Q. Jl R. astr. Soc. (1981) **22**, 279–292

Additional Remarks on Extraterrestrial Intelligence*

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(Received 1981 March 3)

In a previous issue of *The Quarterly Journal of the Royal Astronomical Society* (1), I published an article which argued that we are the only intelligent beings in this Galaxy. The thrust of my argument was simple: if any extraterrestrial intelligent beings existed in the entire Galaxy who possessed a technology slightly in advance of ours and who were motivated to either explore/colonize the Galaxy or contact other intelligent beings, then it is extremely likely that at least one of these hypothetical species would have already sent spaceships to our solar system. Since apparently no such spaceships are in fact present in our solar system, it follows that we are alone in this Galaxy. I supported my argument by showing that the exploration of the Galaxy is possible in less than 300 million years using rocket technology which we already possess and computer technology which computer experts expect us to possess within a century. The computer technology which is necessary for interstellar travel is the capability of constructing a von Neumann machine – a machine which can reproduce itself given the materials that are expected to be available in all solar systems. It is the capability of self-reproduction which is essential for an interstellar probe; the level of intelligence possessed by the probe need not approach the human level, for it must have only enough intelligence to enable it to deal with the space environment in unhabited solar systems.

The article wherein I developed these ideas was actually written about a year before it was submitted to *The Quarterly Journal*, and in that time it was circulated in the form of a preprint amongst various people who are interested in the question of extraterrestrial intelligence. I had hoped to include and discuss the comments which were made on the paper, and include in the form of appendices to the paper some material on ETI which I had learned subsequent to the writing. Unfortunately, the printers were not informed of my change of address from Berkeley to Texas, and consequently the proofs of the article were sent to the wrong address. The Editor of *The Quarterly Journal*, however, has kindly offered me the opportunity of publishing this material in the form of additional short papers in this journal. One such

*Research supported by the National Science Foundation under grant number PHY-78-26592.

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paper on the history of the extraterrestrial intelligence concept (2) has already appeared; the present paper concludes the series.

My conclusion that extraterrestrial intelligent beings do not exist may seem to hinge on the motivations of such creatures, a subject about which we admittedly know very little. However, we know *by definition* the motivations of the most interesting class of intelligent beings: those whose technology is far in advance of ours, and who are *interested in communicating with us*, or otherwise interacting with us. It is this class that most SETI programs are designed to detect, and it is this class whose existence is conclusively ruled out by my arguments in (1). In fact, the average person generally considers this class of extraterrestrial intelligent beings to be all inclusive; an extraterrestrial species which did not fit into this class would not in general be considered intelligent. In deciding whether or not to call a species 'intelligent', we would compare it with our own species, and except for a lack of technology which we hope to make good within a century, we clearly are a member of the class of beings which (i) are capable of interstellar travel, and (ii) are interested in space exploration/colonization and in communicating with other intelligent beings if they exist. Thus in my paper I have followed popular custom and identified 'intelligent beings' with members of this class. Nevertheless, I admit that beings with advanced technology *could* have basic motivations which are totally unlike ours, and hence never undertake an interstellar exploration program. As I argued at length in the first paper of this series (1), however, such motivations would have to be so totally unlike ours and every other living species known to us that assuming such motivations to be common in the cosmos would contradict the principle of mediocrity upon which the entire argument for the existence of ETI is based in the first place. Furthermore, I pointed out at length in (1) that a von Neumann interstellar probe has so many uses besides contacting other intelligent beings that *any* technologically advanced species would construct such a probe.

