

**THE GREAT SILENCE: SCIENCE AND PHILOSOPHY
OF FERMI'S PARADOX**

by Milan M. Ćirković,
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SUMMARY: A review of Milan M. Ćirković's book "The Great Silence: Science and Philosophy of Fermi's Paradox", is given. Proceeding from a consideration of desiderata a competent author of such a demanding endeavor should meet in order for his effort to be successful, the contents of the book is next presented in some detail, while paying special attention to the astrophysical, astrobiological and philosophical foundations of the discourse. A proposed taxonomy of the hypotheses for resolving the paradox and the subsequent rating of the hypotheses in terms of the criteria employed by the author are briefly discussed, and the conclusions regarding SETI practices and future-of-humanity studies are commented. Some observations and minor remarks are eventually offered, which, we believe, may be useful to the author in his future work.

That writing of a book such as Milan M. Ćirković's "Great Silence" makes sense, the author must possess several rare qualities. *Conditio sine qua non* is mastering fully the knowledge of the nascent science of astrobiology and of its sub-field dealing with the Search for Extra-Terrestrial Intelligence (SETI) - from a comprehensive view of the topic in its entirety, down to the tiniest, yet sometimes crucial, details. Equally necessary is the ability to efficiently synthesize the vast corpus of available information in order to classify and critically compare plethora of the diverse and often diverging ideas, opinions and results. Deep comprehension is required of many scientific, philosophical, social and cultural facets of the perennial problem this book is devoted to, and, last but not the least, a considerable literary skill to present all that in an interesting and understandable, yet scientifically rigorous, manner to even a layman reader. Judging from the result, our present author has them all.

Although Ćirković's book is basically on the Fermi's paradox, or more precisely on the attempts to answer the great scientist's legendary question "Where is everybody?", it is, unlike some recently published endeavors, much more than a leisure-time intellectual entertainment. It touches upon many fundamental issues and examines numerous related threads of this monumental, multidimensional problem, striving to place it in the context of a proper scientific discourse.

THE BOOK

Already in the Introductory Note Ćirković readily sets the scene: starting from a cursory introduction of the perennial problem of man's uniqueness in the Universe, in a few simple, precise sentences he states the motivation to write the book, goals to ac-

hieve, his understanding and interpretation of the different notions and concepts involved, as well as hints of his personal credo on the considered matters. Ćirković boldly claims that 'the absence of extraterrestrial life and its manifestations from our vicinity in both space and time' is 'one of the deepest, subtlest, and most persistent challenges in the history of science' that still remains 'completely and irritatingly unsolved' in spite of the considerable effort put into its study. He, therefore, feels a 'profound dissatisfaction' at the fact that Fermi's paradox is not taken seriously enough, in particular in view of its becoming only more serious after the recent advances in understanding the distribution of the Milky Way planets' ages and Earth's place in relation to the timescales involved.

Of particular interest in this respect is Ćirković's effort to situate the problem in a wider context: he discusses the very notion and the role of paradoxes and thought experiments in science, pointing out their usefulness and high relevance especially at the present stage when we are still lacking the general astrobiological/SETI theory. He urges for more theoretical work, emphasizing the need for an improved 'organization of our ignorance' in the form of a taxonomic scheme of the variety of hypotheses proposed to resolve the puzzle, in order to 'introduce some order into that chaos' and to reveal the directions in which to search for the solution. He, however, points out that the scheme presented in the book is just one of the many possibilities, but that it is also of 'paramount importance that we embark on this journey in the first place'.

Ćirković admits a 'moderate pro-SETI bias', powered by his optimism regarding the existence of extraterrestrial intelligence, hence of the viable SETI targets, but warns that communication with these targets might prove to be difficult even to conceptualize, not to speak of obstacles for a meaningful dialogue to be established. In the same context he draws reader's attention to an interesting issue, that of the value - material, intellectual, or spiritual, positive or negative - generated by such communication, and offers in this respect in the Endnotes his reading of the famous Polish writer Stanislaw Lem's seminal novels tackling this theme in a subtle, but profound manner. Even if not in so much detail as in several other articles and books of his, Ćirković critically reviews the actual SETI methods employed since the beginning of the SETI era, but nevertheless argues that 'empirical SETI should proceed, expand and incorporate alternative methods and approaches', considering its heuristic role in reduction of the parameter space for the search and in focusing of the endeavor to 'those regions of the astrobiological landscape which hold all trajectories leading to intelligent observers compatible with all the evidence'.

