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New SETI prospects opened up by current information networking

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Abstract

This paper proposes to think the f_c factor of the Drake equation over, i.e. the fraction of planets with intelligent creatures capable of interstellar communication as defined by Frank Drake in 1961. This factor remains one of the most speculative terms of the equation. The debate about the possible types of technological civilizations raises the question of our own technological level. Starting from Kardashev's classification of extraterrestrial civilizations, Sagan assessed in 1973 that we were a 0.7H civilization. It is argued in this paper that recent improvements in computing technology created a virtual network that could correspond to a 0.4G civilization. Accordingly it is suggested that a new factor should be added to the Drake equation in order to take into account the complexity of information systems and to complement the f_c factor. This new factor, denoted f_d , is the fraction of planets with intelligent creatures capable of producing and sharing large amount of data. This is the case for planet Earth where complex networking technologies are useful for astrobiology as well as for active and passive SETI. A reflection about this new factor is proposed, highlighting the significance of sharing information as an additional step to communicate between galactic civilizations.

Keywords: Civilization, Computing technology, Drake equation, Heterarchy, SETI

Introduction

The Drake Equation attempted to formulate the number of civilizations able to communicate in the Galaxy. The last two parameters of the Equation, f_c , the fraction of planets with intelligent

creatures capable of interstellar communication, and L , the length of time that such a civilization remains detectable, are still considered nowadays to be the two most imprecise terms. However these two parameters are decisive to know if we have some chance, one day, of receiving an E.T. signal. This paper focuses on f_c and questions the possibility of sharing data, considering our own terrestrial example. Since 1961, when the Equation was proposed, computing technologies developed considerably within a very short time-scale. Acceleration in this branch of technology is perhaps a key factor to determine if a new civilization is now emerging on Earth and, extrapolating our case to SETI, to study the ability of a galactic civilization to share information.

Answering the question: “What type of civilization are we?” is the first step to decide whether the technological level of two galactic civilizations is compatible. The classifications proposed in pioneering papers by Kardashev (1964) and Sagan (1973) and their application to nowadays humanity’s technology provide a way to answer this question.

It should be reminded that the Drake Equation has been established as a framework of level of technology based on the sending of radio signals only. Information sciences provide now a new approach. The f_c and L factors do not convey the fact that knowledge is shared by a significant percentage of a civilization. A new factor denoted f_d could be introduced to represent the fraction of planets with intelligent creatures that are capable of widely producing and sharing data.

This ability is important for SETI. The “Welcome ETI” project has been designed for extraterrestrial civilizations able to scan our Internet network (Tough, 1998). Other citizen science projects such as SETI@HOME or SETI Live ask people to analyze data. As new planets have been identified by amateurs using the “Planet Hunter” website (Schwamb, 2012), SETI could be successful thanks to these recent developments in information sciences. Clearly, a signal coming from another galactic civilization has a higher probability to be detected and deciphered if more and more complex networking technologies are developing on our planet.

It should be noted that other authors recently proposed to add new factors into the Drake equation. Zaitsev (2005) suggested introducing a METI (Messaging to ETI) factor f_m between the factors f_c and L . This factor could represent the fraction of communicative civilizations with clear and non-paranoid planetary consciousness. Zaitsev (2006) highlighted the terrestrial paradoxical situation, i.e. we are not a communicative civilization (except for a few messages sent to the stars) although we are in a communicative technological phase.

The Statistical Drake equation proposed by Maccone (2010) allows for many factors to be added in the future as long as more refined scientific knowledge about each factor will be known to the scientists. Maccone named this capability to make room for more future factors the “Data Enrichment Principle”.

The search for extraterrestrial intelligence necessarily requires interdisciplinary collaboration. It was Frank Drake's goal when he wrote the equation as an agenda aimed at gathering specialists of multiple fields. This paper is focused on computing technology, one of these fields in which remarkable advances have been achieved in the last decades, and its impact on SETI.

We present first an overview of f_c and L factors in the 1961's context. Kardashev's classification of civilizations is also mentioned. This historical background is useful to the present analysis in order to update Earth’s classification. The paper discusses the current terrestrial civilization

regarding computing science. Finally it leads to possible applications to the Drake equation and SETI projects, in adding a new factor in the equation and discussing the system of Heterarchy.