Actually, computer technology comparable to that required to construct a von Neumann machine will probably be crucial in our colonization of our own solar system. Dyson has pointed out (3) that the capital cost per colony of space colonization programs such as O'Neill's is at present too high to make colonization spontaneous and self-sustaining. However, when the capital-multiplying characteristics of the von Neumann machines are used, non-government supported colonization becomes feasible. For example, a von Neumann machine probe could be launched from the Earth to the Asteroid Belt, where it would begin to construct more copies of itself. When the number of von Neumann machines became sufficiently large, they could be instructed to manufacture an O'Neill colony, or programmed to search for rare minerals to pay for the original von Neumann probe sent from Earth. Judging that a von Neumann payload would be less than 10^3 tons (see over) the initial von Neumann probe could be launched toward the asteroids via a *Saturn* booster or the *space shuttle*, and the total cost would be less than $\$10^8$ for launch costs. The cost of the probe can only be guessed at, but assuming that self-repairing robots are common at the time of the launch, I would imagine the probe cost to be less than $\$10^9$. If a colony of 10^4 people is eventually built, then the effective per colonist cost would then be $\$10^5$, which in terms of the per capita wealth of the colonizing society is actually less than the per colonist cost of the *Mayflower* voyage (4).

I pointed out in (1) that the Galaxy could be explored by von Neumann probes in less than 3×10^8 years, provided t_{const}, which is the average time needed for a von Neumann probe to reproduce itself in a target solar system, is less than 10^3 yr. This seems a reasonable condition when we compare von Neumann probes with the only actual von Neumann machines of our experience, namely human beings. In their natural environment humans have a $t_{const} \sim 20$–30 years. If we compare a von Neumann probe to an entire technical civilization, then $t_{const} \sim 300$ yr for the time required to build up the United States into an industrial nation. Most of this time was required to develop not the hardware but rather the knowledge of which machines to build. Possessing the necessary knowledge, Germany and Japan rebuilt their industries in a few decades after World War II, requiring only minor investment from outside. As for the t_{const} for space industries, O'Neill estimates (5) that space colonies could be self-sufficient and able to make more colonies in less than a century. Such a rapid space colony construction might require a large initial investment from Earth, and this might correspond to a very large (i.e. expensive) probe payload. As discussed in detail in (1), the intelligent species which constructed the initial probe could reduce the initial investment by building the initial probe small, but programmed to construct larger probes in the target systems. It seems unlikely that a Project Daedalus (6) size payload ($\sim 10^3$ tons), which seems to have most of the essential equipment of a von Neumann probe, would require longer than 10^6 yr to reach the large-scale-probe-making stage, and with this upper bound the estimate of 3×10^8 yr for the time needed to explore the Galaxy is valid. As a rough comparison, recall that *homo sapiens* has been in existence for less than 10^6 yr.

I pointed out in (1) that exploration and/or colonization of the Galaxy could be modelled by the MacArthur-Wilson theory of island colonization. However, this theory must be modified before it can be applied to the problem of interstellar exploration/colonization. The MacArthur-Wilson theory assumes that the dispersal of colonizers is *random*, while the dispersal of von Neumann probes would not be. The von Neumann probes can use radio waves to determine which nearby stars have already been reached by other probes, and launch descendent probes only at those stars which have not yet been reached. Animal colonizers do not have an analogous technique to learn of uninhabited but habitable islands, and so they must use a random search strategy. This also means that a diffusion model (7,8) of interstellar colonization would be incorrect. Diffusion is basically expansion against resistance, and there would be no resistance to the expansion of the volume of stars colonized by the von Neumann probes. In the case of diffusion of gas molecules, the diffusing molecules collide with molecules of the ambient gas, and this leads to (in the usual Brownian motion derivation of the one-dimensional diffusion equation) an equally great probability of going backward as forward from a given collision site. Picture a one-dimensional array of points (stellar systems). The von Neumann probe at x_i would be programmed to send probes to all nearby unoccupied points (in the interval x_{i-r} to x_{i+r}, say) concentrating first on a probe to the x_{i+1} point. (It will have a memory of having arrived from the x_{i-j} point ($j \geqq 1$), so the direction is defined.) If we neglect the reproductive failure rate of the probe at x_i, then with probability one the motion will be forward to x_{i+1}, x_{i+2}, etc., at a rate greater than or equal to $[(d_{av}/v_{es}+t_{const}]$. (These symbols are defined in (1).) By adjusting r, the net probe reproductive rate, we can cancel out the effect of the failure rate. Extending this analysis to three dimensions introduces no new question of principle. The expansion speed would still be $[(d_{av}/v_{es}+t_{const}]$, at least in the later stages of expansion. The earlier stages might be dominated by t_{const}, since there are more than two neighbours. However, for upper bounds on t_{const} like those given above, the time for expansion throughout the Galaxy would be dominated by the properties of its later stages.