Final pages of the Introductory Note Ćirković devotes to presenting his approach and methodology used in writing the book, to a brief description of the plan of exposition and to some technical details facilitating the reading and understanding of the text. In addition he offers a few sharp observations about the available literature and the reliability of general sources of information about

Fermi's paradox. Concluding the chapter he extricates three publications he considers a recommended introductory reading, and emphasizes the principal differences and upgrades of his book with respect to each of these: a much-needed update of the David Brin's (1983) review motivated by the appearance of many new hypotheses published in the meantime and by the recent advent of astrobiological revolution, his consideration of the 'wider astrobiological, philosophical and future-studies related aspects' of the paradox missing in the Stephen Webb's books (2002, 2015), and more detailed treatment of issues regarding the search for general signatures of intelligence advocated for in Paul Davies's (2010) book. In all three cases Ćirković's noble intention with his book is to fill these gaping lacunas and niches in.

The first three chapters (together with Chapter 8) are in many respects possibly the most important ones in the entire book. While the first one provides a historical, methodological and epistemological backbone of the narrative, the following two, discussing its astrophysical, cosmological and philosophical background, represent a sort of book's basic value, distinguishing it from the other enterprises of the kind.

A somewhat longish and rather complex Chapter 1 offers a thorough overview of the paradox and of the main arguments, disputes and controversies associated with its different interpretations and proposed solutions, pointing out in the same time and critically dissecting various misconceptions and misunderstandings often present in the vast literature on the subject. Introducing the paradox via a brief description of the historical lunch of Enrico Fermi and his colleagues at Los Alamos, Ćirković proceeds with formulations of its different versions (Proto/Historical, Weak, Strong, Kardashev), framing them in a wider historical and conceptual context, thus, for the sake of the reader, successfully preventing a potential confusion in this respect. His preference for the StrongFP version, 'allowing a larger spatio-temporal volume and a more inclusive class of phenomena', is motivated by its 'large and obvious advantages' and stems from the fact that 'basic intellectual honesty requires presenting any problem as strongly and forcefully as possible'. He then discusses the spatio-temporal time scales involved (characteristic time for the colonization of the Galaxy vs. age of the Solar System), and the notion of detectability ('a metric telling how difficult is to detect the presence of intelligent species from afar') in regard to SETI, warning that the latter should be decoupled from synchronization ('the extent to which other intelligent species are contemporary to us').

Representing structure of Fermi's paradox schematically turned out to be a simple but useful way to assist the reader in following the thread of reasoning on what actually constitutes the paradox. Decomposing one of the ingredients of the paradox (Additional assumptions) in its own components, reveals the philosophical, economic and methodolog-

ical commitments necessary for any solution of the paradox to be functional. Scientific realism, naturalism, Copernicanism, and gradualism, together with economic assumptions are shown to be such necessary assumptions, which, with the non-exclusivity principle, ('a principle of causal parsimony'), were subsequently used in the rest of the book to judge and compare the proposed solutions.

Ćirković next introduces the Hermit Hypothesis as a special case of the so-called 'xeno-sociological' hypotheses, with the purpose of using it as a null hypothesis upon which the other solutions should be gauged. Refusal of the intelligent beings to expand and communicate, which makes them impossible to detect over interstellar distances, implies, however, their existence, in contrast to Fermi's original conclusion - that there are no extraterrestrial sophonts. He then readily demonstrates that this most common reaction to the paradox (They just do not want to have anything to do with us!) is based on unlikely premises of the universal will of presumably wildly heterogeneous species and on the active suppression against detection of, for instance, traces of advanced technologies.

The serious aggravation of the paradox due to recent advances in astronomy, astrobiology, molecular biology, biochemistry and technology, in Ćirković's perception, rings the bell (Ora est!) and offers an obvious answer to the question 'Why now?'. To that he adds a black-humor observation that the hypothesis on tendency for self-destruction of the technological civilizations is (for now) denied by the empirical fact that our civilization survived three-quarters of a century after the invention of the weapons of mass destruction. Introducing yet another concept, that of the advanced technological civilization as the one exploiting the energy of its parent star (Kardashev's Type 2 civilization), he emphasizes that a success of the SETI search would not necessarily bring the solution of the paradox in its strong formulation. 'Two is sufficiently close to one' when dealing with large samples, thus Silentium Universi remains paradigmatically a statistical problem. The final remarks of the chapter are devoted to the mirroring effect of the paradox, that is to the fact that by studying the reasons for absence of the traces of intelligent beings, we may learn a lot on the future of the humanity itself and on the possible evolutionary paths we as a species may take. With this he concludes: if we are to navigate our Spaceship Earth to the future, we 'better draw all possible lessons from the Great Silence'.

