S E C T I O N VII

THE FERMI PARADOX AND ALTERNATIVE SEARCH STRATEGIES

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VII. THE FERMI PARADOX AND ALTERNATIVE SEARCH STRATEGIES

INTRODUCTION

The Fermi Paradox is essentially the question "Where are they?" or "Where is everybody?" which was reportedly asked by the famous Italian physicist Enrico Fermi at a luncheon meeting with Emil Konopinski, Edward Teller, and Herbert York, at the Fuller Lodge of the Los Alamos National Laboratory in the summer of 1950. The question refers to the absence of any concrete evidence of extraterrestrial visits to Earth, which seems puzzling (hence the word "paradox") if, as some estimate, during the past 5 or so billion years our Galaxy has harbored billions of advanced technological civilizations each with an average life span of millions of years. It would also be a paradox if the answer were "because we are the only ones in the entire Galaxy", because this would then violate the so called "Mediocrity Principle", which states that there is nothing very special about our Sun and about the Earth among the hundreds of billions of solar systems in our Galaxy.

The modern debate on this subject was ignited in 1975 with the publication in the Quarterly Journal of the Royal Astronomical Society (Vol 16, p. 128) of the paper "An Explanation for the Absence of Extraterrestrials on Earth" by Michael Hart. Actually, when I was visiting the Institute for Space Research in Moscow in the summer of 1984, Dr. Iosif Shklovsky told me that we must call it the "Hart Paradox" rather than the "Fermi Paradox" since it was really Michael Hart who brought it to the attention of the world scientific community with his 1975 paper. The Fermi or Hart Paradox has been debated extensively in the literature and in scientific meetings since 1975. In a special meeting, e.g., during the 1979 IAU General Assembly in Montreal, the proceedings of which were published in 1980 (Strategies for the Search for Life in the Universe, Ed. M.D. Papagiannis, D. Reidel Publ. Co., 1980), we debated the four possible alternatives about the value of N, i.e. of the number of advanced technological civilizations in our Galaxy. The points supported were: N is very small (M.Hart), N is very large (T. Kuiper), N is neither very small nor very large (F. Drake), N is either very large or very small (M. Papagiannis), without of course any clear winner.

During the past 10 years many people have offered possible explanations for the absence of extraterrestrials on Earth. These can be subdivided into three general categories:

I. Interstellar travel is not undertaken by advanced civilizations because it is too expensive to be of any value for mass emigration or for interstellar commerce. Unmanned missions to nearby stars for

M. D. Papagiannis (ed.), The Search for Extraterrestrial Life: Recent Developments, 437–442.

purposes of scientific exploration are considered the only realistic possibility of interstellar missions.
II. Interstellar travel does occur but they have not yet reached the Earth because the colonization wave advances very slowly, or because the colonizations process started rather late in the history of the Galaxy, or because it started nearly simultaneously in many regions of the Galaxy which has become like a mosaic of galactic tribes separated by no-man's regions where our Solar System happened to be.
III. The whole Galaxy including our Solar System has been colonized since long ago, but they have purposely chosen not to reveal their presence for a variety of reasons, such as the desire not to interfere with still rather primitive life (the zoo hypothesis), a galactic ethic of letting new civilizations prove themselves by facing alone the crises (overpopulation, nuclear war, etc.) that probably occurs in most cases with the advent of technology (the galactic quarantine hypothesis), and many others.

There are of course also people who believe that the Earth has been visited in the past (ancient astronauts), or that it is being visited now (UFO's) by extraterrestrials. The evidence, however, for either of these contentions is very conjectural and does not stand up to strict scientific requirements such as repeated verifications. Admittedly, it is not easy to dismiss these contentions either, especially since very few scientists are willing to become seriously involved in such investigations. It must also be mentioned that Frank Tipler has strongly advocated the idea that the colonization of the Galaxy will be made with Von Neumann mashines, i.e., with automated systems capable of self-replication when they reach a planet, moon or asteroid where they can obtain the raw materials and the energy needed for such a manufacturing process.

