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The Fermi Paradox: Timescale for the Colonization of the Galaxy

The search for extraterrestrial intelligence (SETI) operates under a few key assumptions. One of the most stringent is that other life is “like us,” that is, with similar biochemistry and preferring to live on roughly earth-like planets. Our Galaxy, the Milky Way, contains roughly 400 billion stars, the vast majority of which are long-lived like our sun. It is about 100,000 light years across, and about 10 billion years old. Credited to physicist Enrico Fermi is the observation that if a civilization had arisen on any single extrasolar planet at any time in the past, they would have colonized the whole galaxy quite quickly in comparison with the Galaxy’s age. Such a civilization should therefore already have a presence here in the solar system, and “Fermi’s paradox” is the question “So, where are they?”

Let us estimate the timescale for colonization of the galaxy in two ways.

1. Population Growth

One way to think about this is to look at population pressure as a motivating force for Galactic expansion. Nobody likes overcrowding, right? Let us start with the earth. We have 6 billion people and the population doubles every 30 years. How many people can earth hold before serious resource depletion occurs? I have no idea, but maybe it is 100 billion = 10^{11} people. At that point, people are going to want to go into space pretty badly. Lets assume there are 100 billion habitable planets in the Galaxy. How long before all those planets get filled up, too?

Procedure: Make a table of two columns, “year” and “population.” Start with year 2000, and population 5×10^9 . Then increment 30 years into the future, doubling the population each 30 years. How long before we overpopulate the earth at 10^{11} souls? How long before we overpopulate the Galaxy at $(10^{11} \text{ people}) \times (10^{11} \text{ planets})$?

2. Spacecraft + Infrastructure Speed

In the last example we may have exceeded the speed of light in populating the Galaxy, which, after all, is 100,000 light years across. Let’s chart out how long it would take a “colonization wave” to reach all the way across the Milky Way. We will use the handy formula $d = vt$, or (distance) = (velocity) $\times$ (time).

At what velocity will the colonization wave travel? Well, it cannot exceed the speed of light, but experienced space travelers will always want to travel VERY near the speed of light so that time dilation causes their trip to be as short as possible. We expect that a technically advanced civilization will build spaceships that travel very near the speed of light. However, it may take time to build the ships and it may take time for individual planets to build up the infrastructure needed to expand colonization efforts to stars even further away from the home world. So an average speed may be only 0.1 or even 0.01 of the speed of light. Let us consider both cases.

Procedure: Assume an (overestimated) distance through which a colonization wave would travel: 100,000 light-years. Why is this an overestimate? For colonization timescales in this method, let us do it twice. We want a slow-velocity (0.01c) time estimate and a fast-velocity (0.1c) time estimate. For the time estimates, invert $d = vt$ to read $t = d/v$. If you use distance in light-years, no other units conversions are needed. Find the fast and slow colonization times.

Analysis

You now have three estimates for the time it takes for an alien civilization to reach planet earth (one for population growth pressure, two for colonization wave speed).

How do these compare with the 10 billion-year age of the Galaxy? (Divide 10 billion by your estimates to get N_c , the number of times the Milky Way could have been colonized again and again — given your 3 different colonization times.) Make a little table of two columns: “Milky Way colonization time” and “ N_c ”. Give your results for the three cases in three rows below the headings.

Do you agree that there is a “Fermi paradox?” Think of at least 5 ways to explain why we are NOT knee-deep in aliens right now.