Continuing in Chapter 2 along the same line of reasoning, Ćirković emphasizes that an intelligent community can choose to follow a large variety of evolutionary paths, while the past is already fixed, and that therefore 'present and future are so much larger than the past'. Hence, he concludes that astrobiological thought 'need not be burdened by past history and local specificities'.

He then proceeds with discussing the main astrophysical and cosmological concepts relevant for the emergence of intelligent life and thus for Fermi's paradox and SETI. First, via a brief historical account, he introduces the new Standard Cosmological

Model, emphasizing the process of the formation of structures as a special case of the 'process of spontaneous symmetry breaking which accounts for ... almost entire information content of the universe'. The habitable islands in the vast intergalactic void are just these 'matter density peaks' that represent structures such as galaxies and their groups and clusters.

Since Fermi's paradox is usually formulated in the Milky Way context, Ćirković recapitulates the basic astrophysical information regarding our Galaxy: its size, estimated number of stars and planets, or more generally - habitats (more than a trillion, not counting the hypothetical free-floating planets), and its structural components (halo, bulge, bar, thin and thick disk). In more detail he discusses the halo and the astrobiologically most interesting thin disc containing metal-rich Sun-like stars. Next he describes the galactic location of the Solar System, its age in comparison to the age of the oldest stars in the Galaxy and of its much younger thin disk, and properties of its galactocentric motion.

Generalizing from these basic data, Ćirković subsequently introduces the concept of the Galactic Habitable Zone (GHZ). In a brief retrospective overview he spans almost a century long history of the GHZ concept, from the Wallace's (1903) book in which author argues that not all the positions Earth can occupy within our stellar system are favorable for the advent of life, to the papers from the very beginning of the new millennium by Lineweaver (2001) and by Gonzalez et al. (2001), describing temporal (beginning of the formation of Earth-like planets, which can be considered as birth epoch of the GHZ) and spatial constraints (inner and outer boundaries of the GHZ, determined by different astrophysical processes, also usually taken as beginning of the GHZ's modern studies) of the Galactic habitability. In this context, Ćirković also describes important contributions of his own research group to modeling of the stellar mass surface density and fraction of habitable cells indicating complex GHZ structure in a simulated Milky Way-like galaxy. Going one step further, he postulates the concept of Galactic Technological Zone, which should be the principal target of contemporary unorthodox SETI. Finally, he discusses various criticisms of the GHZ concept, including the one pertaining to its very usefulness, and offers for each of them convincing answers, warning however, that this interesting concept is still in its 'embryonic stage of development', that it should be used 'with caution', and not 'overrated or taken too literally'.

In the concluding section of Chapter 2, using Borel's "infinite monkeys" theorem, Ćirković demonstrates that spatially infinite universe implies an infinite number of extraterrestrial intelligent species. Then, he gets involved in a rather technical discussion on the analogy of Fermi's and Olbers's paradoxes, with the idea that the role Olbers's paradox used to play in the development of cosmology, Fermi's paradox might play for astrobiology and SETI. The notion of cosmological horizon as 'the absolute outermost limit of any SETI survey' serves

him as an entry point for the extragalactic SETI, which he promotes in the following, and for which he considers the weak points and advantages. Analyzing a plausible, but contrived scenario for extragalactic SETI, he even finds that the intergalactic SETI may appear to make no sense in comparison to the extragalactic one!? Presentation of 'the discrete distribution of expected astrobiological complexity', ranging from zero complexity of intergalactic matter, to low complexity of the thin disc with habitable planets and biospheres possibly resembling the terrestrial one, to high complexity of advanced technological civilizations, concludes the chapter.

To justify the philosophical account exposed in Chapter 3, Čirković considers in more detail an often overlooked fact that 'a philosophical perspective is not optional when young fields like astrobiology and SETI are concerned, it is unavoidable', reminding us of several well-known examples of the kind from the history of science. He emphasizes in this respect the analogy between the situation with cosmology in the mid- 1960s and the present state of astrobiology and SETI, the relationship which he elaborated in great detail in his book "The Astrobiological Landscape" (Čirković 2012). He, however, also warns against superfluous 'philosophical baggage', that of 'definitional challenge' which we should not burden ourselves with in this stage and state-of-affairs with research in these admittedly young fields. He claims that intuitive understanding of life and intelligence or intuitive recognition of cultural properties suffice at this moment, but that later they 'can be discarded... in the face of better understanding'. In this sense, Čirković states that his use of terms like extraterrestrial intelligence, intelligent beings, or sophonts defaults to the 'beings we are interested in meaningfully interacting with', where he includes also the one-sided interaction that includes discovery of archaeological remnants of extinct civilizations.

