Cold War; the majority of the first large projects (the Manhattan Project, Polaris, Apollo) were driven, in one way or another, by geopolitical conflicts. This leads to the question: Does the development of organizational mechanisms supporting complex projects of space exploration require specific political conditions, namely conflicts between large political structures, which can accumulate significant resources and are motivated to use them in space exploration?

In human history, political conflicts, particularly wars, are recognized as an important factor in both technological and institutional development (Lee, 2016; Turchin *et al*., 2022). In a more general sense, conflicts between states are a manifestation of the role of intergroup conflicts as a factor in the evolution of human sociality (Van Hoof, 1990; Shkurko, 2021). The importance of such conflicts in complex projects can be explained by two main mechanisms. First, the political conflict, that is, the conflict between large political entities, ensures the concentration of efforts and resources necessary for the implementation of large-scale projects. Second, the political conflict provides the conditions for the stability of motivation that surpasses the private and short-term motives and interests of individuals

[5]Actually, even institutionalized science and high-tech projects are not necessary for interplanetary communication. Consider a hypothetical example of a civilization, which has no advanced science but has political control over significant territory and resources. If it is stable and exists for a long period of time, it can create megalithic construction visible from the space. Moreover, it can arrange its economic activities, for example by coordinating agriculture on a large scale, for subtle manipulation with albedo or the chemical composition of the atmosphere. Purposeful arrangements of such macro-level effects for decades, centuries or even millions of years can function as at least a one-way communication device, which requires only a relatively simple scientific knowledge and no advanced technologies. Adding elementary optical astronomical tools provides a solution for a two-way communication, at least interplanetary. This example shows that the social organization is more important for space communication than technological development, and that the Drake's *L* factor is probably a much larger than its conventional estimations (e.g. slightly more than 1 hundred years for Earth).

and groups, thus creating opportunities for the maintenance of selected goals related to the conflict. In other words, if a society perceives its life through the prism of actual or potential conflict with other/other societies, this contributes to the allocation of resources on a systematic basis, as well as the creation of innovations that promise to preserve and/or win such conflict. If a project has value, real or imagined, in terms of strengthening a society's position in a political conflict, it may receive support, otherwise, resources may be allocated to other purposes.

From a conflict perspective, space exploration must be supported by political conflicts, both in terms of motivation (because space provides new opportunities and is a new arena for political confrontation) and in terms of creating specific tools. At a larger scale, this perspective corresponds to the discussion of 'grabby civilizations', which should be rapidly expanding in the Universe (Hanson *et al*., 2021; Friederich and Wenmackers, 2023). Explaining the Fermi paradox from this perspective (if ETCs exist) is difficult and can be due to one of two reasons: either ETCs are exceptionally peaceful, and the basis of their social organization does not include intergroup conflicts or is not even based on group relations at all, or their social organization does not allow the emergence of large political formations capable of accumulating the number of resources necessary for the implementation of large projects. Both options are of theoretical interest, but the idea that any of them can be a general, universal rule seems implausible.

The fact that political conflicts are important for technological development on Earth doesn't itself mean it is *the only* social factor supporting large projects. Cooperation was as important as competition in the evolution of humans, and cooperation between groups can be necessary to achieve common goals. International cooperation in human civilization takes place and can support the coordination and implementation of large-scale efforts in areas of common interests, such as scientific research (e.g. human genome project, many space projects), climate change and other issues. There are many social and cognitive mechanisms that help to mitigate the effects of intergroup conflict, from survival needs and other common interests to the complexity of group affiliations or identity policy and management.

