Is the Strong Anthropic Principle Too Weak?

A. Feoli and S. Rampone
Dipartimento di Scienze Fisiche "E.R.Caianiello"
Università di Salerno
I-84081 Baronissi (Salerno)
Italy

Abstract

We discuss the Carter's formula about the mankind evolution probability following the derivation proposed by Barrow and Tipler. We stress the relation between the existence of billions of galaxies and the evolution of at least one intelligent life, whose living time is not trivial, all over the Universe. We show that the existence probability and the lifetime of a civilization depend not only on the evolutionary critical steps, but also on the number of places where the life can arise. In the light of these results, we propose a stronger version of Anthropic Principle.

Entia non sunt multiplicanda praeter necessitatem

W. Occam

1 Introduction

In a seminal paper [1], Brandon Carter proposed two versions of the Anthropic Principle (AP). The weak interpretation, against the "dogma" of the Copernican principle, takes into account "the fact that our location in the Universe is necessarily privileged to the extent of being compatible with our existence as observers". Furthermore he called Strong Anthropic Principle *(SAP)* the statement *"The Universe (and hence the fundamental parameter on which it depends) must be such as to admit the creation of observers within it at some stage"*. Later on many versions and interpretations of the AP have been proposed. A collection of the anthropic arguments is contained in the Barrow and Tipler's book [2] where four different statements of AP are defined: Strong *(SAP)*, Weak *(WAP)*, Participatory *(PAP)*, and Final *(FAP)* Anthropic Principle. While some of these statements appear to have teleological overtones, AP proper sense is that our existence, as intelligent life form evolved on a earth-like planet, is a matter of fact, and Universe laws can not contradict this fact.

Starting from the AP, Carter [3] connected the number n of very improbable steps in the Homo Sapiens evolution to the existence length t_0 of a biosphere, and to the evolution time t_e required to produce an intelligent species on an earth-like planet. Carter's estimation, discussed in Section 2, of how long a biosphere will continue to exist after an intelligent life evolution was $t_0 - t_e = t_0/(n+1)$. By the experimental evidence of our own evolution completed in a time $t_e \simeq 0.4t_0$ Carter was forced to conclude that there are at most two critical steps, even if he "had previously inclined to think that the appropriate value of n [...] was likely to be very large".

Later Barrow and Tipler [4] estimated in fact a much larger n, and they used this argument just to exclude the existence of extraterrestrial human like beings. Unfortunately this result holds also for the Homo Sapiens. It gives the enormous improbability of the evolution of intelligent life in general, and on Earth in particular.

Since Barrow and Tipler's book, the scientific and philosophical debate about AP has been going on with some criticisms and some enthusiastic supporters [5].

For example Rosen [6] shows "the conviction that AP is among the most important fundamental principles around, even [...] the most basic principle we have. What physical phenomenon in the whole wide world are we most sure of, have least doubts about, have the most confidence in? The answer is our own existence. Thus the most physical explanation is one based on our own existence, and that is what is so special about AP".

On the contrary Hawking [7] thinks that "it runs against the tide of the whole history of science. [...] The Earth is a medium-size planet [...] in the outer suburbs of an ordinary spiral galaxy, which is itself one of about a million million galaxies in the observable Universe. Yet the SAP would claim that this whole vast construction exists simply for our sake. Our Solar System is certainly a prerequisite for our existence, and one might extend this to the whole of our galaxy to allow for an earlier generation of stars that created the heavier elements. But there does not seem to be any need for all those galaxies, nor for the Universe to be so uniform and similar in every direction on the large scale."

This is not an objection to the SAP really, but to some teleological arguments related to SAP. Since its appearance, SAP has been forced to have a teleological meaning. For example, Press explicitly warns the readers of Barrow and Tipler's book that the authors want to convince them "of an astounding claim: there is a grand design in the Universe that favours the development of intelligent life" [8].

Anyway in this paper, in order to revise the Carter's formula, we answer Hawking's objection as well. We discuss some assumptions of the Carter's model, and we stress the importance of the Universe extent both in the probability estimation of intelligent life evolution, and in the living time of a civilization (Section 2). We show that these quantities depend not only on the evolution critical steps, but also on the number of places where life can arise.

In the light of our results, a stronger formulation of Anthropic Principle is required, and we give this formulation trying to conciliate both the Copernican and Anthropic principles, following the trend started by Gott III [9] (section 3). Finally we briefly discuss the teleological implications of this point of view (section 4).

2 Carter's formula revisited

2.1 Mankind evolution probability on Earth is worse than expected

Carter's model rests essentially on three steps.