The following four sections discuss the basic philosophical assumptions built in various flavors of Fermi's paradox. Čirković, as his working hypothesis, inaugurates the methodological naturalism, which, in rough, non-technical terms, teaches us not to 'invoke supernatural agencies and capacities' in order to explain the empirical, observed phenomena. He does not get caught in the "trap" of metaphysical naturalism, however, which rejects their very existence, but rather, in considering 'the possible effects of extraterrestrial intelligence on the cosmological environment' embraces the so-called physicalism, 'the doctrine which rejects non-physical causes of physical effects'. Discussing an intellectually attractive explanation of Tegmark's (2008), of the dichotomy between natural and supernatural as due to the "internal" and "external" perspectives of the observer, and explaining the logical flaws of otherwise acceptable coexistence of the supernatural Creator and Fermi's paradox, Čirković regarding supernaturalism concludes that 'the very best one can do is simply to reject it', adding in the Endnotes an amusing observation involving the explanatory nihilism.

Departing from an implication that there exists a material world with its various features, the sci-

entific realism is 'a working philosophy' of practically all science. Together with naturalism it represents 'methodological assumptions ... used in any scientific research', while in the Fermi's paradox context it furnishes the basic premise which simply states that indeed, there are no traces of extraterrestrial intelligence. Čirković opts to consider realism in a weak sense: 'what is real is that which has been established by using empirical science and, in particular, by using methods such as observation and experiment', which is sufficient for the analysis and evaluation of various possible solutions to Fermi's paradox. He, however, warns that it is still necessary in some cases to give up even this weak-sense realism to get a workable solution.

Copernicanism or 'The Principle of Typicality', as Čirković prefers to designate it, obviously plays a central role in the paradox. There is no reason to believe that humans evolved either very early or very late 'in the interval [of time] within which evolution of intelligence is physically possible', hence the intelligence on Earth should have evolved on a timescale close to the median of the distribution of physically possible timescales throughout the Universe. Even if he admits the latter claim to be 'clearly controversial', Čirković firmly sticks to the Copernicanism by stating that it at least 'offers not only potentially testable hypotheses, but whole research programs whose time is yet to come'. Based on the distribution of ages of terrestrial planets in our galaxy, a simple selection effect favors detectability of civilizations older than our own, thus research programs searching for answers to the questions like 'Exactly how much older than humanity do we expect an average Galactic civilization to be?', or 'Is the Sun a typical star [hosting habitable planets]?' should be envisaged and carried out in order to reduce as much as possible the SETI parameter space to be explored. Čirković next warns against oversimplified reading of Copernicanism in the SETI context in the founding-fathers-epoch, but also against its downplaying by the contemporary 'rare-Earth' theorists. By discussing the need to carefully distinguish between preference and typicality and warning against uncritical use of the assumption of underlying Gaussian distributions in SETI parameter space, he concludes the section by reminding us of the danger of coupling Copernicanism with incorrect empirical results or theoretical ideas, since this certainly leads to wrong conclusions.

Gradualism appears in Čirković's line of sight as the weakest philosophical principle considered in the context of Fermi's paradox. Formulated after seminal Lyell's slogan 'the present is the key to the past!', it basically amounts to assuming previous epochs to be fairly similar to the present one 'in terms of acting forces and processes'. Comparing the role it played in the history of geosciences, astronomy and cosmology, Čirković emphasizes that the main problem with gradualism is its dependence on the timescales, that is, on how frequently some phenomenon must occur to be considered either catastrophic or gradual? Since these timescales are in essence conventional, there is no straightforward answer to the question, but this rather points out the

complexity of the whole issue. For the purpose of his analysis, Čirković therefore chooses to treat gradualism as a philosophical principle, in a later Chapter of the book even practically leaving it aside and resorting to a new neocatastrophic paradigm.

