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Fermi's Paradox and Mathematical Theory of Rumours: A Possible New Solution?

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Özet
We propose that Fermi's Paradox about "Where are the Extraterrestrails?" can be solved on the basis of the mathematical theory of spread of stochastic rumours developed by Daley and Kendal (1964), Maki and Thompson (1973) and Belen and Pierce (2004). Analytical formulations and their simulations show that a certain fraction of possible expansion space of a rumour can never be reached; similarly, Earth may had also fallen into this category of never-reachable planets in a possible network of communicating civilizations in the Milky Way.

Anahtar Kelimeler: Stochastic rumour models, simulations of rumor models, Fermi's Paradox, Drake's Equation, Kepler Satellite

1 Introduction

The solar type stars with planets having different surface conditions seem to be abundant in the Milky Way and the appropriate chemical elements and molecules for life are also known to exist in abundance throughout the Universe, implying that life may not be a phenomenan unique to Earth and rather widespread in the cosmos [1, 2, 3]. Thus it woud be quite plausible to assume that life and its advanced (i.e. intelligent and technically capable) forms presently exists in the Galaxy and some of them could have evolved to have the ability to communicate and/or travel over interstellar distances. Why then, we have not met or communicated with any of such extraterrestrials (ETs) is the essence of the conundrum known as the Fermi's Paradox (FP). The problem was first introduced by Enrico Fermi in 1950's as a lunch-time discussion topic at Los Alamos and various solutions to the "paradox" has already been proposed [2]. Recent development in the theory for spread of stochastic rumours by Pierce, Belen and others [9-13] has prompted us to look at the possibility of applying these results for a possible new solution, in ways not explored previously.

2 Theory of Spread of Stochastic Rumours

We will give, first, some relevant details of the theory and modeling results of spread of rumours. The rumour models were considered as part of the epidemic theory for long time [4]. First deterministic mathematical work to determine the spread size of rumours were given by Rappaport and Rebbun, and Rappaport in 1950's [5,6]. Afterwards, spread of rumours has been worked on independently from epidemic theory. The most important and seminal work for the topic has been introduced by Daley and Kendal (DK, from now on) in 1965 [7], which is also the first extensive and non-epidemic approach to the topic. After some time, a second classical model has been introduced by Maki and Thompson (MT) in 1973 [8]. More recently, a third approach was developed by Pierce and Belen (PB), after the year 2000, based on the probability generating functions and matrix methods developed [9, 10, 11, 12, 13].

Here, a short background and summary for the spread theory of stochastic rumours will first be provided. Basic motivations and formulations were already mentioned to be due to DK and MT. In both models, it is assumed that there exists a number of villages (n0 +1 in number) far from each other and only means of communication between them is conducted by a primitive wired-telephone system. It is also assumed that each village has only one telephone machine and only one telephone conversation can be carried out between any two villages at a time.

In the classical DK model, spread of a rumour starts from one village, the initial spreader (source of rumour or the "news"), calling another village, chosen randomly, at time t0 , and thus the process of spread of the rumour is initiated. For enumeration and analysis of the process, the village making the call is named as a "Spreader" (designated by Sp); all the rest of the villages are Ignorants (designated by Ig) at the start. The target village learning the "news", will either be another spreader and its status will be transformed into a spreader (Ig -¿ Sp) if it choses to spread the rumour; or to a silent (Stiffler, St) village which decides not to participate in the spreading process (Ig -¿St). The ones who continue making new calls, until a caller meets a village is not an original Ignorant, but has already learned the rumor, that is, either a spreader (Sp) or a stiffler (St). At this point, the caller (an Sp) converts to a stiffler (Sp -¿St) thinking that the "news" has already been well-spread all over the villages. Any new, first-time-called village (an Ig) can either become an Sp or an St depending on the two models, DK or MT. By giving up the spreading of the rumour, the number of spreaders is also reduced by 1.

When all calls and all combinations of Sp-Ig, Sp-Sp, Sp-St interactions are properly accounted, we reach at the unexpected conclusion that, in both classical DK and MT models, the final ratio of, number of Igs (nf) to their initial number(n0), after a high number of encounters F1, is:

$$F1 = \frac{n_f}{n_0} \tag{1}$$

i.e., aproximately 1/5th of total number of villages have when not yet been informed when the process ended (see Fig 1).