A Reminder of how little we know about the two last parameters of the Drake equation

During the 1961 Green Bank Conference, the last factor, f_c represented “the fraction of extant intelligent life-forms that might have the desire and the wherewithal for interstellar communication” (Drake and Sobel, 1994). This factor was related to the next and last factor of the equation, L , which represented the lifetime of these civilizations and *which has the most to do with our own destiny* (Drake and Sobel, 1994, p. 61). These last two parameters comprised a lot of uncertainties, which led to intensive discussions during the meeting about the type of the probable advanced civilizations in the Galaxy. Finally, the value for factor f_c was estimated somewhere between $1/10$ and $1/5$. The most difficult factor to fix was undoubtedly L . At the end of the discussion, it seemed that the lifetimes of civilizations would either be very short –less than a thousand years (probability of self-destruction) – or extremely long –in excess of perhaps hundreds of millions of years (Drake and Sobel, 1994). One of the Green Bank discussants, Philip Morrison, had worked on the Manhattan Project. This specific context influenced the discussion about parameter L , because, as mentioned by Drake and Sobel (1994) if the capability for total planetary destruction lays within reach of every technologically advanced civilization, how likely were we to find anybody out there?.

Shklovskii and Sagan (1966) adopted a value for $f_c = 1/10$. Of course, even if this value is not very weak, and then the technologically advanced civilizations are not so rare, it does not tell us anything about the compatibility between the civilizations themselves. The last factor of the equation, L , might be more relevant from this point of view. They mentioned that the value of N depends critically on our expectation for the lifetime of an average advanced community. Finally, they adopted $L = 10^7$ years.

Taking into account the other parameters following their own estimations ($N = 10 \times 1 \times 1 \times 1 \times 10^{-1} \times 10^{-1} \times L$) Shklovskii and Sagan found $N = 10^6$ (p. 413). This result was located within the range of values proposed during the Green Bank meeting.

The Drake equation is a marvelous tool to quantify our ignorance, even if some of the first parameters are nowadays easier to estimate. The parameters dealing with civilizations -i.e. technological level, evolution of techniques, civilization lifetime- are the most difficult to quantify. Adding a new factor, as we propose in this paper, does not lead to increase uncertainty but on the contrary highlights some directions (such as sharing information) followed by evolved societies. This could be significant for SETI. Social sciences, such as human history and some predicted social behaviors are needed to discuss these factors.

Classification of Extraterrestrial Civilizations, an overview

In the USA, the Green Bank Conference is usually considered as the starting point of the research about extraterrestrial intelligence. However, during the 1960s, it is in Soviet Union that this research was the most developed. In 1964, the Russian radioastronomer Nikolai S. Kardashev proposed to classify technologically developed civilizations supposed to be present in the galaxy (Kardashev, 1964). He distinguished three types of civilizations based on the order of magnitude of the amount of power available to them:

- Type I - Technological level close to the level presently attained on the earth, with energy consumption at 4×10^{18} erg/sec.
- Type II - A civilization capable of harnessing the energy radiated by its own star (for example, the stage of successful construction of a “Dyson sphere”); energy consumption at 4×10^{33} erg/sec.
- Type III - A civilization in possession of energy on the scale of its own galaxy, with energy consumption at 4×10^{44} erg/sec.

Kardashev assumed that the most probable interstellar communication would be the transmission of information from a more highly developed civilization to a less highly developed one.

In the 1970s, Carl Sagan proposed to add other gradations to fill the huge gaps between each Kardashev’s Type. For instance, he proposed finer gradations like Type 1.1 or Type 2.2 to represent civilizations with an intermediate exploitation of energy. Sagan (1973) suggested Type 1.0 as a civilization using 10^{16} watts for interstellar communication; Type 1.1, 10^{17} watts, and so on. According to Sagan, our civilization would then correspond to a Type 0.7. This corresponds to a logarithmic formula extrapolated from Kardashev’s estimates:

$$K = \frac{\log_{10} W}{10}$$

where K represents Kardashev’s rating of a civilization and W the power this civilization uses for interstellar communication (in megawatts). In this formula, Sagan used 10 terawatts as a value for W (1973 estimate), which he later considered as an overestimate.