As a final entry into the list of philosophical desiderata for the solution of the 'Big Puzzle', Čirković discusses in more detail the already introduced Brin's non-exclusivity principle. To clarify its very meaning and significance in the context of his endeavor at taxonomy of hypotheses, Čirković presents a few illustrative examples using analogies with athletics and soccer (remaining, however, in debt with the reader for a clear interpretation of these examples in terms of their non-exclusivity), switching then to a couple of proposed solutions for the Fermi's paradox that represent the opposite extremes in terms of their status in this respect. Stating that the non-exclusivity is 'a highly desirable property of a hypothesis', he argues that it is not just another realization of the famous Occam's razor. He admits the similarities between the two in view of the preference for a smaller rather than a larger number of causal factors, but also reveals important distinctions: the first pertains to the fact that the Occam's razor favors simplicity of the explanatory hypotheses, while (unlike the non-exclusivity) not tackling their scope; the other pertains to the applicability of Occam's razor in the 'ceteris paribus' (all other things kept equal) situations only, which obviously does not hold when studying Fermi's paradox. Adding the clarification about non-exclusivity as a particular realization of a wider principle of rationality (rejecting solutions worse than the problem itself), and considering the Hermit Hypothesis as paradigm of such a solution, Čirković explains that, while the non-exclusivity is used in his book as 'a tool for sorting out the jungle of hypotheses and performing the taxonomical task set', the status of this philosophical criterion is not the same as that of the other ones mentioned above. Instead, if Fermi's paradox gets solved in the future, that is, if we find out which hypothesis is the true one and whether it is exclusive or non-exclusive, this will provide the truth value of the non-exclusivity and of the Copernican assumptions, while the others will still remain in the realm of philosophy.

That the Chapter 3 is fundamental for comprehending Čirković's philosophical and scientific rationale in the SETI context, confirm also the next three sections, in which, even somewhat in passing, he discusses the continuity thesis, implying that 'there is no unbridgeable gap between inorganic matter and living systems', the postbiological evolution, which must, in his opinion, be seriously taken into account in SETI studies, wrapping it all up with a sharp criticism of the (in)famous Drake's equation and the practice of its 'ritual invocation' in the discussions of Fermi's paradox. "Let the Games Begin!" is the title of the final section of the chapter, which leads the reader to the very core of the book - the discussion and comparison of a plethora of various hypotheses proposed for the solution of Fermi's paradox and of their 'taxonomy imposed by the philosophical

assumptions sketched above' - laid out in the next four chapters.

Just for the reason that they represent the essential part of the book, I am not going to review at large Chapters 4 – 7, since I believe these should be left to the reader to savor and judge them by itself. Let me just mention that in each of these chapters one of the four distinct taxonomic classes of hypotheses, as proposed by the author, is presented in great detail. Each of these classes violates one of the previously described philosophical or economical assumptions: by abandoning either realism, naturalism, or gradualism, one gets, respectively, solipsist, rare Earth, and neocatastrophic families of explanatory hypotheses, while violation of economic assumptions too, gives rise to logistic solutions. Čirković masterly summarizes in the extremely reduced form the answers to Fermi's question for each of these families in turn as: 'They are here', 'They did not evolve', 'They have been destroyed or transformed', and 'They have been prevented from coming/developing yet'.

After surveying the 'battlefield' of hypotheses in the previous chapters, Čirković in Chapter 8 resumes with what actually is one the main purposes of the book, that is with searching for the best solution. Recognizing that this very much depends on the adopted set of the criteria for evaluation and thus suffers from unavoidable subjectivity, he introduces grades to be given to each of the hypotheses, 'along the lines set by David Brin' but with refinements and upgrades described in Chapter 3. To facilitate the procedure and make things for the reader easier to follow, he presents a table with all the considered hypotheses arranged into above defined four broad categories, containing for each of the entries its grade and a comment emphasizing the principal argument for the grade. Stating that no explanatory hypothesis can be considered 'a clear and obvious favorite for resolving the problem', thus none has been given the highest grade, Čirković defines the criteria in a range from how many 'of the philosophical precepts' a given hypothesis respects, to the use of as little auxiliary assumptions as possible, to the 'severity of violation of the non-exclusivity principle', and so on.

Assessing the possible weaknesses of the taxonomy scheme, Čirković next discusses a '[thus far] probably underestimated' overlap of different hypotheses and categories, that is 'how tightly [various items on the list] are casually connected and integrated in explanatory hypotheses'. In the same context he considers the composite hypotheses, 'fractionally combining some of the individual items', and explains the philosophical and practical difficulties with such approaches, which, however, lead us to conclude that there, after all, 'might not be that many high-quality, non-exclusive solutions to the Strong Fermi's paradox, as it may seem'.

Following an introductory clarification of basic notions and concepts, in this case applied to a fuzzy boundary between manifestations of extraterrestrial civilizations and artefacts of their astroengineering

feats, Čirković provides an exhaustive list of both kinds of such potential SETI targets. In the case of manifestations, they range from the nightglow produced by the artificial light sources to shepherding of comet- or asteroid-like bodies into orbits intended for best utilization of the resources they contain; in the case of artefacts, the list is even longer, spanning artefacts from Dyson spheres intended for habitation, harvesting of energy, or computation, to extragalactic Planck-energy accelerators used for research or defense. Both lists end up with a wild card item, standing for artefacts due to 'motivations, goals, and capacities entirely unknown and unconceived by us so far'. These wild card items are 'paradigmatic unknown unknowns', and one has to have an open mind when considering such possibilities, as they might very well 'contain most of the detection cross section in the Galaxy'.