In the Pierce and Belen (PB) model, using the same interaction rules but including the multiple spreading centers at the start, in the rumour spreading process, one gets the result

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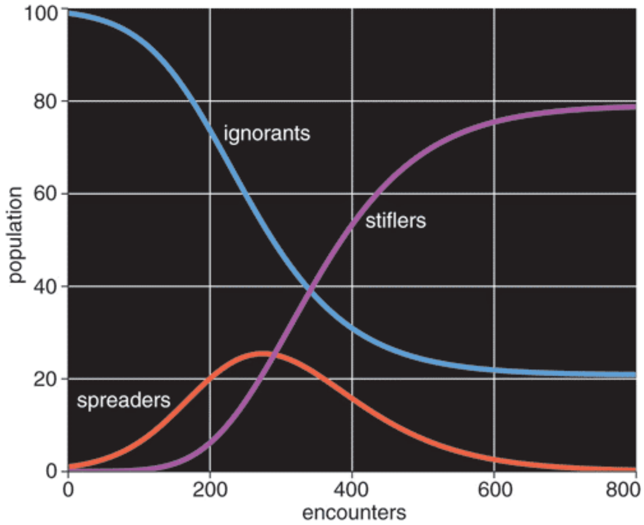


Şekil 1. Representation of 3 classes of participants in the classical theory of spread of rumours for the case of classical DK and MT models (The figure is adapted from [19]). In the assyimptotic limit, as the line of "ignorants" indicates, a good fraction (20%) of total population of initial ignorants can not be reached by the active spreaders. (The latter will also correspond to the un-discoverable fraction of civilizations in the discussion of present work.)

that

$$F2 = 0.368 \tag{2}$$

That is, larger than a third of "Ignorant" population stays as un-explored or un-discovered! This unexpectedly larger fraction is understood to be due to earlier encounters when spreading of the rumour starts from more than one center, spreaders meet another spreader (who learns the "news") much earlier, resulting with a higher percentage of un-reached ignorants when rumour spreading process ends (when all spreaders give up and become silent members). One extra condition in all the process was that total number of percentages at any moment of the spreading process has to satisfy

$$Sp + Ig + St = 1. \tag{3}$$

Computer simuations by Belen[12] and BP [11] confirm these results with some further elaborations for rumours with general initial conditions. For example, an error analysis made by Runga-Kutta method shows that, when the size population of number of villages (in the Fermi Paradox solution application, the number of civilizations in the Galaxy, trying to contact each other)

$$n_0 + 1 = n_l = 259 \tag{4}$$

is reached, error terms in the final percentages reduces to zero. This can be taken as the limiting number of villages (or in our parlance, the number of 'contactable' civilizations) where the analysis in the theory of stochastic rumours become valid. Low value of limiting number, n_l, of villages (or, civilizations) who can contact each other for the validity of rumour spread results is also unexpected, since this number is quite within or below the possible number of communicating civizations in the Galaxy (see Table 1, in the next section).

3 Spread of Rumours Applied to Interstallar Communications

The assumptions used in the analysis of theory of rumours are quite compatible with the conditions under which the spread of interstellar communications could have been carried out:

a. Setting of distant villages with only one means of (wired) telephone communication is rather quite parallel with the large distances between communicatable civilizations preventing their frequent and direct contacts. We can also quite reasonably assume that the only possible way of communication among them would be the use of electromagnetic waves (probably, the radio). The behaviour of a capable but ignorant civilization after the first contact is quite uncertain; however, responses similar to the explorative-villagers who become the new spreaders (development or acquisition of necessary means for further exploration -continiue to the search efforts with a SETI type instrumentation, for example- acting as a new explorer civilization) is quite reasonable and possible.
b. Since the Earth has not yet received any call (or, no visits by extraterrestrials, ETs were yet met or none communicated with us), we may be in the position of an "ignorant village" who will not learn about the "news" (i.e., the existance of ETs) until a call is "discovered" or to be made. This way, we also (secretly) assume that, there are already some type of communicating civilizations that can make such a "call", or, put an invitation to us to "join the Galactic Club".

Therefore, we can assume that, even though we have no clue about it, there may still exist one (or several) interstellar civilization(s), even a communication network (because, as Fermi Paradox discussions reveals, we eagerly and scientifically expect extraterrestrials to exist and keep wondering why we have not met them!) unaware of existance of dwellers of Earth. It is also possible that, they may be aware of us but, wait for us to show more signs of maturation, like, be able to save our World from the present-day perils of global warming and environmental degradations! (see Fig 2).

4 Drake's Analysis: The Number of Civilizations in the Galaxy

In 1961, radio astronomer Frank Drake devised a "simple" formulation -now known as Drake's Equation (DE)- attempting to identify various parameters that woud help us decide the number of communivative civilizations in the Milky Way, at the present epoch. There are several versions of its expression and we will follow that of Nicholson's [1]. DE provides a useful focus for debating the key issueds that has to be resolved in relation with the Fermi's Paradox.