Newman & Sagan (**8**) have used a diffusion model of interstellar colonization to conclude that the time required to colonize the Galaxy would be several orders of magnitude above the 3×10^8 yr obtained in (1). If correct, this estimate would invalidate the arguments in (1) against the existence of advanced extraterrestrial intelligent beings. However, the work of Newman & Sagan seems vulnerable to the above general criticism of diffusion colonization models, namely that they cannot be applied to the colonization activities of intelligent beings. In illustration of this, note that two of their key formulae [Nos (77) and (78)] used to deduce the interstellar colonization rate imply $\Delta x = 2v\,(\psi\gamma)^{-1/2}$ for a two-dimensional colonization, where Δx is the average step size (the average distance travelled by the colonizers in going from one colonization site to another), γ is the relative population growth rate, ψ is the relative emigration rate and v is the average velocity of the colonization front. Applying this to the colonization of North America, we have from Newman & Sagan's own paper that $6 \times 10^{-4} \leqq \gamma \leqq 10^{-2}$ and $\psi = 3 \times 10^{-4}$. This gives $\Delta x \sim v\,(1-3) \times 10^3$ miles. For v, let us use 3000 miles/500 years. This yields $\Delta x \sim 10^4$ miles as the average step size, which is ridiculous. M.D.Papagiannis, who has independently discovered many of the arguments against ETI which I have used (**9,10,11**), has pointed out (**12**) another difficulty with the Neuman-Sagan analysis. They assume t_{const} to be 10^5 yr, which is much too high.

The conclusion of (1) that ours is the only technical civilization now existing in the Galaxy does not depend on any biological or sociological arguments except for the assumption that a communicating species would evolve in less than 5 billion years after the formation of an inhabitable planet and begin interstellar travel. Nor does the conclusion depend on the solar system formation rate, nor the number of habitable planets in a solar system, nor even the nature of habitable planets.

If the galactic age is 18 billion years or older (and this is possible according to current observations (1)), then we can relax the assumption of evolution of intelligence in about 5 billion years after planetary formation. In fact we can conclude that we are the only technological species which now exists in the Galaxy around main sequence stars of spectral type earlier than G3, assuming that any intelligent species would develop interstellar travel before its star leaves the main sequence. If the destruction of its solar system does not motivate a species to develop interstellar travel, it's hard to imagine what would. (Recall that our Sun is type G2, so it is a member of this class.) Stars in this class will leave the main sequence in about 13×10^9 yr or earlier, and so by the arguments in (1), the number of species around such stars now is less than

$$(13 \times 10^9 \text{ yr} + 3 \times 10^8 \text{ yr})/(18 \times 10^9 \text{ yr} - [13 \times 10^9 \text{ yr} + 3 \times 10^8 \text{ yr}]) \sim 3.$$

(That is, one-third of all stars that have ever existed in the Galaxy came into existence longer than 13·3 billion years ago. Since none of these stars produced an intelligent species and since the intelligent species production rate should be constant, this means that less than three species could exist now. Actually, two would be a better estimate than three, since there are twice as many stars younger than 13·3 billion yr as there are older than 13·3 billion yr.) This assumes a constant star formation rate. If we take into account the decrease of the star formation rate, we get one as the upper bound to the number of technological species now existing around stars earlier than G3.

For simplicity the analysis in (1) was based on the Drake equation, but it should be clear that the same arguments can be used with any other plausible equation for the number of communicating species in the Galaxy, with the same results.