- The probability that an unlikely evolutionary step, which is thus "slow", compared with the majority of evolutionary steps, will happen at time t is

$$P_i(t) = 1 - e^{-\frac{t}{\alpha_i}} \simeq \frac{t}{\alpha_i} \tag{1}$$

where α_i is the timescale for the occurrence of the ith "improbable step", with the requirement $\alpha_i >> t_0$, where t_0 is the biosphere existence length.

- The n "improbable steps" are statistically independent,

$$P(t) = \prod_{i=1}^{n} \frac{t}{\alpha_i} \tag{2}$$

- The conditional probability that mankind evolves at time t, given that it occurs on before t_0 is

$$P'(t) = \left(\frac{t}{t_0}\right)^n \tag{3}$$

Using (3), the expectation value $\bar{t} \simeq t_e$ for the appearance instant of intelligent life is

$$\bar{t} \equiv \int_0^{t_0} t\, dp' = t_0 \frac{n}{n+1} \tag{4}$$

This value implies a strong bound to the time a biosphere will continue to evolve in the future

$$t_0 - \bar{t} = \frac{t_0}{n+1} \tag{5}$$

This bound has been used to exclude the existence of extraterrestrial intelligent beings: most earth-like planets around G type stars will be destroyed long before or just after intelligent beings have a good chance of evolving.

Why does this result not hold on Earth? It is trivially true that humans must have evolved much before life ceased on Earth, but *reasonable* values of n give *unreasonable* values of $t_0 - \bar{t}$, even assuming the "optimistic" Carter's estimation. [1]

[1] We do not think, as also pointed out by Carter [3], that there are n steps in the Homo Sapiens evolution which are statistically independent, but we would rather believe that the events are chained in such a way that one step may occur only if the previous one has happened. Our opinion is supported by several studies about the evolution (see for example [10]). If this is true, Carter's evaluation appears to be overestimated (This claim is proved in the Appendix I).

Might Carter's derivation be an argument not only against the existence of extra terrestrial intelligence, but also against our own existence? Or has Earth some special properties compared to the rest of the Universe?

2.2 Intelligent life evolution probability in the Universe is better than expected

Just following the Mediocrity Principle we must think that Earth is not a special locus in the Universe but a number N of earth-like planets certainly exist, and this number is related to the number of galaxies[2] Could this influence the Carter's estimation?

It is very easy, by using a binomial distribution, to compute the probability that a number K of civilizations can develop on these N planets, starting from the hypothesis of the Carter's model. For the sake of simplicity we consider $\alpha_i \simeq \alpha_j \quad \forall i, j$.

$$P(K civilizations) = \binom{N}{K} \left(\frac{t}{\alpha}\right)^{nK} \left[1 - \left(\frac{t}{\alpha}\right)^{n}\right]^{N-K} \tag{6}$$

In this case the development probability of at least one civilization all over the observable Universe is

$$P(t) = 1 - \left[1 - \left(\frac{t}{\alpha}\right)^{n}\right]^{N} \tag{7}$$

This evidences that the number n of very improbable steps can be, and in fact it is, balanced by the abundance (N) of trials. See for example Figure 1, where we report a plot of $P(t)$ as function of N, once fixed t, α, and n.

[2] The Drake's formula [11] allows a probabilistic estimation of the technological civilizations we could find in our Galaxy. If we take only some terms of the formula and we consider in the same way all the other observable galaxies, we can obtain the probable number N of earth-like planets in the Universe where an evolution could have started (Details are reported in the Appendix II).

This result holds also when we substitute the general expression

$$P(t) = 1 - \left[1 - \prod_{i=1}^{n}\left(1 - e^{-\frac{t}{\alpha_i}}\right)\right]^N \tag{8}$$

to the previous one.

2.3 How long does a biosphere remain habitable after intelligent life evolution?

Now we modify the third Carter's step (3), based on the fact that an intelligent species has been produced before t_0 on Earth, by conditioning the probability (7) on the evidence that at least one civilization has developed all over the Universe.

By applying the Bayes formula we have

$$P'(t) = \frac{1 - \left[1 - \left(\frac{t}{\alpha}\right)^n\right]^N}{1 - \left[1 - \left(\frac{t_0}{\alpha}\right)^n\right]^N} \tag{9}$$

Then we compute the expected appearance time of at least one civilization all over the observable Universe, given that it is found on at least one planet before t_0.

