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On the Detectivity of Advanced Galactic Civilizations

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Even with slow rates of technological advance, extraterrestrial civilizations substantially in our future will have technologies and laws of nature currently inaccessible to us, and will probably have minimal interest in communicating with us. If this communication horizon is $\sim 10^3$ years in our future, other crude estimates previously published imply that only $\sim 10^{-4}$ of the technical civilizations in the Galaxy are accessible to us. The mean distance to the nearest such society is then $\sim 10^4$ light years. Radio detection of extraterrestrial intelligence seems to imply either (1) much larger telescopes or antenna arrays for the detection of civilizations within our Galaxy than now exist; or (2) attention to the nearer extragalactic systems, with smaller radio telescopes, to detect the very small fraction of very advanced societies which may choose to make their presence known to emerging civilizations via antique communication modes.

Mankind now possesses the technological capability of communicating at radio frequencies, over distances of many thousands of light years, with technical civilizations no more advanced than we. But before a program is initiated to search systematically for such signals it is important to demonstrate at least a modest probability that one technical civilization exists within such a range. The possibility that much more advanced civilizations exist—societies which can be detected over much larger distances—will be discussed presently. The pitfalls in placing numerical values on the component probabilities of N, the number of extant technical civilizations in the Galaxy, are numerous and treacherous; nevertheless, there does seem to be a limiting factor whose significance has not always been appreciated.

While much more sophisticated formulations are now available (see, e.g., Kreifeldt, 1971) the first algebraic expression for N, due in its original formulation to F. D. Drake, will serve our purpose:

$$N = R\,L \tag{1}$$

Here R is the rate of emergence of communicative technical civilizations in the Galaxy, and is a function of the rate of star formation, the fraction of stars which have planets, the number of planets per star which are ecologically suitable for the origin of life, the fraction of such planets on which the origin of life actually occurs, and the fraction of such planets on which intelligence and eventually technological civilizations actually emerge (see, e.g., Shklovskii and Sagan, 1966; henceforth, Reference I). L is the mean lifetime of such civilizations, and is strongly biased towards the small fraction of technical civilizations which achieve very long lifetimes—lifetimes measured on the geological or stellar evolutionary time scales (Ref. I). But such civilizations will be inconceivably in advance of our own. We have only to consider the changes in mankind in the last 10^4 years and the potential difficulties which our Pleistocene ancestors would have in accommodating to our present society to realize what an unfathomable cultural gap 10^8–10^{10} years represents, even with a tiny rate of intellectual advance. Such societies will have discovered laws of nature and invented technologies whose applications will appear to us indistinguishable from magic. There is a serious question about whether such societies are concerned with communicating with us, any more than we are concerned with communicating with our protozoan or bacterial forebears. We may study microorganisms, but we do not usually communicate with them. I therefore raise the possibility that a horizon in communications interest exists in the evolution of technological societies, and that a civilization very much more advanced than we will be engaged in a busy communications traffic with its peers; but not with us, and not via technologies accessible to us. We may be like the inhabitants of the valleys of New Guinea who may communicate by runner or drum, but who are ignorant of the vast international radio and cable traffic passing over, around and through them.

A convenient subdivision of galactic technological societies has been provided by Kardashev (1962). He distinguishes Type I, Type II and Type III civilizations. The first is able to engage something like the present power output of the planet Earth for interstellar discourse; the second the power output of a sun; and the third the power output of a galaxy. By definition, Type I civilizations are capable of restructuring planets, Type II civilizations of restructuring solar systems, and Type III civilizations of restructuring galaxies. I believe that a civilization of approximately Type II has, with an exception to be described later, reached our communications horizon. For computational convenience, I also assume that a civilization which has emerged to Type II technologies has also successfully passed through the critical period of probable technological self-destruction—the period in which terrestrial civilization is now immersed.