There have also been suggestions that advanced civilizations might indeed be very rare in the Galaxy, primarily because of the exceedingly long periods (billions of years) that seem to be needed for the biological evolution to teach this advanced stage. It might be, e.g., very difficult for a planet to maintain liquid water on its surface for billions of years. It has also been suggested (B. A. Balazs) that only a small fraction of the stars of a spiral galaxy manage to avoid the destruction of all life from a nearby explosion of a supernova. The few privileged stars are located in a narrow zone of the galactic disk where the orbital period of the stars practically coincides with the orbital period of the density waves that create the spiral arms, and thus some of these stars, like our Sun, manage to stay in the inter-arm region for billions of years away from the spiral arms where supernova events are far more common.

From this brief summary one can easily see that the idea of a paradox has stimulated a lot of thinking and has led to the proposal of many different solutions that cover a wide spectrum of possibilities. The result could have been interpreted as total confusion, but fortunately out of the chaos often comes creation, and this is what has happened in this case too. We have simply recognized that we really do not know what exactly is the situation and that none of us can be too doctrinairial since none of us can guess with confidence how

civilizations far more advanced than ours are likely to behave or act. We also began to realize that debates, useful as they might be in helping us understand and focus on important issues, they were never going to solve this problem. The only way to solve it is the experimental search, which in view of the uncertainties mentioned above, ought to be more flexible to allow the experimental testing of alternative theories, and indeed this is the direction in which we are now moving

The NASA SETI Program, discussed in detail in Sections V and VI, will carry the main thrust of this effort, but will be supplemented by several other searches, some more conventional as project Sentinel of Paul Horowitz, the piggyback project Serendip of Bowyer and Werthimer, and the eavesdropping efforts using computer techniques of Sullivan and Knowles, or less conventional such as the optical searches of Feitas and Valdez for artificial objects in the L4 and L5 Lagrangian-points of the Earth-Moon system, or the infrared searches of Papagiannis for space stations in the asteroid belt. In a way then these long debates had a beneficial effect and instead of dividing us they have united us in a broader and more comprehensive search strategy.

The Co-Chairmen of the corresponding Session of the Symposium were scheduled to be Philip Morrison of MIT and V.I. Slysh of the Institute for Space Research of the USSR Academy of Sciences. Unfortunately Dr. Slysh was not able to attend, though he has sent his contribution for the Proceedings, and as a result Dr. Morrison was the only Chairman of the this Session.

The first paper of this Section is by Frank D. Drake of the University of California, Santa Cruz. After discussing the Fermi Paradox and the different explanations that have been offered, he proceeds to place his support in favor of the economic factor. He accepts the idea that advanced technological civilizations will colonize their solar system with O'Neill space colonies, but he estimates that interstellar colonization is millions of times more expensive than interplanetary colonization and therefore interstellar missions of manned probes can be justified for no other reason except as occasional scientific missions and even those would probably be carried out with unmanned probes at considerably lower cost. Consequently he believes that the intelligent thing for extraterrestrial intelligence would be not to become involved in interstellar travel, and he hopes that our radio search will prove that indeed this is what they have done.

John H. Wolfe of the Ames Research Center explains why he thinks manned interstellar travel is very unlikely. He sees three basic reasons for which interstellar travel might be undertaken: Colonization, Survival, and Exploration. Civilizations may survive only if they mange to reach social and environmental stability, in which case they do not need colonization. Survival from physical disasters does not seem a good reason either. During the Red Giant stage they can move to the outer edges of their solar system and return back to the inner regions at the beginning of the White Dwarf stage. Supernovae occur only in massive stars which have a much shorter life span, most likely too short for the appearance of an advanced civilization. (He does not say what would they do if a supernova is about to occur in a nearby star).

