A copernican answers Fermi

George Rebane – 8 June 2018 (V21nov18)

Introduction

World renown 20th century physicist Enrico Fermi asked, "Where are they?" He was referring to extraterrestrial intelligent (ETI) civilizations which around 1950 were already being searched for without much luck. In this short paper I make the plausible assertion that our Milky Way galaxy is indeed teeming with sentient and sapient life, and offer a plausible explanation as to why our current search for ETI (SETI) has drawn a blank and, with high probability, will continue to do so.

My arguments will draw heavily on assumptions I and other cosmologists share as copernicans. Nicolaus Copernicus (1473-1543) was a Renaissance-era mathematician and astronomer who formulated a controversial model of the universe that placed the Sun, rather than the Earth, at the center of the universe, thereby destroying the then millennium plus dominant, Earth-centric universe explicated by Ptolemy, a Roman mathematician and astronomer of the second century AD. Today, a copernican is one who, lacking evidence to the contrary, argues from the position of commonality or mediocrity, or that what we see or experience is not anything special or out of the ordinary in the general scheme of such things. The ptolemist argues the counterpoint, and sees a given situation or event as being singular, special, or unique in its scheme of things. We honor both men by incorporating their names into our language in the lower case. And to simplify things further, here we also include the so-called Mediocrity Principle (q.v.) into the definition of 'copernican' instead of calling them out separately in the sequel.

The debate about the existence of ETIs goes on with the often heard plaintive, 'Are we alone?' The copernican answers with a firm 'Of course not!' and cites a growing body of evidence from astronomers and cosmologists that make an extremely plausible, if not highly probable, case for a universe teeming with not only sentient (self-aware) life, but also profoundly sapient (wise) life. However, to date and in spite of all this inferential evidence but still no received ETI signals, Fermi's question continues its challenge with then 'where are they?'

My own answer to this question requires us to visit a preamble of assumptions on which a specific answer is based. The foremost of these assumptions, shared by many philosophers and scientists, is that once a civilization of sentient life on any exo-planet, including Earth, becomes sapient, to the extent that it starts using electro-magnetic (EM) communications that then radiate into space, it then goes through a rapid phase of technology advancement that ends either in its own destruction or achieving the Singularity (q.v.).

If even a small fraction of evolved bio-sapient civilizations in the galaxy achieve Singularity, given the cosmic timespans involved, the universe and our galaxy would then be awash with post-Singularity life. When we consider the possible development phases for life, it quickly becomes clear that without the intercession of intelligence, bio-life evolves very slowly at first (relying on probabilistic resources) becoming sentient only after some billions of years, and then very quickly thereafter (in mere millions of years) leaps to sapience. And once a sapient

civilization learns science, the leap to the utilization of EM transmissions is almost instantaneous (i.e. less than a millennium).

It is when EM transmissions commence that the doomsday clock also starts ticking, marking time to either the civilization's wholesale destruction or the end of its bio-life which then (hopefully) will begin a new post-Singularity phase. As we already see from our own copernican perch, bio-sapience is short-lived in any case. From our own experience, a current reasonable duration of this phase is about two hundred years, of which we have already consumed the first hundred.

Post-Singularity civilizations will quickly shed their biologically evolved repositories, and adopt more capable and enduring material strata, first for the computations of intelligence and then consciousness. On Earth we have come to refer to this form of trans-human life as being silicon based, but no one knows what kind of computronium post-Singularity life will adopt and in what time frame all of it will come to pass. (Computronium was coined by Drs Margolus and Tomasso of MIT as comprising any mass or even fields that can be complexified sufficiently to support computation. Most certainly a brain is computronium. Ray Kurzweil has posited that we will soon be able to arrange matter on the atomic scale so as to make even a rock into computronium able to house a supercomputer.)

Post-Singularity life presents pre-Singularity life with a number of problems and conundrums, primarily because of the rapid acceleration of intelligence once life is freed from the shackles of biological (Darwinian) evolution. We as pre-Singularitarians have literally no concept of what kind of thoughts and thinking is possible for post-Singularity life forms. In the same vein, we have no idea how to communicate with such ETIs, or even know if they have any desire to communicate with lower life forms like us. As copernicans, the only thing of which we can be reasonably certain is that Homo Sapien is not the most evolved form of life in the galaxy (hence universe), let alone occupying the pinnacle of intelligent life in our galaxy. Hence, our search for ETI has been focused on the attempt to detect EM transmissions from other pre-Singularity civilizations in the galaxy.