The notion of detectability as a measure to be used in evaluating the above targets from a SETI point of view is next elaborated in terms of the features it should possess to 'convey really useful practical information'. These encompass detectability being a simple scalar and non-negative measure, space and time dependent, function of the observational methodology and available devices, containing a reference to the type of civilization in some convenient taxonomy, and superadditive. Higher priority is thus to be given to SETI projects with high values of detectability parameter, i.e. to those looking for 'traces and manifestations of interstellar colonization and appropriate energy consumption'.

Although the list of projects of search for detectable astroengineering artefacts given in the book is not very long, it still, according to Čirković's optimistic observation, appears to herald better times.

The hypotheses are next discussed in terms of features common to or impacting several of them, like the (in)capacity for generalization to the rest of the Universe of a particular 'Great Silence' explanation proposed for the Milky Way, postbiological evolution/superintelligence/technological singularity, temporal ordering of technologies, assumed existence of overwhelming or somewhat less powerful sophonts and their benevolent vs. malevolent attitudes, etc.

The concluding section of Chapter 8 represents a sort of crescendo of this chapter and of the book as a whole. In it, Čirković presents a choice of hypotheses 'which fared the best under the analytic weapons discussed in this chapter'. Again, I am not going to reveal the winners, leaving to the reader to discover them for itself; instead let me just note that three 'patchwork quilt' clusters are proposed involving several related hypotheses, which cannot singularly explain the StrongFP, but taken together can provide a plausible solution. Čirković comments: 'Unsurprisingly, each of these clusters has a distinct flavor and a distinct set of research and even ethical prescriptions', and asks self-imposing questions: 'What roads should we take from there? Which research directions look most likely to yield advances in our understanding of Fermi's paradox? What fruits can we expect from further work?' Possible answers to these questions he considers in the final chapter

of the book, which he dubs a wake-up call as there is 'a tremendous amount of work to be done'; in the same time, however, he proclaims that 'there is reason for substantial optimism that we could make huge strides in answering this puzzle' in the foreseeable future, that is in coming years or decades, at most.

It may seem somewhat at odds with Čirković's persistent support for the SETI projects that his personal preference lies with the hypothesis that appears to render these efforts futile (see, however, Section 9.2 for a hint of justification). This hypothesis is, in fact, the top entry in the short list of 5 hypotheses representing his 'subjective favourites', and contains, as readily explained, hypotheses he finds 'to be the most thought provoking, original, intriguing, or aesthetically pleasing - as eminently distinct from most likely to be true'. This slight departure from the scientific and philosophical discourse promoted throughout the book can be understood as a small concession to the curiosity of the reader, and hence considered as a welcome and relaxing inset.

Appropriately enough, Čirković begins the final Chapter 9 of this fascinating book with a 'cartoonish' summary of the main achievements and conclusions of his endeavor. He emphasizes once again that Fermi's paradox is a 'complex and rich intellectual problem' which deserves a distinguished place in the history of ideas, that four distinct categories of solutions to the problem exist, each of which, however, rejects at least one of the major philosophical/economic assumptions, that there are a few explanatory hypotheses which represent real 'plausible responses to the strongest version of the paradox', and that the tight connection - which he continuously points out - between Fermi's paradox and the future of humanity 'severely constrains the options for the future evolutionary trajectory of ... human civilization'.

Čirković next introduces the three topics he feels urged to discuss in more detail. In the philosophical context he deliberates the stronger version of the paradox as an ultimate challenge to Copernicanism, in the astrobiological context he promotes the postbiological evolution as one of the 'radical ideas [that] deserve more scrutiny', and in the SETI practices context, he advocates for the necessary reforms and modernization of the enterprise.

Copernicanism vs. anthropocentrism is, in Čirković's view, a stubbornly persistent controversy of utmost importance, thus he repeatedly turns back to it to further improve our understanding of the former and to offer additional arguments for rebuking the latter. He suggests that what he dubs the implicit filter, acting on both methodological and evolutionary levels, produces a false 'illusion of [our] exceptionality', giving rise to observation-selection effects that represent a 'major obstacle to our insight'. In the face of the Fermi's paradox he presents us with the dilemma: 'either we are missing something crucial or we need to abandon the Copernicanism ...' proposing, however, certain recipes to guide us out of the anthropocentric trap; these include abandon-

ing our Galactic provincialism, that is putting our evolution in a wider context - 'at least the Galactic one', finishing the Copernican revolution in terms of 'reappraisal of our position in terms of universal complexity', and redefining what we consider as a success of SETI efforts, that is 'understanding of the general shape of the astrobiological landscape of the Milky Way', with 'natural supplemented by intentional'. Designating anthropocentrism 'the most powerful drug of the human mind', he relentlessly clashes with its prejudices and fallacies, concluding the section with an interesting consideration that our own descendants in far enough future might look and behave so differently from us that they can be safely taken as aliens from the point of view of present humans.