In the first paper of this series (1), I discussed in some detail the possible motivations for interstellar travel on the part of intelligent beings. I emphasized that the desire to communicate with other intelligent species is sufficient to cause advanced intelligent beings to undertake the exploration of the Galaxy via von Neumann probes if not by other means. Such a motivation is required to be present in any species with whom we could communicate at our level of technology or higher. If it is assumed that such a motivation is not present in any advanced species, the SETI radio searches may as well be abandoned forthwith. Besides acting as a means of communication, the von Neumann probes could be used to explore and/or colonize the Galaxy, whatever the ETIs wanted. If ETIs are in general not possessed of the desire to communicate, explore, or colonize, then their psychological makeup must be utterly unlike ours. But such a psychology would contradict the principle of mediocrity which is used to justify their existence in the first place.

It has become generally accepted that the motivations for interstellar travel will not be a desire to relieve population pressure, nor will it be a desire of would-be space travellers themselves to colonize extrastellar planets. The travel time between stars – from a century to 10^4 years, depending on the expense of the rockets used – is so enormous that no space traveller nor his immediate descendents could expect to see the end of an interstellar voyage. Instead, the motivations for interstellar travel must be very long term; those who originate an interstellar probe cannot expect the project to be completed in their lifetimes if ETIs have life expectancies comparable to ours.

But the same must be true of any intelligent species which decides to undertake interstellar communication. If we accept Sagan's optimistic estimate (13) that civilizations are on the average about 600 light years apart, then the civilization which decides to begin sending radio signals cannot in general expect to receive a reply for 1200 years, a time period which is about the same as the time before an interstellar probe would arrive at the nearest star and begin to send back information. In other words, any beings who plan to communicate over interstellar distance must be so motivated that they are willing to continue a project for at least a thousand years. But if they are willing to wait a thousand years before receiving a radio signal from a nearby civilization, then they should be willing to wait a thousand years before receiving a signal from their own interstellar probes. Furthermore, the probes, in contrast to radio beacons, have many uses besides finding other intelligent species, as I pointed out in (1). Thus even if an advanced intelligent species were convinced – say by the publication of a paper like (1) – that they were alone in the Galaxy, they would still launch probes.

The probes could, for example, be used to colonize the Galaxy. The primary motivation for this would be to maximize the survival probability of intelligent life in general, and of the probe-making civilization in particular. (Supporters of SETI tacitly and often explicitly assume that extraterrestrial civilizations will want to communicate with others for this reason – see Appendix II.) I personally feel that advanced civilizations would be non-racist, or at least would contain individuals commanding large economic resources who were themselves non-racist, and would consequently see no distinction between intelligent robots – the von Neumann probes – and intelligent beings produced by natural evolution. An individual (or civilization) who is non-racist cares more about the preservation, propagation, and advancement of his cultural traditions, his ideas, and his modes of thinking than about the propagation of his body shape. As the sociobiologist Dawkins (14) points out, the evolution of reinforcing ideas, which he calls memes, is much more rapid and important under civilized conditions than the evolution of genes. Memes can be propagated just as easily in intelligent robots as in human beings, if not more so. I would guess that in any advanced civilization there would be some non-racist individuals who realize this and would attempt to propagate their memes throughout the cosmos by sending out von Neumann probes. Note also that transmission of information via radio as in the various CETI proposals is really an attempt to propagate memes. Just information about the technology, social structure, and so forth possessed by the transmitting civilization would be sent by radio. If the technology and social structure of the sending civilization is superior to that of the receiving civilization, the receiving civilization will adopt the superior science and social structure of the sending civilization. The memes of the former would replace the memes of the latter; in other words, the memes of the former have colonized new territory. I for one would regard this as a good thing. If an advanced civilization were to transmit to us the social techniques which would guarantee the abolition of war, I think everyone would agree that such techniques should be permitted to eliminate war-making ideologies – war memes – from the human social structure. In fact, as I argue in Appendix II, the hope that advanced extraterrestrial intelligent beings would transmit such beneficial memes to us with the replacement of our deficient memes by these extraterrestrial memes, is really what motivates most SETI proposals. But if the propagation of memes throughout the cosmos is regarded as a good thing, then von Neumann probes should be launched, for they (as opposed to radio beacons) can carry ideas to *all* stars – those surrounded by advanced technological civilizations, those with a single planet inhabited by primitive intelligent beings, and those with no living beings anywhere in the stellar system.