By setting $\gamma_N = \frac{1}{1-\left[1-\left(\frac{t_0}{\alpha}\right)^n\right]^N}$ we have

$$\bar{t} = \gamma_N \int_0^{t_0} \frac{d}{dt}\left[1 - \left(1 - \frac{t^n}{\alpha^n}\right)^N\right] t dt \tag{10}$$

$$= \gamma_N N n \int_0^{t_0} \frac{t^n}{\alpha^n}\left(1 - \frac{t^n}{\alpha^n}\right)^{N-1} dt \tag{11}$$

By the Newton formula

$$\left(1 - \frac{t^n}{\alpha^n}\right)^{N-1} = \sum_{k=0}^{N-1} \binom{N-1}{k} \left(\frac{t}{\alpha}\right)^{nk} (-1)^k \tag{12}$$

we have

$$\bar{t} = \gamma_N N n \int_0^{t_0} \sum_{k=0}^{N-1} \binom{N-1}{k} \left(\frac{t}{\alpha}\right)^n \left(\frac{t}{\alpha}\right)^{nk} (-1)^k dt \tag{13}$$

$$= t_0 \gamma_N N n \sum_{k=0}^{N-1} \binom{N-1}{k} \frac{(-1)^k}{n(k+1)+1} \left(\frac{t_0}{\alpha}\right)^{n(k+1)} \tag{14}$$

and, when $N = 1$, we recover the Carter's result (4).

So the time a biosphere will continue to evolve in the future is

$$t_0 - \bar{t} = t_0 \left(1 - \gamma_N N n \sum_{k=0}^{N-1} \binom{N-1}{k} \frac{(-1)^k}{n(k+1)+1} \left(\frac{t_0}{\alpha}\right)^{n(k+1)}\right) \tag{15}$$

We can see, in Figure 2, $\bar{t}$ as a function of N, and, in Figure 3, the corresponding behaviour of $t_0 - \bar{t}$ in terms of N (in the plot the values are scaled by t_0). It is easy to verify that the expected living time of a civilization increases with the number of earth-like planets in the Universe[3]

3 Mediocrity Anthropic Principle

So we can answer Hawking's objection with our demonstration that the abundance of creation is *necessary* for the life evolution: the occurrence of intelligent life is related, according to the equations (7,9,15), to the enormous number of galaxies. It seems that the constraints on the initial conditions and universal constants invoked by AP are not enough to avoid contradictions with the mankind existence (Carter's formula (5) is an example). They form just a necessary but not sufficient condition.

We suggest a stronger version of SAP. A stronger formulation of SAP must include the existence of a large number N of earth-like planets such to balance the number of improbable steps n necessary for evolution. It can be formulated in this way: *"The Universe*

[3] For computing purposes a useful approximation of (14) is given by

$$\bar{t} \leq t_0 \frac{n}{n+1} \gamma_N N \left(\frac{t_0}{\alpha}\right)^n \left[1 - \left(\frac{t_0}{\alpha}\right)^n\right]^{N-1}$$

(and hence both the fundamental parameter on which it depends, **and the amount of places where the evolution can take place***) must be such as to admit the creation of observers at some stage,* **and to assure them a not trivial living time***"*. As it rests on the Mediocrity Principle, we call it *Mediocrity Anthropic Principle* (MAP).

4 A little bit of teleology: classical and quantum finalism

In our results there is no compelling evidence of a "design" in the Universe. We can think that intelligent life is born by chance thanks to the enormous number of galaxies.

On the other hand a finalist interpretation is still possible. In fact we want to stress that there are different kinds of finalism.

In classical mechanics one can strike a target with an arrow using suitable initial conditions: the finalist strategy is the choice of the initial velocity $\vec{v_0}$.

In quantum mechanics, if we consider a potential barrier V and we want to detect at least one particle with energy $E < V$ on the other side, we must use another strategy. We cannot calibrate the initial conditions so that the winning behaviour is to shoot a lot of particles through the barrier. When the game is ruled by probabilistic laws, the abundance of attempts is the best strategy to follow: this is an example of quantum finalism.

In the cosmological case the equations (7,9,15) suggest that both ways have to be followed. It seems that the fine tuning of initial conditions and universal constants is not enough to assure the birth of Homo Sapiens. The extent and abundance of creation in the Universe could complete the right finalist strategy.

Acknowledgments

The authors are grateful to Gaetano Scarpetta and Rossella Sanseverino for useful suggestions.

References

[1] B.Carter, "Large number coincidences and the Anthropic principle in cosmology," *in IAU Symposium* **63***: Confrontation of cosmological theories with observational data* edited by M. Longair (Reidel, Dordrecht, 1974), pp. 291-298.