It is observably certain that, if they communicate at all, post-Singularity lifeforms communicate using methods and modalities that are beyond broadcasting omni-directional EM signals all over the galaxy (e.g. using directed neutrino beams and taking advantage of exotic shapes of space, or using new forms of quantum entanglements). With this preamble, we will sally forth to answer Fermi's question and understand why we have yet to detect any EM transmissions from sapient ETIs.

Before concluding this introduction, it is critical to point out that given the circa 200-year time limit on every sapient civilization's doomsday clock, the physical form of the EM transmissions which cross the galaxy are therefore in reality very thin EM annuli of about 200 light-years (ly) in width. With eventual destruction or achieving Singularity, all such transmissions will simply 'blink out', returning such exo-planets to EM silence after each emits its brief expanding ripple into space. We can then imagine the galactic plane as the surface of a calm pond on which the first drops of rain start to fall, each giving rise to the familiar circle that quickly dies out as it expands. This schema is shown in the not to scale Figure 1 where Earth is within the 200ly annulus of a planet orbiting Star B. There we also see that Star A's annulus has already passed

Earth, and Star C's annulus has yet to reach Earth. It is clear now that today we can receive signals from a randomly transmitting ETI only if we are in its EM annulus, while also looking at precisely the right originating spot in the sky, and have the appropriate algorithms to dig (detect and understand) the signal out of its noisy background.

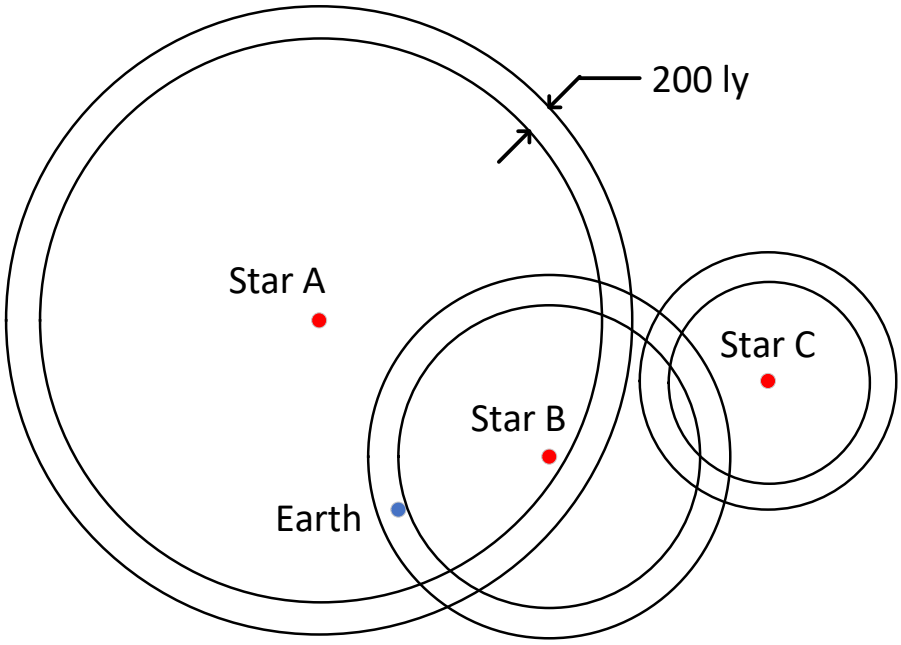

Figure 1. The expanding ripples of ETIs' EM annuli

Now let's look at the relevant numbers that drive the analysis and answer Fermi. The astute reader understands that the cited numbers are but current estimates which will still serve were more accurate numbers used in a later update of this work. In all cases I attempt to use the more 'conservative' values to lend maximum credibility to the result.

The Numbers of Our Galaxy

The Milky Way (MW) is a very copernican galaxy, very similar in size and structure to billions of other such galaxies in our universe. We are told by astronomers that MW contains somewhere between 200 and 400 billion stars (amazing that we don't have a better count), essentially all of which are ringed by planets of various sizes and at various distances that coagulated from the interstellar dust cloud when the star was born and ignited its nuclear fire. Of those hundreds of billions of planets, we have pretty good estimates of the number that orbit in the so-called 'Goldilocks ring' – not too hot, nor not too cold according to the standards of Earth's bio-sphere. The Goldilocks planets number around 40B with diameters ranging from those similar to our gas giants to the relatively tiny size of Mercury. If we further fine tune the potential repositories of life down to metallic near Earth-size planets, then we wind up with 11B of them, still a huge number distributed evenly within the galactic disk.