The important point to note is that *any* motivation for sending out radio signals to contact other intelligent species is also a motivation for launching von Neumann probes. The technology for the two methods of contact is comparable (**1**); the cost of the two methods is comparable (**15**); the waiting time before the first entry into a nearby solar system with von Neumann probes is comparable to the waiting time before first contact with the nearest civilization if the most optimistic estimates of galactic civilization density are correct. Furthermore, motivations can change on the original planet of the intelligent beings over the thousand or so years needed before a reply was received from the nearest interstellar civilization. If the radio beacon project was abandoned by a later generation after a century, the effort would be wasted from the point of view of the beings who started sending the signal. With von Neumann probes, it is only necessary to be motivated for interstellar exploration for the few years necessary to build the probes. After the probes are launched, a change in motivation on the original planet will not prevent the probes from carrying out their mission. Therefore, any civilization with individuals or groups who can command the economic resources to construct interstellar radio beacons and who can remain motivated or expect their successor to remain motivated for contact for the long waiting periods necessary for results, would also be willing and able to construct von Neumann probes. Since no civilization has done so, no advanced technological civilization interested in communicating with us now exists in this Galaxy.

ACKNOWLEDGMENTS

I am grateful for extensive discussions on the subject of this paper and (**1**) with a large number of people, especially K. & P.Anderson, J.D.Barrow, R.Bracewell, J.H.Brooke, N.Calder, F.Dyson, R.O.Hansen, S.Jaki, T.B.H. Kuiper, A.R.Martin, P.Morrison, C.Sagan, B.J.Sargent, L.Shepley, J.Silk, F.J.Tipler, Jr, J.A.Wheeler and P.Yasskin.

APPENDIX I:

EXTRATERRESTRIAL INTELLIGENCE AND THE ANTHROPIC PRINCIPLE

The Anthropic Principle, at least in its weak version, has begun to attract the interest of many cosmologists in recent years. The reason for this widespread interest is that the weak Anthropic Principle, which says that the properties of the Universe must at least be *consistent* with the existence of intelligent life in some form, holds the promise of being able to predict the values of the fundamental constants. Such an accomplishment would be beyond the power of the present-day grand unified theoretics. As 't Hooft (**16**) has pointed out, the grand unified theories can in principle predict such things as the fine structure constant (17), but only at the price of introducing other fundamental constants, such as the X-boson mass and various Higgs particle masses. There is no reason in principle why the Anthropic Principle should require additional physical constants in order to determine those physical constants with which we are familiar. However, in order to use the weak Anthropic Principle to determine these constants, it is necessary to assume that intelligent life, if it exists at all, *must* be roughly similar to human life (18,19). In particular, it is necessary to assume that all intelligent species must arise on a planet not earlier than 1–2 billion years after its formation (which follows from the estimates of the evolutionists on the extreme unlikelihood of intelligence evolving) and not later than 15 billion years after its formation (18,19) (which means that it must arise around a star earlier than G5 before the star leaves the main sequence). The weak Anthropic Principle does not require intelligent life to arise even on an Earth-like planet containing life – indeed it cannot make such a requirement if it is to be consistent with modern evolution theory (and the results of this paper). When the Anthropic Principle assumes that intelligent life, where it exists, must be similar to human intelligence, it is basically applying a principle of mediocrity. It is in *this* way that the Copernican Cosmological Principle – that the Earth's history is typical – is correctly applied to intelligent life. It is incorrect to use the Copernican Cosmological Principle to require the inevitable evolution of intelligence on an Earth-like planet. As pointed out in (2), such an approach smacks of the orthogenetic (teleological) view of evolution, and is utterly contrary to the Darwinian view of evolution. The present-day theory of evolution, the Modern Synthesis, stresses the great contingency of all branches of the evolutionary tree: those possible branches which could terminate in intelligent life are extremely small in number when compared with the total number of possible branches. To require intelligence on even a large fraction of Earth-like planets is basically an attempt to re-introduce teleology – final causes – into the biology of a single planet. The history of science over the past few centuries demonstrates the futility of such an approach. Even those who argue for a place for teleology in modern science have admitted it only on a cosmic scale (20).