The equation also provides us with numerical examples to draw parallels with the concept of "communicating villagers" of the rumour theory. First, a short review of Drake's Equation (DE) as discussed in [1, 2] will be given.

The DE can be expressed as

$$N_c = R_*(f_p)n_L(f_l)(f_i)(f_c)L \tag{5}$$

where,

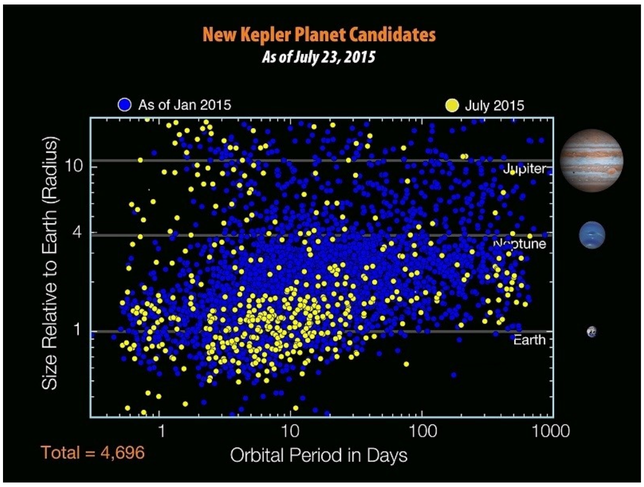
- N_c: the number of comunicative civilizations in the Milky Way Galaxy;
- R_*4: the star formation rate in the Galaxy, in units of (number of stars)/year, or (*/yr) which is quite well known for

Şekil 2. An imaginary web page of a galactic level inter-civilizations star-net system by Timothy Ferris. What is caled the Sagittarius Home Page has some titles interest to us: "News and Views from the Galaxy's Sagittarius and Perseus Arms", with an interesting subtitle: "Emerging Civilization in Orion Spur". In this case, advanced ETs are aware of us and will probably, give us a call, hopefully soon!

the Galaxy, and usually considered a number between 1-10 */yr;

- f_p: fraction of stars with planetary systems, for which better estimates are available after the discovery of high number of transiting planets discovered, mainly by Kepler spacecraft [14]. It is a number probably near to 0.1 or higher (See Fig 3).
- n_L: number of planets in a planetary system, suitable for life which can be as high as 2 -as might have been in the solar system, if Mars might have also been alive in the past- or as small as 0. Recent advances in planet hunting by Kepler satellite and other means indicate that multi-planet systems do exist [21]; however, there are many stars with no planets detected yet (by the present methods); therefore the average number could be something 0.5 or smaller.
- f_l: fraction of suitable planets on which life actually have started; another difficult parameter to estimate: it may range from 1 (certainty) to 0,001 (very difficult).
- f_i: fraction of life-starting planets which developes intelligence; probably most difficult of all parameters, ranging from 1 (certainty) to 0.0001 (very very difficult). There are indications that this number is nearer to high side [22].
- f_c: how probable is that intelligent species will develope a communicative technology with interest in other interstellar civilations; here we are also in the realm of speculative guesses. Most cited numbers lie in the range 1 to 0.1.
- L: lifetime (in yr) of a communicative civilization with interest in interstellar communication. With the only example of Earth, we have proposals ranging ge100 yrs (this phase might have been almost over, see [15], to a million yr or more, as suggested by Sagan and others [20]).

Existance of R* and L indicates that civilizations come and go in the history of Galaxy. What really matters is the



Şekil 3. Planets as discovered by Kepler Spacecraft as of July 1915. There are many earth-size planets with orbital periods, usually less than a year. One has to consider, also, types of stars that these planets rotate around. Then the number of earth-like planets will further reduce.

communicative civilizations still alive at the present era (up to several 100 years from our present time) of Earth's history.

We will present, in Table 1, results of some optimistic, pessimistic and also, the more likely estimations for Nc . Table also includes possible number of communicating (spreaders) and non-participating (ignorants) civilizations, n the context of theory of rumour spread with general initial conditions.

In accordance with Table 1, most likely number of civilizations communicating in the present epoch in the Galaxy could be somehing betwee few million down to about few 100. On the high side, it could go as high as Nc = 2.5 millions ("Saganesque" estimation). In this case, if a single superciviliation is in search of other communicable civilizations, and if we apply the present theory of spread of rumors to this set of discoveries, a total of about Nc - M1 2 million of them could have been discovered, leaving M1 500 000 of them undiscovered, only to give up, upon the false assumption that all has been discovered! If more than one civilizations had initiated such a search task, they will give up much earlier, probably after about discovering Nc - M2 1,5 million of them, leaving about M2 1 million of them unexplored. (In this result, we are aslo assuming that, they are not aware of 'pitfalls' of such a search due to the results of theory of stocastic rumors!)