Irrespective of the evolutionary and social basis of intergroup relations, the interrelated problems of goals' stability and accessibility of opportunities remain a potential barrier when it comes to projects with an extremely long implementation period, significantly exceeding the time horizon of the practical motives of individuals. Projects related to the exploration of deep space, interstellar communication and space colonization require planning for hundreds and thousands of years. On Earth, biological evolution relies primarily on immediate rewards that secure certain ways of acting. One of the main differences and competitive advantages of humans as a biological species is associated with the ability to focus on delayed rewards. Any complex activities (e.g. training or work) and social organizations depend on delayed gratification. However, time discounting restricts the effectiveness of regulating behaviour via delayed rewards. If the reward extends beyond the lifetime of the individual, maintaining his regulatory function becomes a difficult task. In turn, institutional conditions also have a certain time horizon for effective planning. In modern societies, it does not exceed several decades. Moreover, some features of the institutional organization of the most technologically advanced societies significantly shorten the possible planning horizon, particularly the duration of electoral cycles and political competition, which contribute to a focus on quick results and, consequently, short time horizons. In non-competitive political systems, institutional conditions for long-term planning are more favourable, but such systems seem to be less innovative, less efficient, do not benefit from intellectual diversity and are more dependent on the individual predispositions of leaders.

The social conditions for the implementation of large and long-term projects required for space exploration can be an insurmountable barrier when it comes to projects that require an exceptionally high level of coordination, a very large amount of resources and a very long implementation time. However, the experience of human civilization shows that with economic and technological development, the feasibility of projects increases and they become more accessible to smaller groups and associations. In a socially and politically heterogeneous population, this creates opportunities for at least some of these groups to start projects in space exploration. The nature of the political and cultural

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organization of society, therefore, should indeed be considered as a possible source of barriers to space activities, but the possibility that they impose universal institutional restrictions on space exploration does not seem very plausible.

Social science explanations: consequences

One of the most important achievements in sociological theory, associated with the functional approach and particularly Merton, was the idea that to explain social phenomena, what matters are not so much the motives and intentions of human actions, but their objective consequences, including unforeseen, unintended ones (Merton, 1968). Attention to the consequences may be a more promising strategy in the sociological explanation of the Fermi paradox than attempts to assess ETCs' motives and capacities.

Pessimistic assumptions that ETCs at a certain stage perform actions that lead to self-destruction are common in the explanations of the Fermi paradox. Specific mechanisms may vary: environmental degradation, mutual destruction in wars, pandemics, etc. (Casti, 2011; Webb, 2015; Schleicher and Bovino, 2023). All of these options describe the consequences of certain actions, usually unintended. The experience of human history shows that any of these options looks quite possible. However, the question is whether such possibilities form a universal rule, that is, a necessity.

The L variable in the Drake equation contains an implicit assumption about the finiteness of the ETC lifetime, an assumption which, strictly speaking, is by no means self-evident. Even though political and cultural communities (often called 'civilizations') arose and died in the history of mankind, the idea of some natural 'life cycle' looks like nothing more than a poetic metaphor. Such 'civilizations' never were completely isolated, and their 'dying' was accompanied by many processes ensuring their connection and continuity with the entire history of mankind (migration, cultural influence, the emergence of new political entities, etc.). The fact is that the history of human civilization shows the absence of any 'life cycle' of humanity as such.

An alternative version of this argument refers to the finite life span of biological species, resulting in the conclusion that humans as a biological species, has a finite life span as well (da Silva, 2022). However, such an argument is also highly problematic. The transition to the cultural stage and technological development leads to a weakening of the biological factors that determine the limited life span of species. Social organization, science and technology provide enough opportunities to overcome the effects of typical biological factors of extinction of species, associated primarily with changes in the ecosystem, and to control the further biological evolution, from effective medicine to a transition to a postbiological stage. The explanation of the finiteness of the life cycle of the civilization of intelligent beings therefore cannot be based on the biological analogies of the 'life cycle'.

