Energy use, entropy and Extra-terrestrial Civilizations

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Abstract. The possible number of extra-terrestrial civilizations is estimated by the Drake-equation. Many articles pointed out that there are missing factors and over-estimations in the original equation. In this article we will point out that assuming some axioms there might be several limits for a technical civilization. The key role of the energy use and the problem of the centres and periphery strongly influence the value of the *L* lifetime of a civilization. Our development have several edifications of the investigations of the growth of an alien civilization.

1. Introduction

One of the most puzzling questions of mankind is whether there are other civilizations in the Cosmos and the many research activities that address this subject are generically that called Search for Extraterrestrial Intelligence (SETI).

The number of actual civilizations in our Galaxy can be estimated (we will not interested in extragalactic scales in accordance with the original goal of Drake) by the Drake Equation, which was outlined by Dr Frank Drake as a focus for the Green Bank Conference in 1961. The equation contains the most important factors regarding the necessary conditions of intelligent life and is normally expressed as:

$$N = R_* n_p f_{pl} f_l f_{civ} L \qquad (1).$$

where N is the number of intelligent civilizations in our Galaxy, R_* means the rate of star formation, n_p is the number of planets in the habitable zone around a star, f_{pl} is the fraction of habitable planets, f_l is the fraction of life-bearing planets, f_{civ} is the fraction of civilized ones, and finally L is the average lifetime of an intelligent civilization. [1,2].

We pointed out earlier that some of these factors over-estimate N and there are missing factors in (1). [3] If we assume that there exist some axioms valid on every extra-terrestrial (ET) civilizations we are able to give a new estimation of the L_{com} factor. This factor was introduced in [3] and means the communicative lifetime of an alien civilization. The majority of the matter of a rocky planet is from the dust of a supernova explosion therefore likely contains elements useful for nuclear fission. Lithium which is also convenient for energy production via nuclear fusion was synthesized in the primordial nucleon synthesis. Its abundance is matter of disputes [4] and may changed by giant stars [5]. We

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assume here that a rocky planet has the same amount of lithium source as the Earth (and we allow only one order of magnitude step in each direction).

If the Darwinian evolution is correct, and the role of the Maximum Power Principle (MPP) is valid in every ET ecosystems we must assume

- An exponential growth in technology, population, energy usage while abundant energy resources are present
- Shorter life intervals for these civilizations

In the second section we investigate our axioms on the role of the evolution and the MPP. After this we add together the time intervals of different energy sources as main sources in an ET society. Finally we investigate the role of the centres and peripheries in a society which has no more available abundant energy sources. It contains some consequences for the communicative lifetime of a civilization like this.

2. Axioms and suppositions

In this section we discuss how many axioms we need to imagine a technical civilization on a distant rocky planet.

As we know the Darwinian evolution describes the development of the species on the Earth but it may very possibly regulate the evolution of organic forms everywhere where life once emerged. Therefore its universal validity is our first axiomatic assumption.

The second assumption is the presence and validity of the MPP. It was introduced and detailed in [6,7] and states that species which use the available energy with greater speed can evolve faster. In other words the most important attribute of the evolution in consideration of energy use that evolution follows th steepest descents in the energy use. If a technical civilization was able to emerge from the natural environment it uses more energy than which is naturally available. This type of a society can cross the limits which come from the operation of the natural ecosystem. Therefore this society can grow until the energy sources will be depleted. I.e. our second axiomatic assumption is the presence and operation of the MPP.

Finally we assume that the evolution is a long process and contains many dead ends. Hence there are many (possibly carbon based) remnants under the surface which accumulate energy.

3. Energy use and technical civilizations

The continuous growth of a society causes growing energy demand. If the axioms which was detailed we can expound the connection between the development and energy use. The second law of thermodynamics can be interpreted alternatively: processes decrease the work-performing capability of the energy. I.e. the MPP guarantees that the

$$\frac{\partial S}{\partial t} = \max. \qquad (2)$$

partial derivative will have its maximum value. If the equalization is finished there will be no more thermodynamic free energy therefore the system is in its lower available state. Hence the economic (or social, technical etc.) growth is purely the continuation of the evolution of species in human circumstances and the consequence of the MPP because mankind’s efforts to grow as fast as possible are in accordance with the MPP and equation (2).