The MW disk itself is about 160Kly (160,000 light years) in diameter. It is fairly thin, measuring only about 2Kly in thickness with a very dense and extremely EM-noisy central bulge of large stars and black holes which is about 15Kly in diameter as shown edge-on in Figure 2. The central bulge is a very chaotic place with stars passing each other frequently and so closely that any planetary systems initially organized by any of them would have been rent asunder soon after the galaxy formed some 8-10B years ago. We recall that the Big Bang, which started our visible universe, occurred about 13.8B or, say, 14B years ago (close enough for government work), therefore it took things a little over 5B years to settle down to a more or less orderly formation of galaxies comprised of early stars and gaseous star nurseries.

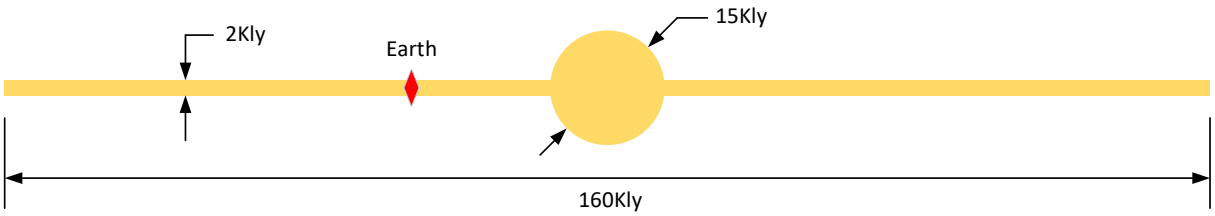

Figure 2. Milky Way galaxy edge on and to scale.

Our copernican sun and solar system formed about 5B years ago when soon thereafter the MW's star formations settled into a fairly steady rate of about seven per year adding to a population of hundreds of billions – in other words in our analysis we may safely ignore this accretion for ETI purposes, and focus on the 11B Earth-size metallic planets orbiting in their stars' Goldilocks zones. (This does not say that evolutionary bio-life could not form elsewhere, however erring toward or limiting ourselves to numbers that more closely bunch around our own copernican experience is prudent.)

Our final important assumption about life in the MW is that, even on the 11B life-inviting planets described above, their 'probabilistic resources' are sufficiently limited so that life actually ignites on only one out of ten thousand of those planets. This reduces our potential EM emitters to 1.1M planets in this galaxy. Even this figure gives rise to a sizeable number of annuli spreading across our galactic disk, but as we shall soon see, we're not done culling the field – there is the little matter the speed of light (at 1ly/year), and accounting for the span of time during which the emissions have occurred and will occur.

And the last 'geographical' factor to consider is Earth's location about 26Kly from MW's center and, again being conservative, we assume that we cannot detect ETI emitted EM signals from within and beyond that very noisy central bulge. And as we shall see in Figure 3, this cuts out a large swath of the galaxy from the view of our radio telescopes. We reward our analysis with the assumption that we can 'see' the relatively close star systems located between us and the central bulge. It will become apparent later that this addition will not change the main thrust of our conclusions.

So Where Are They?

To begin answering that, we again look at ourselves and estimate that the mean time from planet formation to the emergence of EM transmitting civilizations is about 5B years, with a generous standard deviation (sigma) spread of 50M years. (Our potentially sapient dinosaurs were wiped

out about 63M years ago.) That means that the brief ETI transmissions from each of the 1.1M star systems will be extended over several hundred million years, with almost half or 550,000 of them having already been emitted over the last 150M years (3-sigma duration).

Recalling the annuli of Figure 1, it is clear that the overwhelming number of the already emitted EM ripples have passed Earth and are now millions of light years outside the MW in inter-galactic space. The only annuli which we could possibly still see are those that 'recently' started from the farthest visible edge of our galaxy and are bathing us now with some remaining part of their 200ly wide band of EM waves. From the described geometry of our galactic disk, the greatest distance from Earth to a visible EM transmitter on the other edge of the MW is about 101Kly (See Figure 3 below). This means that at best today we can only see EM signals which were transmitted no earlier than 101K years ago; anything transmitted before that from within the MW has already passed us or 'blinked out'.