Transitions from one level to another could lead to dramatic periods of societal implications. A common speculation suggests that the transition from Type 0 to Type I might carry a strong risk of self-destruction since, according to some scenarios, there would be no longer room for further expansion on the civilization's home planet, a case similar to a Malthusian catastrophe (i.e. population growth leading to problems of subsistence).

In contrast to simply increasing the maximum power level covered by the scale, Sagan suggested adding another dimension: the information available to the civilization: “*If we have used numbers to describe energy, we should perhaps use letters to describe information*” (Sagan, 1973, p. 238).

Sagan assigned letter A to represent 10^6 unique bits of information (Sagan, 1973) (less than any recorded human culture) and each successive letter to represent an order of magnitude increase, so that a level Z civilization would have 10^{31} bits. To calculate the value of H, Sagan used the game of 20 questions. To identify something, you divide the universe in two parts by asking questions such as “is it an object?” Most of humans find the answer using 23 questions, so by dividing the universe in 2^{23} bits, that is 10^7 bits. We succeed in such a game because we do it with

people living in the same context as us, which reduces the possibilities. Sagan assumes that the 1973 human civilization uses 10^{13} bits corresponding to letter H. Therefore, in this classification, 1973 Earth is a 0.7 H civilization.

In 2013, do people on Earth still represent a 0.7H civilization? Since 1973 the energy consumption has only doubled. The Arecibo radiotelescope which sent the 1974 message, has a more powerful antenna than the Evpatoria radiotelescope (Zaitsev, 2006). The most powerful lasers produce power in terawatts. So the value of W in 2013 is still close to Sagan's 1973 estimate.

Classification of Extraterrestrial Civilizations, Current Earth's type

Today we have more powerful techniques to make extrapolations. We may use technical statistics based on quantity of available information. The first web server *Info.cern.ch* was created by Tim Berners-Lee in 1989. In June 2012, 697,089,482 web sites were reported by Netcraft. The total power demand in 2005 (including associated infrastructure) is equivalent (in capacity terms) to about five 1000 MW power plants for all the servers in the U.S. and 14 such plants for the world (Kooimey, 2007). According to these data, the value of W is 10 GW. This would give a K value of 0.4. This assessment can be discussed. According to Sagan, W represents the power a civilization uses for interstellar communication. If a label "communication" can be put on web or email servers, it is more difficult for other servers used for computing or bank services.

In April 2012, the encyclopedia Wikipedia contained over 19 million articles, and an average of 6474 new articles per day. Some studies show that it is more accurate than the Encyclopedia Britannica. Nineteen million of articles of 3000 bits each represent $57 \cdot 10^9$ bits. A single encyclopedia of this size represents a D civilization according to Sagan's formula. If each server had the content of the Wikipedia website, this would represent $40 \cdot 10^{12}$ bits. The quantity of virtual information available on the web represents half the information the Earth civilization had access to in 1973. This is equivalent to the data shared by a G civilization according to Sagan's formula.

The 0.7H civilization represents most of people living on Earth, finding information in printed books or computers, producing manufacturing objects, etc. However there is nowadays an emerging situation where more and more people manage an increasing quantity of data. Radio broadcasting took 38 years to reach an audience of 50 million people, television 13 years, and the Internet only 4 (United Nation schoolbus document). Some social network applications added 100 million users in 9 months, iPhone applications hit 1 billion in 9 months. Developments in computing technologies have led to huge changes in information traffic.

Earth's civilization can be regarded as a type 0.7H, but it has now a virtual network corresponding to a 0.4G civilization. It corresponds to all the people spending most of the time connected to each other via Internet or cell phones. Digital natives is a nickname for the Y generation, i.e. people born after 1979 who have an intuitive use of all these devices.

The aim of this paper is not to quantify a new social group or to discuss if the 0.4G civilization is the same thing that the Y generation. We propose to call this new “network civilization” the 0.4 G civilization in the following sections, but a better definition could be given over the next few years by researchers in social sciences.