Therefore the total amount of an accumulated energy source (signed by R) lasts for

$$T_{use} = 1/k \times \ln(r_0 / R + 1) \qquad (3)$$

The k means the fractional growth in the consumption per year, r_0 is the initial consumption of the investigated source.

Table 1. Different energy sources and their usage times

Type	Assumed amount (Gigatons)	Usage time (years)
Hydrocarbons	10^5-10^{10}	10^2-10^4
Fissile materials	0.01-10	10^2-10^3
Lithium 6	0.001-100	10-10^3
Lithium total	0.01-1000	100-10^4
Materials from the planetary system	10^{10}-10^{58}	10^4-10^9

We assumed that the transitions from a depleting source to a richer one happen when the depletion just have started, i.e. the growth is continuous. The amount of these sources allows a technical civilization to exist for ~ 10^4-10^9 years order but there will be a (recently unknown) distribution according to the age at the collapse. There might civilizations which did not collapse and presently are active.

4. New estimation of L_{com}

The L_{com} means the time interval in which we can accept signals from a non-silent technologically developed ET civilization. It was originally assumed that whenever a civilization enters the realm of communicative technologies it will remain there for indefinite time. Therefore L_{com} is estimated to be in the orders of billion years.

However if our chain of thought is correct, there were civilizations which collapsed due to a crisis caused by energy shortages and/or ecosystem collapse. These events might be more common in the Universe as the MPP is valid and makes societies to grow and use more energy and raw materials. If a society's growth is led by apparently abundant resources the control of nature ceases over it and the society does not recognize feedbacks from the nature. Therefore the short term regulators do not have any effect on the growth hence this growth exceeds the sustainable level. When the apparently abundant source is gone society collapses.

According to these results L_{com} might be with 0-6 orders of magnitude smaller. In order to avoid giving irresponsible estimations we have to consider the following:

- There are possibly other abundant energy sources in a planetary system. If a society is able to use the lithium based fusion for 10^4 years with growth rate of 5%, it will be 714 times bigger energy consumer at the end. It means the colonization of the near space.
- It is possible to construct a sphere around the central star and use all of its energy. In this case there will be a sphere with IR-radiaton in the centre of this planetary system.
- If there is failure during an energy source change due to technological gaps the collapse may occur.
- Not only the amount of energy sources counts but their flow is also important. If there is a bottleneck effect on this field for a growing civilization it may collapse.

We do not know any of these civilizations but it is not reasonable to suppose that all of them have been able to solve the problem of energy source transitions. Therefore it is very likely that L_{com} might be with 0-6 orders smaller

5. Collapse due to energy shortages. Distribution of goods

If an ET society's growth is in danger due to an energy crisis there is a new possibility to avoid the sudden collapse and the centres of these civilizations will be able to continue growth [8]. The distribution of goods in a growing society where MPP is valid follows a power law graph.

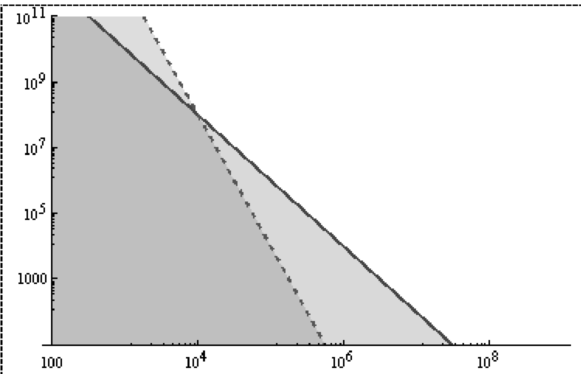

Figure 1. Power law distribution of goods in a society similar to ours. If we consider the group of riches with a step of one magnitude more richness there will be a step downward in the magnitude of the number of the persons who owe that richness. If the centre takes energy from the periphery it can continue its growth, i.e. the steepness of the graph increases (dashed line). Meanwhile the periphery sinks into poverty. The amount of the goods (the integral of the two functions) remains the same or slowly decreases. If there is severe tension accumulated on the periphery collapse occurs.

6. Conclusion

We introduced some axiomatic assumptions in order to investigate the role of entropy and MPP in the biological evolution and societal development. We pointed out that the growth of a technical civilization is strongly connected with the Maximum Power Principle and the growth is only a natural consequence of this principle.

L_{com} may be smaller with several orders of magnitude because of the limited energy sources and/or flows. These two phenomena may cause the end of a civilization. More precise estimations are needed to calculating the effect of these phenomena on $L_{com.}$

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