When we apply these numbers to the distribution of emission times – where Earth resides at the copernican mean – and calculate the maximum number of the original 1.1M ETI emitters that we could potentially see, we arrive at 878 ET civilizations that have sent out their randomly distributed EM annuli over the last 101,000 years. Figure 3 shows the galactic disk from above and gives us an idea of the distribution of these potentially visible 878 or circa 1,000 planets (green dots, Earth at red diamond) along with a sampling of few of the annuli making their way through the galaxy. We note in the figure that the width of the shown annuli scale to no larger than the line widths of the indicated circles. This gives an idea of the enormity of distances and time intervals involved when we consider that it takes 200 years for each circle to enlarge by less than one line width shown in the figure.

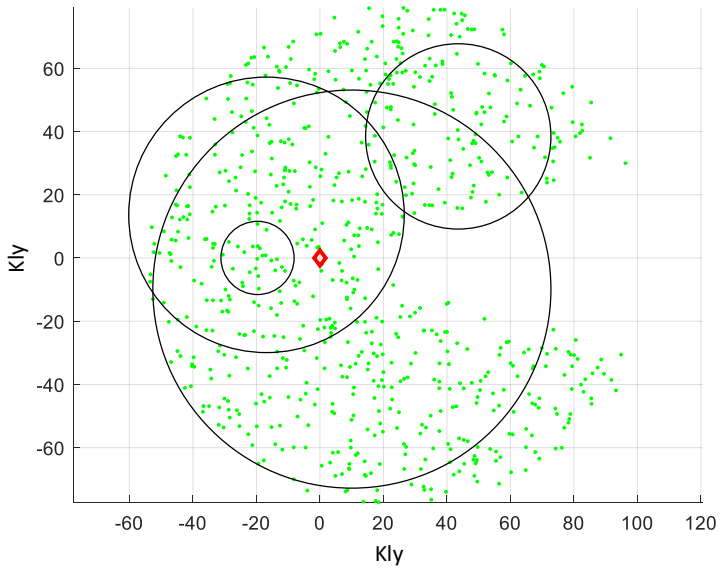

Figure 3. Top view of the Milky Way showing distribution of the current circa 1,000 potentially visible ETI planets.

To appreciate the very short timespan during which potentially detectable ETI planets must have transmitted, we examine Figure 4 below which shows the cumulative distribution of EM emissions from the 1.1M planets over a period of 300M+ years. The copernican Earth is at the mean of this normal distribution with a 50M year standard deviation (sigma).

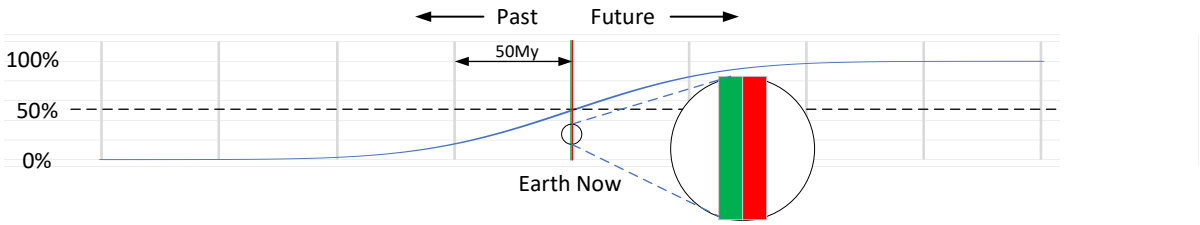

Figure 4. Cumulative distribution over time of the 1.1M EM transmissions from ETI planets.

The figure shows the percentage of the 1.1M planets' EM transmissions. To appreciate the source of the circa 1,000 ET planets that we may potentially see, we have expanded the red and green lines showing the 'now' of the Earth (red), and the 101Ky time window in our immediate past during which the candidate planets would have randomly emitted their EM annuli. The point here is that the width of the green line indicating this time window is still wider than 101Ky on the time scale of the graph. And it is the percentage of 'recently' emitting planets within this green line time window that number 878 or our circa 1,000.

If we now simulate the recent emissions of these planets, distributed randomly and uniformly over both the last 101K years and in the visible galactic plane, then we can calculate how many of those emitted EM annuli are now bathing Earth with their ETI signals. In other words, the only such planets visible to us are those in whose annuli (see Figure 1) the Earth currently resides. The number of such planets is a new random variable whose distribution we must now compute by applying one additional caveat, namely that our ability to dig signals out of interstellar noise is limited by a number of factors, the most significant being the EM transmission's signal-to-noise ratio (SNR).