Also, eschatological explanations of the Fermi paradox cannot rely on external influences as a universal mechanism. As da Silva (2022) correctly points out, it is unlikely that cataclysms on a planetary and cosmic scale that can lead to the sterilization of the planet or the destruction of civilization (falling asteroids, burning out a star, supernova explosion, gamma-ray bursts, etc.) will regularly occur precisely in that short period in which civilization is at the stage of technological development; it is more likely that they will destroy life as such before the appearance of intelligence. But at some level of technological development, most of these cataclysms will not pose an existential threat to civilization, since it will be able to find ways to protect itself or, at least, to manifest their presence to future civilizations.

That's why, if there is a universal mechanism underlying civilizations' destruction, it should rather be endogenous (da Silva, 2022). da Silva (2022) recently proposed a 'closed bottleneck' solution to the problem, by arguing that in the course of civilization evolution, there is a bottleneck, which prevents technologically advanced societies (like ours) from going to the next stage of evolution and transition to the 'adult civilization', which can successfully solve major developmental problems. The bottleneck is related to the inability of a technologically advanced civilization to find a sustainable strategy of development, i.e. to maintain the balance between technological and ethical development. The author doesn't clearly explain the nature of 'ethical development' but mentions the inability to deal with the growing complexity of a technological society as a universal barrier preventing the transition through the bottleneck due to extremely high vulnerability to internal or external shocks. But actually, the main argument supporting this view is the Fermi paradox itself, i.e. the author deduces the danger of the bottleneck situation directly from the fact that we don't see any examples of a successful transition to the next stage.

From the social science perspective, the argument looks poorly elaborated (actually, it wouldn't be taken seriously in a social science journal) and is not very convincing, even if to set aside the vagueness of concepts and the formal description of relations between technological and 'ethical' development. Imbalances in the development of various components of social systems, as well as between society and the environment, accompany the entire history of mankind and at all levels: individuals, groups, organizations, institutions and societies. In Marx's theory, internal imbalances between the level of development of technology (productive forces) and the system of social relations and institutions were considered the main source of social development. The postulates of early systems theories that a social system should be stable and based on stable institutions were rejected not only by alternative sociological paradigms, such as structuralism or constructivism but also by functional analysis itself (Merton, 1968), as well as the idea that the unintended consequences of human actions and institutions are necessarily dysfunctional (Merton, 1968).

In turn, the growth of complexity does not necessarily create critical vulnerabilities for the social system. The notion that extremely complex systems cannot be managed can only be true as long as 'management' refers to traditional hierarchical models based on rigid procedures. However, our current understanding of governance is more complex and allows alternative ways of solving management and administration problems. If we talk about ways of managing the development of the entire human civilization, then the idea of the 'Global Government' turned out to be untenable. This, however, does not mean that the alternative is chaos and anarchy, eventually leading to disaster. Since the 1990s, the concept of global governance has been widely discussed in political science, suggesting that the management of highly complex and heterogeneous social systems can be based on a network of related, but relatively independent mechanisms that connect different actors and different levels of the system, mainly based on 'soft' and flexible, consensus-based methods (Dingwerth and Pattberg, 2006; Weiss, 2013; Zürn, 2018). More importantly, elements of such approaches were put into practice concerning various global problems and various areas of international activity, from climate change to international cooperation in the Arctic. If da Silva's thesis is correct, this means that such management models cannot be effective, but so far there is no clear evidence that their inefficiency is inevitable.

Nevertheless, the idea of a 'bottleneck' in the development of civilizations is of interest and value. Even the time estimations given by da Silva (the time required for the transition to a 'mature' civilization), which have the order of 10^2–10^3 years, look plausible, taking into account the pace of technological development of modern human society. However, it may be based on somewhat different mechanisms related to the capacities available to society and the consequences of their use.