[2] J.D.Barrow and F.J.Tipler, *The anthropic cosmological principle* (Clarendon, Oxford, 1986), pp.15-23.

[3] B.Carter, "The anthropic principle and its implications for biological evolution", Phil. Trans. R. Soc. Lond. A **310**, 347-363 (1983).

[4] J.D.Barrow and F.J.Tipler, *The anthropic cosmological principle* (Clarendon, Oxford, 1986), p. 556.

[5] Y.V.Balashov, "Resource letter AP - 1: The anthropic principle", Am.J.Phys. **59**, 1069-1076 (1991) and references therein.

[6] J.Rosen, "The anthropic principle", Am.J.Phys. **53**, 335-339 (1985).

[7] S.W.Hawking, *A brief history of time* (Bantam, New York, 1988), p. 126.

[8] W.H.Press, "A place for teleology?", Nature **320**, 315-316 (1986)

[9] J.R.Gott III, "Implications of the Copernican principle for our future prospects", Nature **363**, 315-319 (1993).

[10] I.Asimov, *A short history of biology* (The Natural History Press, New York, 1964); Y.Iwasa, S.A.Levin, "The timing of life history events", Journal of Theoretical Biology **172**(1), 32-42 (1995).

[11] F.D.Drake, *Intelligent life in space* (Macmillan, NY, 1960); C.Sagan, *Communications with extraterrestrial intelligence* (MIT Press, Cambridge, Mass. 1973); L.R.Doyle (ed.), *Circumstellar habitable zones* (Travis House, Menlo Park, California, 1996).

Appendix I

In this Appendix we show that Carter's evolution probability (2) is an overestimation when the evolution steps are chained.

In this framework we divide the timescale in discrete intervals of τ width and suppose that the occurrence probability of the ith "improbable step" at a given instant of time $t_i = m_i\tau$, given it did not occur in the $m_i - 1$ previous instants is

$$\frac{1}{\alpha_i}\left(1-\frac{1}{\alpha_i}\right)^{m_i-1} \tag{16}$$

If we require the occurrence of n events in a fixed series of instants such that $0 < t_1 < t_2 < ... < t_n$, the probability of the whole sequence is

$$\prod_{i=1}^{n}\frac{1}{\alpha_i}\left(1-\frac{1}{\alpha_i}\right)^{m_i-m_{i-1}-1} \tag{17}$$

For the sake of simplicity we can assume that $\alpha_i \simeq \alpha_j$ so that the equation (17) becomes:

$$\left(\frac{1}{\alpha}\right)^n \left(1-\frac{1}{\alpha}\right)^{m_n-n} \quad \text{where} \quad m_n - n = \sum_{i=1}^{n} (m_i - m_{i-1} - 1) \quad \text{and} \quad m_0 = 0 \tag{18}$$

In this way the probability the Homo Sapiens evolves by a time $t = t_n$ is

$$P(t) = \frac{n\tau}{t} \binom{\frac{t}{\tau}}{n} \left(\frac{1}{\alpha}\right)^n \left(1-\frac{1}{\alpha}\right)^{\frac{t}{\tau}-n} < \binom{\frac{t}{\tau}}{n} \left(\frac{1}{\alpha}\right)^n \left(1-\frac{1}{\alpha}\right)^{\frac{t}{\tau}-n} \tag{19}$$

where the first term takes into account all the possible choices of $t_1, t_2, ..., t_{n-1}$ such that $0 < t_1 < t_2 < ... < t_{n-1} < t_n = t$. If we assume a great value for t_0, we can approximate (19) by a Poisson distribution, and neglect τ, by assuming α timescaled in the same way as t.

$$P(t) = \frac{1}{n!} \left(\frac{t}{\alpha}\right)^n e^{-\frac{t}{\alpha}} << \left(\frac{t}{\alpha}\right)^n \tag{20}$$

Appendix II

Frank Drake conceived an approach, the *Drake equation*, to bound the terms involved in estimating the number of technological civilizations that may exist in our galaxy. The Drake equation identifies specific factors which play a role in the development of such civilizations. From this equation we take only the followings:

- R_*, the rate of formation of suitable stars,
- f_p, the fraction of stars with planets (Extra sun system planets are proved to exist. A recent example is the one discovered near the star Lalande 21185.),
- n_e, the number of earth-like planets per planetary system,
- f_l the fraction of those planets where life develops.

These factors have been evaluated on the about 10 billions of known galaxies, to obtain an estimation N of earth-like planets in the Universe. Although there is a questionable estimation of the parameters of this equation, a not-optimistic evaluation puts N in the order of 10^{13}.