Spherically spreading signal energy diminishes in proportion to the inverse square of the range to the transmitter. While the detection probability calculations which depend on receiving beam 'width' (steradians), integration time, type of detection algo used, etc, in addition to the sky search schema utilized are out of scope here, for our analysis we assume that all of these factors limit our ability to detect out to a generous distance of 40Kly. Signals from transmitting planets beyond that range have a SNR too small for us to detect even if we were to be fortunate enough to point our receiving beam right at them.

A random sample from such a simulation is shown in Figure 4 where the heavy blue circle shows our 40Kly detection range. In this instance Earth is in the contemporaneous annuli of four emitting planets, however, only one of the planets' EM emissions is detectable – the detectable planet is shown in blue and the undetectable ones are black. As we shall soon see, this concurrence of annuli is a relatively rare event in our galaxy.

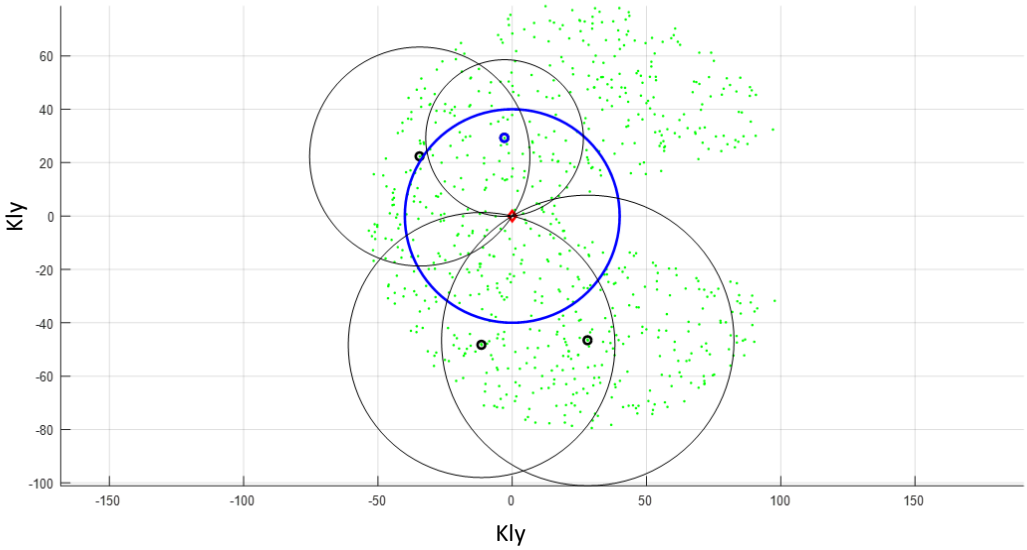

Figure 4. ETI emissions from currently visible (black) and detectable (blue) planets

From a 10K sample of the visible location and transmission distributions that would generate geometries like that shown in the above figure, albeit most empty or not nearly as populated, we obtain our final result – the distributions of the currently visible EM transmitters (Figure 5) and of those currently detectable (Figure 6).