The lower limit of the 'bottleneck' is determined by the level of development at which technological and, more importantly, social (political, institutional and organizational) capabilities can produce effects that are destructive for the entire civilization. Such conditions arise, for example, after the invention of weapons of mass destruction, not simply when they are invented, but when institutions and decision-making systems ensure their manufacturing and the conditions for using them. On Earth, this point was reached in the early 1960s, rather in the mid-1940s. Another possibility is the development of complex and dangerous technologies (e.g. nuclear power plants, geoengineering projects, self-replicating systems) with personnel training, funding regimes or control mechanisms that do not guarantee their safe operation. Finally, such conditions may arise when there are a large number of independent producers of technologies and products, the total effect of which on the economy, Nature and society can be destructive, but which cannot be foreseen, assessed and/or controlled. As long as society operates on a small scale, unforeseen consequences of their use can lead to local crises, as was the case regularly in the history of mankind (destruction of ecosystems, imbalances in the economies), but not to the destruction of human civilization as such. However, at some level of development, the forces in which humanity operates are capable of destroying civilization on a global scale.

The upper limit of the 'bottleneck' can reasonably be associated with the stage when a civilization creates first sustainable and self-sufficient colonies in space (e.g. on other planets of its system). In this case, the risks associated with the inability to manage the consequences of the use of available forces and energy, as in the early stages of civilization, will likely be localized again, and the very distances between the colonies will become a natural barrier to the catastrophe going beyond the boundaries of one colony. At this stage, the loss of the social, cultural and political homogeneity of civilization, its diversification and the growth of heterogeneity become probable, but from the point of view of space exploration, this only increases the stability of civilization.

Within this 'bottleneck', the risks are real, even if they result not in the destruction of civilization, but only in its degradation to the lowest levels of development, in terms of the scale of resources used. Managing complexity can indeed be a major barrier to overcoming this bottleneck. However, it may not be related to the complexity of the social system as such. The growing complexity of society is accompanied by the progress in control tools, both in a purely technological sense (from the first cybernetic systems to modern environmental monitoring systems based on the Internet of Things, artificial intelligence systems, etc.), in an intellectual sense (the emergence of scientific management, the development of operations research, modern project and risk management, etc.) and institutional sense (formation of advanced models of political governance, both democratic and authoritarian, regional regimes of international relations, international organizations and concepts of global governance). As Beniger (1986) argued, the development of modern society was possible thanks to the 'revolution of control', that is, the development of ways of rational and formalized processing of information at various levels. Information technologies are only the tip of the iceberg, and the origins of the revolution are at the end of the 19th century and are associated with the processes of development of formal rationality and bureaucratic management systems that are well known to sociologists (Weber, 1978).

At the same time, the very development of such control systems creates consequences that may lead to an increase in the complexity of controlled systems at a faster pace than the progress of control systems themselves. The creation of new management systems, for example, in project management, or based on artificial intelligence (AI), makes it possible to develop a fast-growing number of new products and organizational systems, to implement more complex and large-scale projects than was previously possible. Their implementation and use, in turn, create qualitative changes in the social system as a whole. A multitude of independent actors capable of accumulating and managing increasing resources create effects whose cumulative impact is unforeseen and requires the creation of new control mechanisms post factum, as happened, for example, in response to the COVID pandemic or in attempts to create rules for regulating AI *after* its actual entry into the mass market.

Thus, the threat to ETCs can indeed be associated with development gaps, but rather between control mechanisms and the consequences of their use than between technologies and ethical structures. Such a gap may be universal if we accept the assumption of a civilization's social heterogeneity (diversity of preferences, motives and goals), political heterogeneity (the presence of various actors or social systems capable of accumulating resources and making decisions that have a large-scale impact on society) and bounded rationality (the absence of complete information about the conditions and consequences of actions). At the 'bottleneck' stage, such a gap can lead to unforeseen consequences of actions or decisions, which can be destructive to civilization.