An example of such cosmic teleology is the principle that the Universe is not merely *consistent* with the existence of intelligent life, but in fact intelligent life is *certain* or even *required* to evolve somewhere – this is called the Strong (18) or Participatory (21) Anthropic Principle. If this principle is to be consistent with the biologists' argument that the evolution of intelligence is unlikely to have evolved even once in the visible Universe, then we are forced to conclude that the Universe is either open (22), or if closed then the deceleration parameter q_0 is very close to 1/2. Furthermore, the Universe must have large regions where the matter density is roughly homogeneous (23). These requirements are necessary if the product of the number of Earth-like planets with life N with the probability P of evolution of intelligence on such a planet is to equal one. In short, the Universe must be even more enormous than Wheeler's estimate (24) based on the lifetime of a closed Robertson-Walker Universe. Note also that this estimate of the size of the Universe based on the Strong Anthropic Principle does not require the assumption of universal homogeneity and isotropy as does the Wheeler estimate. Thus this estimate based on the biologists' estimate of P is not open to the criticism (25) that it is possible to have a small, very anisotropic (100 kps radius at maximum) Universe which lasts for many billions of years. If intelligent life were inevitable on an Earth-like planet, then such an anisotropic Universe would satisfy the strong anthropic principle. If on the other hand the biologists' view of evolution is correct, and the view of evolution taken by physicists Morrison & Sagan is wrong, then such a Universe *would not* satisfy the strong anthropic principle.

In the nineteenth century there was a fierce debate between physicists and biologists over evolutionary principles. Lord Kelvin detested (26) the contingency of Darwinian evolution (he could accept (26) an 'inevitable development' evolutionary view somewhat akin to that espoused to Morrison & Sagan (1)). To attack the Darwinian theory, he calculated that no known forms of energy could supply the Sun and Earth with heat for the time scales required by the contingent Darwinian theory (27). In the case of the Sun at least (27), his calculation was correct. Historically, Kelvin's argument was used to discredit the biologists' understanding of evolution. However, had it been assumed that the biologists' understanding of purely biological evidence was correct, Kelvin's argument would have lead to a prediction: some unknown force is responsible for the Sun's light and the Earth's heat. In fact, the American geologist Chamberlain actually made such a prediction by assuming the biologists to be right and Kelvin's estimate of the age of the Sun to be wrong. Chamberlain argued that if the biologists were correct, then Kelvin's calculations necessarily implied the existence of an unknown form of energy:

> 'Is present knowledge relative to the behaviour of matter under such extraordinary conditions as obtain in the interior of the Sun sufficiently exhaustive to warrant the assertion that no unrecognized sources of heat reside there? What the internal constitution of the atoms may be is yet open to question. It is not improbable that they are complex organizations and seats of enormous energies. Certainly no careful chemist would affirm either that the atoms are really elementary or that there may not be locked up in them energies of the first order of magnitude.... Nor would they probably be prepared to affirm or deny that the extraordinary conditions which reside at the centre of the Sun may not set free a portion of this energy' (28).

But the above words were written in 1899, much too late to suggest a search for the power source. The nineteenth century physicists' belief that they knew more about biology than the biologists caused them to miss a golden opportunity. Are twentieth century physicists going to make the same error? One physical consequence of the biologists' value for P is a value for q_0, if the strong Anthropic Principle is accepted. Are there other consequences?

If so they may never be found, because anti-anthropocentric teleology retains a strong hold on the physics community. In *Life Cloud*, Fred Hoyle asserts:

> 'The idea that in the whole Universe life is unique to the Earth is essentialy pre-Copernican. Experience has now repeatedly taught us that this type of thinking is very likely wrong. Why should our own infinitesimal niche in the Universe be unique?' (29).