When these estimations are refined using the "More Likely" numbers (partly in line with the recent planetary system discoveries and related analysis [21]), we reach at the number of possible communicable civilizations in the Milky Way Galaxy "contemporary" with us, to a mere Nc' $\tilde{1}$000, and, about a fifth (actual fraction is 0.203) of them (M1' 200) has to go undiscovered. For the case where search space is to be searched by several civilizations overlappingly, undiscovered number will increase to M2' 300, in line with Eqn (2) above[1].

[1] A recent estimate for the number of Earth-size planets in the Galaxy goes as high as 1 billion[23], this way, doubling the value of f_p by x2. However, other large uncertainties about emergence and evolution of life and civilizations are still valid. Therefore, we did not diverge from our line of conclusions for the present discussion

Çizelge 1. Parameters for estimating N_c4, the number of communicating civilizatons in the Milky Way Galaxy.

Parameters[1]	Optimistic estimates[2]	Pessimistic Values[3]	More likely values[4]
Nc	2.5×10^6	1	782 ($\tilde{1}000$)
M1 $= N_c \times F_1$	500 000	$\tilde{1}$	158 ($\tilde{1}50$)
M2 $= N_c \times F_2$	920 000	$\tilde{1}$	288 ($\tilde{3}00$)

[1] R_*, f_p, n_l, f_L, f_i, f_c, L
[2] 10, 1/2, 1, 1, 1, 1/2, 10^6
[3] 1, 1/2, 1/2, 0.2, 0.2, 0.1, 10^3
[4] 5, 1/2, 1, 1/4, 1/4, 1/2, 10^4

5 Conclusions

We can find parallels with the assumptions in the workings of the theoretical and simulational results of spread of stochastic rumours and contacting interstellar civilizations (if any) in the Galaxy. Results show that high fractions of search space by (an) advanced civilization(s) has to always include some unexplored regions due to the inherent uncertainties if the rumour theory has any applicability to the case. Since almost all the conditions for the theory of spread of rumours seems to be valid in a possible SETI type search, this is likely to be applicable to the Fermi Paradox case. Probably, the Earth falls (or, has already fallen) into this un-discovared group of planets. That means, either our system is not searched due to the pitfalls that exist in such a search (as some theories such as the present one implies) or we will be discovered by time, if such an advanced civilization has already started such a search, or has not given up by "some" reason!

Existance of "intrinsically" **un-explorable (large percentages of search) regions** in any search space may have other implications not easy to guess. One unexpected example that comes to mind, is the "second foundation" concept of **Isaac Asimov** in its "Foundation" series of science-fiction novels [16]. In the sequel, a Galactic empire is built by distant future human discendants and there exist "psyco-historians" (a kind of guardians for the Galactic Empire) of the "Foundation" ruling the Empire, and at some point in the sequence of events, they decide (at some level of development of the Empire) to create a "Second Foundation" in the Galaxy, at a distant, (and not-so-easily discoverable!) part of Milky Way. Its aim was to "save" the Galactic State, when long "dark ages" were foreseen by " the guardians", quite before its fall. It is not clear if Dr Asimov had something in his mind for a place which was also "theoretically undiscoverable" (as in the case of spread of rumours theory) when he was creating the sequels to the series!

In the case that we are the first galactic super civilization[1] that will be capable of such a search (by radio or optical or other type of searches -as in SETI activities-, or by direct visits -as in Asimov's "Galactic Empire" direct interventions style-, "searchers" **must be careful before concluding that any search space envisionable is fully exhausted!** If one considers present miniscule fractions of possible phase space anticipations covered by various active SETI programs, it is easy to see that there is indeed a very long way to go before discovering any new civilizations (f we can survive!). Even when searches come to a level that most the phase space covereges are achieved, we may indeed be wrong for reasons we have never anticipated. OR, we do need to find ways to overcome this apparently inherent mishap (due to such an apparently unrelated topic as the spread of stochastic rumours implies!).

[1] A recent claim that our Galaxy may contain a Type II civilization being capable of most of the energy emitted by their host star [22] brings forward the classification of civilizations by Soviet physicist Nikoli Kardashev in early 1960's [24], again. In this schema, our civilization is on the way of being a Type I civilization, that will be capable of using all (or, most) of the energy that falls on their surface from our star, the Sun, probably in about several centuries.

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