These ideas can now be restated as follows: let f_g be the fraction of technical civilizations which survive for geological or stellar evolutionary time scales, L_g, and let L_d be the mean time to self-destruction of those Type I civilizations which do not achieve Type II technologies. Then,

$$L \sim (1-f_g)L_d + f_g L_g \qquad (2)$$

Accordingly, the total number of extant civilizations in the Galaxy,

$$N \sim R[(1-f_g)L_d + f_g L_g], \qquad (3)$$

is different from the number of civilizations within our communications horizon,

$$N_c \sim N_I \sim R[(1-f_g)L_d]. \qquad (4)$$

The ratio of these lifetimes

$$N_c/N \sim [1+f_g(L_g/L_d)]^{-1}, \text{ for } f_g \ll 1 \qquad (5)$$

$$\sim (L_d/f_g L_g), \qquad \text{for } f_g L_g \gg L_d. \qquad (6)$$

Equations (5) and (6) are independent of R. Of the civilizations within our communications horizon only

$$N_c' \sim Rf_g(1-f_g)L_d \qquad (7)$$

are destined to have lifetimes $\gg L_d$.

We now specialize to some illustrative numerical cases. I emphasize that values differing by several orders of magnitude from the ones I choose are certainly conceivable and may even be probable. We adopt (Ref. I) $L_g \sim 10^9$ yr, $f_g \sim 10^{-2}$, and $R \sim 10^{-1}$ yr^{-1}. I further assume $L_d \sim 10^3$ years. From events of the past few decades a case can be made for L_d 1–2 orders of magnitude smaller; the resulting conclusions will be correspondingly more pessimistic. Independent of the choice of L_d, as long as $L_d \ll L_g$, we find $L \sim 10^7$ years, and $N \sim 10^6$ galactic civilizations (Ref. I). Assuming such civilizations are randomly distributed, the mean distance to the nearest is a few hundred light years, and searches for such civilizations, using existing technology, would seem to be in order. However, if we count only those civilizations within our communications horizon, we find, with the same choice of numbers,

$$N_c/N \sim 10^{-4} \qquad \text{and} \qquad N_c \sim 100.$$

In this case the distance to the nearest communicative civilization is $\sim 10^4$ light years—well beyond easy detectability, assuming that our communicant is at approximately the same technological level and we have no prior knowledge of where to look. And of these 100 societies only $N_c' \sim 1$ is likely to avoid self-destruction.

Almost all of these 100 civilizations of Type I or younger must have technologies significantly in advance of our own, and it may very well be possible to make contact with them. But the prospects are very much dimmer than in the case of 10^6 communicative galactic civilizations. The situation can be improved somewhat by taking $L_d <$ the interval to the communications horizon, rather than equal to it as we have assumed here; but we have been optimistic in our choice of L_d and I find it difficult to imagine that many civilizations $> 10^3$ years in our technological future would be anxious to communicate with us.

The situation seems to be that Type II or more advanced civilizations may be, in terms of contemporary terrestrial communications technology, at small distances from us—but, in the same terms, non-communicative; whereas Type I civilizations may be communicating—but tend to be too far away for us to detect easily. The operational consequence is that the detection of civilizations of Type I or younger is more difficult than has generally been assumed, and that such an enterprise will require much more elaborate radio systems—for example, very large phased arrays—than currently exist, and very long observing times to search through the $\sim 10^9$ stars which must be winnowed to find one such civilization.

On the other hand somewhat more serious attention must be given to the question of Type II and Type III civilizations—the level where, according to the previous argument, most of the technical societies in the universe are. A Type II civilization can communicate with the Earth from our nearest galactic neighbors; a Type III civilization can communicate across the known universe—and this employing only laws of nature which we now understand. If only a tiny fraction of such civilizations are interested in antique communications modes they will dominate the interstellar communications traffic now accessible on Earth. The best policy might therefore be to search with existing technology for Type II or Type III civilizations among the nearer galaxies, rather than Type I or younger civilizations among the nearer stars.

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