Furthermore, in a review of an earlier version of this paper, Carl Sagan contended:

> 'But then what are we to make of Tipler's introduction of the so-called "anthropic principle" which, I believe hinders rather than helps Tipler's position? In this debate are extremely strong echoes of the confrontation between the Copernican and Ptolemaic world views' (personal communication).

APPENDIX II:

THE MOTIVATIONS BEHIND THE MODERN BELIEF IN EXTRATERRESTRIAL INTELLIGENCE

In (1) I suggested that the main motivation of modern proponents of the ETI concept was, in Carl Sagan's words, 'The expectation that we are going to be saved from ourselves by some miraculous interstellar intervention'. Sagan was deriding UFO believers, but his remarks also apply to him, as a reading of his popular writings on ETI will show. For example, in his latest book, *Broca's Brain* (30), he asserts on page 275 that the mere detection of an ETI radio signal will give us

> '... an invaluable piece of knowledge: that it is possible to avoid the dangers of the period through which we are now passing ... such knowledge, it seems to me, might be worth a great price.'

And on page 276:

> 'The translation of a radio message from the depths of space ... holds the greatest promise of both practical and philosophical benefits. In particular, it is possible that among the first contents of such a message may be detailed prescriptions for the avoidance of technological disaster, for a passage through adolescence to maturity.... It is difficult to think of another enterprise within our capability and at a relatively modest cost that holds so much promise for the future of humanity.'

[In fairness to Sagan, I should remark that he denies being motivated by a hope of extraterrestrial salvation] (personal communication).

In his introduction to his anthology, *Interstellar Communication*, the Harvard astrophysicist A.G.W.Cameron writes:

> 'If we can now take the next step and communicate with some of these [advanced extraterrestrial] societies, then we can expect to obtain an enormous enrichment of all phases of our sciences and arts. Perhaps we shall also receive valuable lessons in the techniques of stable world government' (3).

In his book with Wickramasinghe, *Life Cloud*, the steady-state cosmologist Fred Hoyle contends:

> '... In the analogy of ... English soccer, the achievement of space communication would put us in the position of a club newly admitted to the fourth division. There would be an enormous way to go before we could hope to climb up among the big boys of the first division.... A few centuries hence space travel will reach its natural limitations. What then? Degeneracy or a determined effort to climb to the first galactic division? The choice hardly needs serious discussion. Our long evolutionary experience as the Earth's outstanding predator will inevitably force us to make the attempt, and it is equally inevitable that the attempt will supply a much-needed unifying influence within our species – a unifying influence that has been so sadly lacking through recorded history' (32).

But amongst all the articles on ETI written by supposedly sober scientists, the one in which the semi-religious salvation motivation behind the recent interest in ETI stands out most clearly is the paper, "On hands and knees in search of elysium" by Frank Drake:

> 'Interstellar contact would undoubtedly enrich our civilization with scientific and technical information which we could obtain alone only at very much greater expense. More than that, it is extremely likely that any civilization we detect would be more advanced than ours. Thus it would provide us with a glimpse of what our own future could be.... From this we could understand the way of life most likely to be best for us in the long run' (33).

Drake then goes on to argue that we could probably learn the techniques of 'immortality' from these beings:

> 'I fear we have been making a dreadful mistake by not focusing all searches... on the detection of the signals of the immortals. For it is the immortals we will most likely discover.... An immortal civilization's best assurance of safety would be to make other societies immortal like themselves, rather than risk hazardous military adventures. Thus, we could expect them to spread actively the secrets of their immortality among the young, technically developing civilizations' (33).

When the English natural philosopher William Whewell published in 1853 a book which criticized the belief in extraterrestrial intelligent beings (2,34), the optical physicist Sir David Brewster was outraged (35). Brewster's personal version of Christianity was based on his belief in extraterrestrial intelligent beings (he had the idea that human souls were reborn on other planets: this was the immortality promised in the New Testament). Consequently, Brewster attacked Whewell with a missionary zeal (36). Today, Drake evinces the same missionary zeal in support of ETI:

> 'The obstacle to progress is not nature, certainly, nor even the level of our technology. It is our own motivation and wisdom. A large fraction of our population must be persuaded of the value if we are to invest the required resources (to search for ETI)' (33).