Finally the exploration of other solar systems will probably be done with robots and not with manned probes because of economic, safety, flight time, and other reasons. In addition to being too expensive, as Drake stated, Wolfe says that it might also be too hazardous if there are small boulder-like objects in interstellar space. A 100 gm interstellar particle encountered by a spaceship travelling at V=0.2 c will produce an explosion equivalent to a 40 kiloton bomb, and the spaceship would need a 10 meter thick solid Tungsten shield to survive this encounter. He concludes, therefore, that advanced civilizations do not engaged in interstellar travel because it is so much easier for them to transfer information via interstellar communications.

Ben R. Finney, the author of the next paper, is an anthropologist from the University of Hawaii who has studied extensively human migration, especially the discovery and settlement of the Pacific islands by the Polynesians and the subsequent fate of these colonies. We are clearly an expansionary species, he says, and our recent technological achievements make us think that we can colonize the entire Galaxy. But this might be excessive arrogance, a hubris as is called in ancient Greek tragedies which is punished by the gods. He describes several examples of stalled colonizations or expansions. Some Polynesian settlements became extinct, such as the one on the rugged Pitcairn Island of "Mutiny on the Bounty" fame, and the Easter Island with its famous huge stone statues where rapid population growth destroyed the environment and led to bloody inter-tribal wars, famine, and finally to the collapse of this civilization without any of them escaping to other islands. China had also a spectacular short period, 1405 to 1435 AD, of maritime supremacy and expansionistic sea ventures in the India Ocean with huge, nearly 500 ft long, ships. This period of rapid expansion, however, came rapidly to an end, possibly because of the rise of a brand of neo-Confucianism which favored introspection rather than action. He concludes by saying that though it might be in our hubristic nature to predict our expansion into the Galaxy, there is no way to specify how far these expansionary urges may take us in the long run.

The next paper is by Eric Jones of the Los Alamos National Laboratory, who continues on the same theme of interstellar migration. Eric Jones made some of the first computer simulations of interstellar colonization and computed the time it takes for the colonization wave to sweep through the Galaxy. Also he and Ben Finney organized in 1983 at Los Alamos a conference on Interstellar Migrations. He feels that there will always be the adventurers and those that lust for new places, who will ultimately "blaze the trail" to the stars. It took less than 500 years from the time Columbus discovered America to go to the Moon, and in another 500 years there will probably be more people living in space colonies than on our planet. This new space civilization will have at its disposal colossally larger quantities of energy and raw materials and therefore it will be able to undertake trips to other stars. Jones examines the possibility of using microwave propulsion acting on Dyson sails made possibly of thin (~5 μ) SiC fibers of high strength. Also of galactic nomads hitchhiking on interstellar comets to other stars. He points out that we will never know the answer to whether or not there

are other advanced civilizations in the Galaxy until either we will succeed in finding them with out SETI work, or we will colonize the entire Galaxy and we will find no one there.

Edwin L. Turner of Princeton University presents a new potential explanation for the Fermi Paradox. If the time interval between successive appearances of different advanced civilization in the Galaxy is much shorter than the time needed by one civilization to colonize the entire Galaxy (typically estimated as 10^7-10^8 years), then the galactic disk will look like a map with different interacting galactic civilizations occupying distinct galactic regions, along the boarders of which there might be no-man's bounderies that have purposely remained uncolonized. It is conceivable, Turner says, that our Solar System might be in such a no-man's region, which would explain the absence of extraterrestrials in spite of the fact that the Galaxy has been fully colonized. Another explanation of the Fermi Paradox, Turner says, is the possibility that the age of the stars of the galactic disk might be considerably smaller (5-6 billion years) than the age of about 10 billion years that is commonly assigned to them. If this is the case, the appearance of advanced technological civilizations might have only just started in our Galaxy.

John A. Ball of the Harvard-Smithsonian center for Astrophysics and the initiator of the often discussed "zoo hypothesis", examines 10 different answers to the question "where is everybody?" They range from "there is no one out there" to "they exist, but do not care about us", with several other intermediate possibilities. He also makes several interesting observations, such as that "an Earth-like planet is to ETI what an empty eggshell is to a bird." He believes that if these advanced civilizations had chosen to announce their presence to us, we would have known it. Therefore, he says, the proper question to ask is not "how can we become aware of ETI?", but rather "why are we anaware of ETI?"