At the same time, the assertion that such a possibility is inevitable does not yet have reliable grounds, and the only fact in its favour is the apparent absence of other technologically advanced civilizations. This fact is contradicted by another fact, namely the existence of such a civilization on Earth, the fact of its ongoing development and the beginning of a new stage in space exploration, the fact of a minimal ability to respond to emerging global problems and find solutions to them, even if these solutions are far from perfect. Equally important is that the unforeseen consequences do not necessarily mean that they are harmful to survival and development. One key idea of the functional approach in sociology, mentioned above, is that unintended consequences can be functional for the social system and often lead to sustainable solutions. Social sciences show that the conditions for the maintenance and development of social systems are often the unforeseen consequences of actions, including actions taken by selfish, stupid and aggressive people. Therefore, even the 'consequences' approaches doesn't convincingly resolve the Fermi paradox, which remains an exceptional intellectual challenge for the social sciences.

Conclusion

The apparent absence of intelligent life in the universe beyond the Earth is a scientific problem for the social sciences regardless of the 'objective' state of affairs. If the emergence of intelligent life is a fairly regular and natural process, and civilizations arise regularly, then there must be reasons why their activity remains invisible to us. A multitude of civilizations means a great variety of motives, goals, opportunities and strategies, and if there are technological civilizations, evolving for thousands and millions of years, we can reasonably expect that at least some of them will be able and willing to be active in space, look for other worlds, create structures of astronomical scale and participate in interstellar communications. And since we are talking about actions, the social sciences must explain what could be the universal reasons preventing such activity in space.

If intelligent life, reaching a high level of technological development, arises, but is extremely rare and far from us, the Fermi paradox remains a social science problem. Even if their occurrence is extremely rare, millions of years of their evolution allow us to expect that they will somehow manifest themselves, probably even in other galaxies. Their awareness of the exceptional rarity of intelligence would perhaps be a strong motive for promoting space exploration and signalling their presence. If they are rare this probably should foster them to support life beyond their own home, to establish colonies and propagate, to manifest their presence and to do their best to find someone else. Thus, civilization has to be active in space. Otherwise, there must be reasons why such civilizations have a limited lifespan or cannot move to the scale of space activities that make their presence visible at distances of millions of light years. Even if ETCs are *extremely* rare and we just hadn't sufficient time to meet them, as several solutions conclude (Haqq-Misra and Baum, 2009; da Silva, 2022), the Fermi paradox is relevant to the social sciences as it requires understanding how they can evolve in extremely long time perspective.

If humanity is the only intelligent species in the universe, at least in the observable universe, even in this case the Fermi paradox has implications for the social sciences. Because it allows and requires an inversion of the situation and evaluates it from the point of view of a hypothetical observer located somewhere far from the Earth: if another intelligent life appears somewhere in the galaxy or the observable universe, will it face the Fermi paradox – within a time perspective of thousands, millions, billions, ten billion years? Would this hypothetical observer see an empty universe? If the Earth is unique, the Fermi paradox is transformed into a question about the future of mankind – a future that goes far beyond the standard forecasting horizon in the social sciences. It is obvious that at present the social sciences are completely unprepared to analyse social processes in such a time perspective, neither conceptually, nor methodologically, nor intellectually.

To date, social sciences cannot provide any universal solution to the Fermi paradox. There are several putative mechanism, related to motivations, capacity building and unintended consequences, which can reduce the probability of ETCs' visibility and presence in observable universe. None of them however seems to be as an inevitable barrier for their presence in the universe. The most plausible explanation is that ETCs are actually rare enough to make these barriers reduce their activity to the level, which make them invisible for us. However, this solution can only be temporary. This means that in the long-term perspective, some ETCs will finally pass these barriers and manifest themselves in space.

There is another option. Perhaps in the foreseeable future, there will be some kind of drastic change in our awareness and understanding of the universe, and we will encounter manifestations of extraterrestrial intelligence directly. It may turn out that intelligence is widespread in the universe and we just missed it somehow. In this case, the Fermi will generally lose its relevance, and the social sciences will face a new challenge – studying and explaining many civilizations in the universe. However, even in this case it will remain a problem, posing a question: Why we hadn't seen them before? And this question will remain to be primarily a social science problem.

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