Different ways of sharing data and implications on SETI

The SETI community presents a hierarchical organization (Billingham, 2002). In order to send a message from Earth such as the one sent from Arecibo in 1974, people of the 0.7H civilization needed some hierarchical organization to have access to the transmitter, to compose and agree about the content of the message and finally to get the right to send it. For instance in the case of the Arecibo message, there was no real worldwide debate about the data and information sent. The way of sharing data was then *hierarchical*. This is not the case now (Denning, 2010). Technology to send messages is today available for a lot of skilled people and several initiatives have already been done in that direction (Zaitsev, 2006). This way of sharing data is called *heterarchy*, a term used in biological taxonomy as well as in information sciences (Crumley, 1995). There would be only very few people sending messages in a galactic civilization using a strong hierarchy, whereas people would be communicating with the same rights in a civilization where heterarchy would be dominant. This point could have important implications on SETI.

The use of heterarchy in SETI projects started in 1997 when Allen Tough designed the Welcome ETI website. The technology used, now called web 1.0, consists of a server with a team knowing languages like HTML for writing texts. It is a hierarchical organization because nobody can write a word without sending it to people having access to the server. This technology was until then the only one available. Five people composed the leadership team and their 98 signatories wrote a short biography. This experiment was unsuccessful. As there was no widespread wifi or 4G-network at the time, the web site was intended for interstellar probes looking for intelligence through the Internet (Tough, 1998). Maybe it would be easier today for extraterrestrials to find web contents because it can be downloaded through radio waves to cell phones and mobile devices.

Most newly created websites are using web 2.0 technology. It is the case of the *Earth Speaks* project website. The main difference between web 1.0 and web 2.0 technologies can be identified by the way people receive and share information. The sizes of both websites are comparable: 44 Mbytes. However the number of files differs.

The principal investigator of *Earth Speaks* project is Doug Vakoch (Vakoch, 2010). The copyright of the website dates from 2009. Everybody on Earth can create an account on this website and writes one or several messages answering the question “what should we respond?” (to a possible extraterrestrial message). All the messages are freely available via a map (figure 2), a cloud of words or by navigating from the latest one to the earliest. There is no real hierarchy. This website uses web 2.0 technology. Once logged, everybody can evaluate each message rating it with 1 to 5 stars, answering the question “How appropriate would it be to communicate this message in an actual transmission to an extraterrestrial civilization?”.

The *Earth Speaks* website can be downloaded on a hardware support but some of its functions are available only with a network connection. It requires access to other servers such as Google Map. Saving it on a hardware support is like taking a picture of a living entity. You see it as it was at a given time and it differs from the current website.

The authors of the *Earth Speaks* messages don't need particular knowledge. They just need to understand English or Spanish and the way to fill a form on the web. They don't have to contact people involved in SETI or to be a member of SETI related organizations such as the SETI League, the Planetary Society, the SETI Institute or the International Academy of Astronautics.

There are more than ten years of technology between the two sites described above. A human will clearly see the difference. Just imagine we decide to broadcast the data into space using laser or radio waves. For the *Welcome ETI* messages, only one transmitter is needed to send the 99 “who we are” pages using for instance the alphabetical order. You can then add the 49 articles or select some of them. As there is not a single way to order the 956 *Earth Speaks* messages, it is difficult to send them from the location of their author all around the world at the same time. The power of the transmitter can be modulated according to the number of stars coming from the rating (Shuch, 2007). For instance an *Earth Speaks* message with 5 or 4 stars could be sent with more power than a message the users would have found less appropriated. Intelligence on Earth could be detected more easily if all the people of the 0.4G civilization had the possibility to broadcast messages in the same way they can add content on the *Earth Speaks* website.

A 0.7H civilization will find the *Welcome ETI* website more convenient because it can identify the authors, surf in an organized hierarchical way or print some papers. A 0.4G civilization will appreciate the *Earth Speak* website because people will be able to easily contribute to an evaluation of its content.

Heterarchy can then increase the probability of receiving a non-intentional broadcast but requires some technological improvement. Earth scientists can start building a kind of galactic web browser by sending probes and telescopes in space. They will have to be active in searching for galactic data instead of waiting passively that something comes to them.

The *Earth Speaks* and *Welcome E.T.I* websites are used to produce multimedia data: text, pictures, etc... The same comparison can be done between projects analyzing scientific data: , [SETI@HOME](#), SETI Live and Planet Hunters. The [SETI@HOME](#) participants need to install the BOINC software to get some data to analyze. Their home computer will process the data and return the results to get some new work to do. It's a hierarchical system with few human interaction. The user don't have to understand the science behind [SETI@HOME](#) to participate. SETI Live and Planet hunter ar Citizen science projects. The user needs some tutorial to understand what kind of signal he has to find in the curves or graphs presented by the related web interface. The planet (PH1b) around KIC 4862625 was discovered by volunteers searching the first six Quarters of publicly available Kepler data as part of the Planet Hunters citizen science project (Schwamb 2012).