To me the clearest evidence for a save-the-world semi-religious motivation underlying SETI proposals is the treatment pro-ETI reviewers give critical papers. For example, paper (1) was originally submitted to *Science*, where it was reviewed by Sagan. Sagan rejected the paper for a number of reasons which were plausible, but I thought I could refute them by presenting my argument in more detail. I thus made modifications in the paper to answer (at least in my opinion) his objections. *Science* indicated, however, that it did not wish to consider the paper further (it did not forward my reply to Sagan), so I submitted the revised version to *Icarus*. Sagan was again the referee. Although the paper had been changed to reflect Sagan's criticisms, Sagan rejected the paper with a referee report *which was identical to the referee report for Science*. Had Sagan rejected the paper with a claim that my changes were inadequate, or asked someone else to referee the paper (and reply to my changes), I probably would have disagreed with the rejection, but I would have felt the rejection was based on scientific grounds. As it is, I feel as if I have become involved in a theological debate.

Philip Morrison's reaction to my paper is also instructive: although there is no suggestion in my paper that we should completely give up on radio searches (a radio search would, after all, test the assumptions in my paper), Morrison said:

'... Should we not listen for the odd beacon, or even the radio signal updating their machine in this neighbourhood, which will come here one of these eons? I quite agree we could give up after say a century or two of empirical search, but not after a few Tipler-months of analysis' (personal communication).

One wonders if Morrison would be so afraid that anti-ETI papers would cause us to abandon radio searches if he were not also afraid that to abandon radio searches would be to abandon all hope of extra-terrestrial salvation (**37**).

My experience with pro-ETI referees is not unique. Professor Michael Hart, who is a leader in criticizing some of the assumptions made by the ETI-proponents (**38**), informed me that he also has had great difficulty in getting anti-ETI papers published, particularly in the US. There seems to be less difficulty in publishing such papers in Britain, where opponents of the ETI concept are about as numerous as proponents.

There is considerable evidence that the intellectual climate of opinion on ETI has changed in the past few years. In fact, a short version of my paper (**1**) was recently published in the American journal *Physics Today* (**39**). (The paper was apparently not sent to referees; the editor made the decision to publish it himself.) The basic argument, the if-they-existed they-would-be-here thesis, has been actually independently discovered by a number of astronomers and physicists in the 1974–1980 period. Iosef S.Shklovskii, who with Carl Sagan, was the author of *Intelligent Life in the Universe* (**40**), which was probably the most influential book in spreading the ETI doctrine during the 1960s, has changed his mind about the existence of ETI, citing just this argument (**41**). The argument has also been independently developed by Dyson (**3**), Papagiannis (**9–12**), and Hart (**38**).

The question is, why has this argument against the existence of ETI been independently discovered by a number of people in the 1974–1980 period and not before? Indeed, one wonders why Shklovskii & Sagan did not themselves put forth the von Neumann probe idea, since the spread of galactic civilization via robot intelligent beings was discussed in the final chapter of their book. If one accepts the idea of interstellar travel, and accepts the idea that it is possible to build intelligent self-reproducing robots, then one is forced to conclude that if an advanced civilization existed, they would be here. Yet Shklovskii and Sagan did not point this out. Some scholars have suggested that people did not really believe in the possibility of interstellar travel in the 1960s, in part because interstellar travel was always pictured as involving ultrarelativistic rockets (which are prohibitively expensive), but also because exploration and/or colonization was thought to require the existence of Earth-like planets in the target solar system. (Only on such planets, it was believed, could colonies be formed.) But the wide publicity given the proposals of G.K.O'Neill to build colonies not on planets but in interplanetary space changed people's view of the possibility of interstellar colonization. In fact, G.K.O'Neill himself independently discovered the von Neumann probe interstellar colonization mechanism, and concluded that ETIs do not exist [personal communication].

The argument seems conclusive to me. I think we shall have to accept the fact that we are unique in the Universe.

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