Ćirković is positive that the postbiological civilization is what awaits humans in the future. Hence he proposes conclusions relevant for the present day SETI, pointing out that we should not search for the habitable planets in warm circumstellar habitable zones, but that, taking into account postbiological evolution, astroengineering and space colonization, we should rather 'focus on regions with the greatest amounts of resources, including metals and energy, as well as low working temperatures, as the best locales for optimized computation'. We should understand that the possible future contact with extraterrestrials, if it ever takes place, will probably not be with humanoids, but with a superior information-processing system. We should, thus, reject currently prevailing SETI reasoning beyond Fermi's paradox, liberating it from the biological evolutionary baggage of the species.

An intriguing perspective in this respect represents possible future gradual disappearance of the distinction between biological forms and non-biological information systems, i.e. between humans being able to rebuild themselves from the molecular level up and machines, rendering attempts to discern between biological and postbiological, as well as between natural and artificial, superfluous.

One can reasonably assume that the influence of the sophonts in our cosmological domain to the physical environment can be represented as an inverted parabola with a maximum, indicating the competition between two different trends, the ever increasing impact to the environment characteristic of a young civilization in ascent and minimization of such impact with mature civilizations, driven by practical and ethical reasons. The need for achieving efficient symbiosis with nature leads Ćirković to argue that 'exploration and colonization of the Universe are essentially ecological endeavors'.

A few sentences at the end of the section are devoted to the so-called Big History, that is to attempts 'at giving an overview of history from the Big Bang to the present', offering to the social sciences and humanities a way to join 'the mighty river of Copernican sciences'.

Remaining in the realm of 'innovative, bold, radical thinking', with 'an eye to the future', and perhaps somewhat biased towards 'grand schemes', Ćirković next pays attention to issues like distributed

computing, the Internet of Things and rethinking of the conventional concept of extraterrestrial intelligence, creation of artificial black holes and basement universes, impressive scheme of selfish biocosm, and similar, hailing in the process some recent proposals involving Cosmic Microwave Background or lattice QCD (Quantum ChromoDynamics) calculations, turning 'classical metaphysical questions' into 'legitimate subjects of scientific inquiry'.

Fermi's paradox as a provocation to our concepts and beliefs Ćirković promotes as a means to search for the 'overarching explanatory structure, drawing an outline of the high-complexity, self-aware sector of the total astrobiological landscape', and for 'understanding the place of mind in the cosmological scheme of things'. Asking the question on whether there may be a unified solution to the strong Fermi's paradox, Ćirković concludes that this is highly unlikely, and that relative frequency of different explanatory mechanisms is what matters. A single, non-exclusive hypothesis may account for a major part of the paradox, while other plausible options may 'play auxiliary or local roles'. With full appreciation of the importance of the cognitive, social and historical sciences to resolving the strong Fermi's paradox, in particular its xeno-sociological half, he makes a prediction that with the progress of astrobiological revolution, many new hypotheses will be proposed, but that all of them shall still require abandoning of one or more philosophical/economical assumptions to arrive to a plausible explanation. Hence, he states, the future may bring about the more refined taxonomies of ideas than the one proposed in this book, but 'the approach itself will still be validated'.

In the final section of the chapter and of the entire book, Ćirković reiterates some of his strongest criticism regarding the flirting of the orthodox SETI with anthropocentrism which he sees as the main reason for the failure of the search carried out in terms of the 'patient radio listening'. He also offers a clear answer to the question on what has to be done, expressed in the form of 'one more exhortation' to the SETI enthusiasts: to overcome the prejudices of the past, to scrub and remove the noise 'clogging the channels' consisting of fallacies on the human exclusiveness and nonsense propagated by the media, to overcome the academic and interdisciplinary borders. All this requires a huge effort to revive and reinvigorate 'space programs and cosmic thinking on a global level'.