Discussion

Coming back to the Drake equation, if there are many 0.4G civilizations in the universe, could this fact have an impact on f_c ? An E.T. 0.4G civilization receiving the Arecibo message will not send us a reply but instead could add some data or comments at the end of the message,. We don't know how this civilization could react to the content of this type of message. Maybe will it broadcast the messages and the comments in several relays using *heterarchy*? Maybe will it just broadcast the comments in the same direction as the Arecibo message they have intercepted, M25?

However, the galactic web browser able to look for messages coming from civilizations using *heterarchy* is not yet available on Earth. Scientists just have the antennas waiting for a reply, in the expectation that the civilization receiving our message will send the comment in the opposite direction. It is the same situation as when someone is checking new emails every minute for a reply, whereas the reply has been posted on a forum on a web page. The big difference is that no antenna is waiting for the reply, which furthermore might come a long time later. The newly proposed factor, f_a , the fraction of planets with intelligent creatures capable of producing and sharing large amount of data, could translate this ability of sharing information in space not only in a one to one communication protocol. A planet with an equivalent of the 0.4G civilization could also have new possibilities to detect such a signal, building projects such as *Earth's speaks* or *Welcome ETI*.

On Earth, *heterarchy* messages could offer an alternative solution to overcome the problem of time devoted to listening to the stars with specific wavelengths. Very few astronomers can nowadays consecrate time to do this work, whereas astrobiological data become more and more numerous, especially in the field of exoplanets detection. A way to concretely use our huge progress in computing technology, and throughout a *heterarchy* way, could be the development of new softwares and network infrastructures dedicated to a SETI purpose. New researches could then be both carried out using still existing data (SETI@HOME, KEPLER data), and for new detections of E.T. messages.

Allen Tough passed away on 27 April 2012 but the *Welcome ETI* website is still available. The content can be printed and kept in a museum. Keeping the *Earth Speaks* website online during more than ten years will be more difficult. Software will be upgraded and will require new installations. The data are on several servers owned by multiple organizations. However will they still exist within ten years? A print copy of the 956 messages can be archived in a museum but it would not be of great interest without a map on which to click to select the place where it has been created.

Conclusion

Heterarchy can increase the probability of receiving a non-intentional broadcast but requires some technology improvement. People on Earth can start building their galactic web browser in sending probes and telescopes in space. Scientists will have to be active in their search for galactic data instead of waiting passively that something comes to Earth.

A hierarchical civilization with only one entity (organization, leader) having the capability of producing interstellar messages will be less detectable than a civilization with many communicating entities, as shown in this paper with the example of the new *heterarchy* civilization. On the other hand, our technology is not yet efficient enough to receive too complex or too weak signals from such a galactic civilization.

Heterarchy illustrates the importance of sharing a large quantity of information.

In this paper we proposed to add a new factor f_d in the Drake equation in order to express the ability for an E.T. civilization to share information. Considering passive SETI (which is the purpose of the Drake equation), this could be an additional tool for such a civilization to be detected (by Earth's instruments in the future) and to be deciphered with a better efficiency. Considering terrestrial informatics activities, our technological development through *heterarchy* could be of significant interest not only for passive SETI but also for active SETI. This paper could open a discussion about these aspects involving specialists from different fields.

If a meeting about the communication with extraterrestrial intelligences had to be scheduled nowadays, specialists of informatics, human-computer interface, sociologists, etc. should be invited. Their contributions could take place between those about intelligence (f_i) and interstellar communication (f_c). A long time should be allocated to science of civilizations, evolution of techniques of communication and the way information could be shared or be compatible between different galactic civilizations.

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Complementary Web sites:

For the Drake Equation: http://imagine.gsfc.nasa.gov/docs/ask_astro/answers/970924.html

For the original story about the Fermi paradox:

<http://www.fas.org/sgp/othergov/doe/lanl/la-10311-ms.pdf>

For the United Nation Schoolbus document:

<http://www.un.org/cyberschoolbus/briefing/technology/tech.pdf>

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