Charles L. Seager of the San Fransisco State University and of the NASA-Ames Research Center, one of the pioneers of SETI, suggests that this should not be called the "Fermi Paradox" but rather be referred to as the "Fermi Question" because of the many uncertainties and unanswered points, which simply do not allow us to reach any serious conclusions. This point of view, by the way, was advocated by several other participants (Morrison, Papagiannis, et al) and seems to be indeed the only rational answer to the famous question posed in 1950 by Enrico Fermi. It also suggests that we must persue a variety of search paths, i.e., a more flexible search strategy, since none of us can claim to be certain of the best approach. The following three papers present some of these alternative strategies that broaden the spectrum of our search efforts.

D. Hoang-Binh of the Observatory of Paris, Mendon, France, suggests that stellar civilizations instead of transmitting at a single frequency might be using simultaneously several frequencies to compose a cosmic alphabet which would facilitate, as in our case, the transmission of messages. He notes that the recombination lines of Hydrogen, especially the 10 or so lines in the spectral region of the water hole, might constitute an ideal set for this purpose and therefore they ought to be investigated.

Nikolai S. Kardashev, a Vice President of the Space Research Institute of the USSR Academy of Sciences, Moscow, USSR, and also a Vice President of COSPAR and of our IAU Commission 51, advocates the search for superstructures, involving even the restructuring of an entire galaxy, constructed by supercivilizations. He believes that supercivilizations would have a tendency to collect the resources of an entire galaxy into a small volume, a process which he calls "the urbanization hypothesis". As an example he uses a rotating disk with a radius of 12 pc, a tapering thickness of less than 1 km, and a rotation period of about 2,600 years. He assumes that this disk has the mass and the luminosity of a whole galaxy with 10^{12} suns, but that the radiation is emitted primarily as thermal radiation. (It is hard to see how a supercivilization would be able to collect the mass of a whole galaxy into a small, properly structured shape, or how they would be able to produce such colossal amounts of energy without natural thermonuclear fusion, or without melting and evaporating their thin disk with mammoth energy producing plants. It is conceivable, however, that they would know physical processes that we do not know and therefore they would be able to do things which to us now seem impossible). He also has a cute cartoon of such a supercivilization and a Table with six possible scenarios for the evolution of ETI.

Michael D. Papagiannis of Boston University, the President of IAU Commission 51, reiterates in the last paper of this Section the advantages of a more flexible search strategy which would be able to explore different avenues and and test experimentally several competing theories. One of the possible alternatives of the Fermi Paradox is that the colonizations of the Galaxy, including the colonization of our Solar System, has been carried out a long time ago but for some reason they have chosen not to reveal their presence. Extraterrestrials undertaking interstellar trips, of probably several centuries and many generations, are likely to continue to live in space habitats when they colonize a new solar system, because they must have become accustomed to living in space habitats with zero or very low gravity. They would still need, however, raw material, which they could obtain most readily from the asteroid belt. A careful search is being planned through the IRAS data of objects in our Solar System for objects with an unusual infrared spectrum, such as objects much hotter than what is justified from their distance to the Sun, which could indicate the possible presence of a large artificial object in our Solar System such as an O'Neill space colony or a materials processing plant. IRAS obtained infrared measurements at 12, 25, 60 and 100 microns and the IRAS Asteroid Working Group is preparing a detailed catalogue of Solar System objects which is expected to contain more than 10,000 objects, about 2000 of which are correlated to known asteroids. Checking out our own Solar System seems also to be a prudent approach in a universal search for extraterrestrial intelligence. We would look foolish to future generations if we would keep searching throughout the Galaxy, when all we might have needed to do would have been to look in our own backyard.

THE EDITOR

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