It appears very appropriate to wrap up this overview of the content of the book with the concluding words from the author himself: '*Abandoning past prejudices is not enough*. There has to be a positive momentum, an awakening, a new spirit of open-mindedness towards original, speculative, even crazy leaps on both the theoretical and the empirical stage. After all, this is what science has stood for in its most brilliant moments: courage, conviction, and the spirit of adventure. These qualities might, in the final analysis, withstand the test of cosmic time, repulse the last challenge to Copernicanism, and ultimately break the Great Silence.'

CONCLUDING REMARKS

The Great Silence is undoubtedly an outstanding book that brings about many important new insights and a greatly improved understanding of the complex problems involved with Fermi's paradox. Hence, it is only natural that it does not always make an easy reading; the contents, however, for the most part should not be too difficult to comprehend even for the non specialists and laymen. Author of the book, Milan M. Ćirković, is a competent and eloquent narrator. He does not make any compromise with the scientific correctness of his writing, nor concessions to the complexity of its topic. His text is reach with profound details, refined humor, subtle digressions, and carefully chosen quotations, which makes reading of the book both inspiring and enjoyable.

To be completely honest with the author and the reader, and as impartial as the honorable role of an objective reviewer requires, let me mention few minor remarks, which do not affect the overall positive impression about the book, but may perhaps be useful to the author in his future endeavors. I am perfectly aware that writing a critical overview of such a vast and complex subject like Silentium Universi, even upgrading it in many respects in the same time, is a difficult, perhaps next-to-impossible, task. Still, one must say that the present book is not in all its parts of the same quality, in the sense that in most cases the relevant topics are indeed brilliantly described and summarized, but that there are few places where author remains in debt with the reader for simpler and more clear explanations, not overexerted with nonessential information/discussion and unnecessary excursions into a wider context. It is also not entirely self-standing in the sense that the reader is (perhaps too often) assumed either to be familiar with certain notions and subtle points, or expected to consult a voluminous literature suggested.

Small errors to be corrected in the second edition include: proto vs. historical (two labels for the classical, weakest, version of the paradox), missing gradualism in the subtitle of Chapter 3, Red Herrings in the title of Section 3.5 not being justified in the following text. One must also say, however, that, remarkably enough, there are almost no misprints and spelling errors in the text.

There are several important added values of the book worth mentioning: an indeed comprehensive list of references with nearly 1000 entries, which will certainly represent a valuable asset for every student of SETI in the years to come, the numerous comments, additional information, pointers to the literature, and similar, compressed in the Notes at the end of the text, as well as a useful Index at the very end of the book. Another, in my opinion really remarkable, added value of the book are the illustrations of Slobodan Popović Bagi, who in an original way, using maximally reduced visual/graphical tools,

unmistakably catches the very substance of the information to be conveyed in a given context.

I wholeheartedly recommend this excellent book to every interested reader, concluding this review of mine with the words of David Brin from the back cover of the book: 'A detailed, logical, impartial and much-needed exploration, examining one of the most fascinating controversies of this (or any era)'.

NOTE ON THE AUTHOR

Milan M. Ćirković (1971), senior research professor in astrophysics, is an original author who dares to roam the mystical realms at the very frontier between science and (science) fiction. He often deals with problems which belong to nascent disciplines, or may not at all (yet) rate as genuine mainstream research topics, assessing them from astrophysical, astrobiological, cosmological or philosophical points of view while trying to build (rudiments of) their epistemological foundations. In all his writings and, more generally, in his very approach to the studies of SETI, life in the Universe, future of the humanity and similar fundamental topics, Ćirković often looks for inspiration, ideas and analogies with scientific discourse in the classical literature and fine arts, sometimes even in sports or a pop culture, while, more specifically, with great respect he considers excerpts and arguments from the unjustifiably proscribed science fiction literature: this book proves the latter to be a noble and valuable effort.

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**ВЕЛИКА ТИШИНА: НАУЧНИ И ФИЛОЗОФСКИ АСПЕКТИ
ФЕРМИЈЕВОГ ПАРАДОКСА**

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Приказ књиге

У чланку је дат приказ књиге Милана М. Тирковића “Велика тишина” посвећене Фермијевом парадоксу. Полазећи од разматрања пожељних особина које компетентни аутор овако захтевног подухвата треба да поседује да би његово настојање било успешно, у наставку је детаљно приказан садржај књиге, при чему је посебна пажња била посвећена астрофизичким, астробиолошким и фи-

лозофским расправама. Предложена таксономија хипотеза за решавање парадокса и затим спроведено вредновање хипотеза на основу критеријума које аутор користи су кратко дискутовани, а закључци у вези са SETI праксом и изучавањем будућности човечанства коментарисани. На крају су дата нека запажања и примедбе које, верујемо, могу да буду од користи аутору у будућем раду.