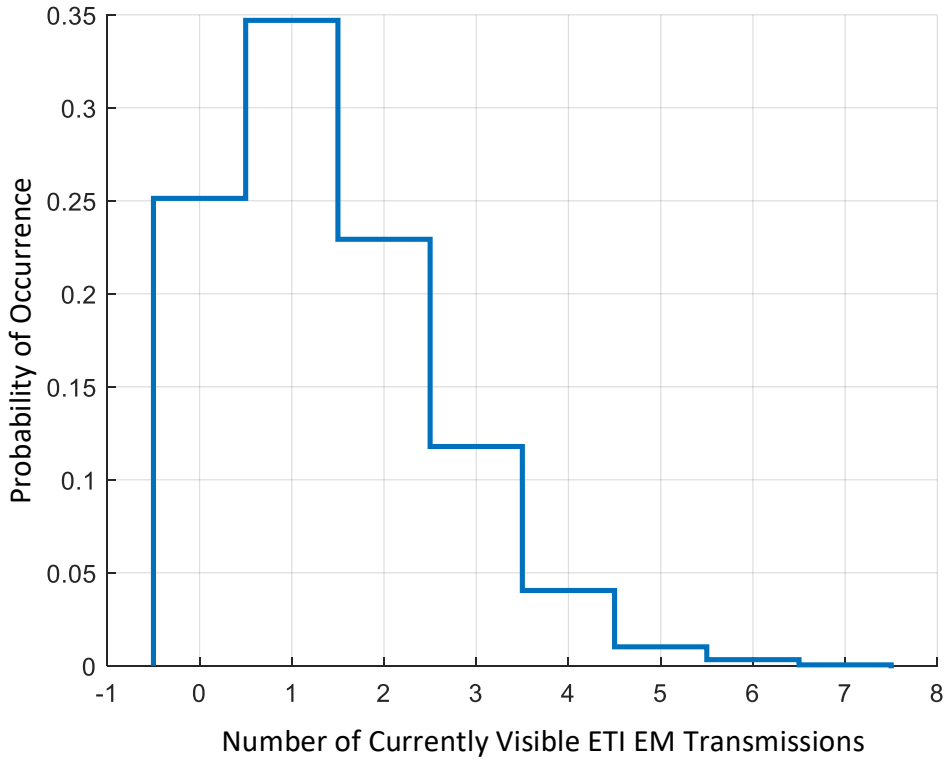

Figure 5. Probability Distribution of Currently Visible ETI Transmitters

From Figure 5 we immediately see that there is already a one out of four chance that we are not in the EM annuli of any of the circa 1,000 potentially visible ETI transmitting planets, and a little more than one out three chances that there is one planet (the black planets of Figure 4) that we could possibly find and detect if it were within 40Kly of Earth. But the real answer to Fermi lies in the probability distribution of detectable EM emitting planets (such as the blue planet in Figure 4), shown below in Figure 6, that are within our stipulated generous 40Kly range.

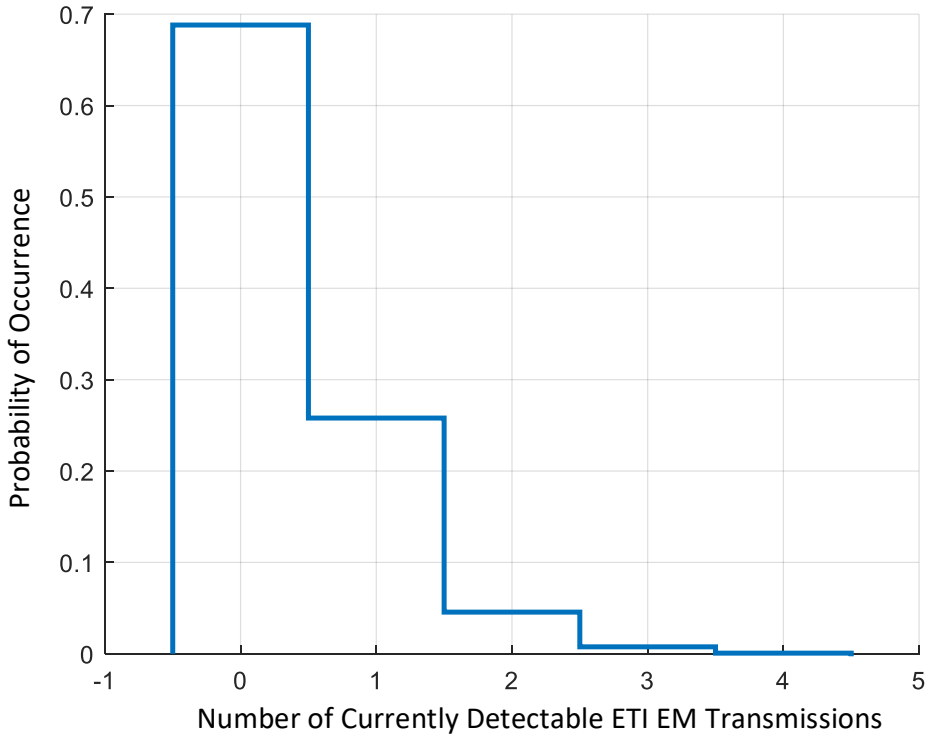

Figure 6. Probability Distribution of Currently Detectable ETI Transmitters

And here we have the answer Professor Fermi was seeking. As a copernican, I have argued that the Milky Way is most probably teeming with sentient and sapient life in which both pre- and post-Singularity civilizations abound. However, at any given time during this epoch in the life of the galaxy, Earth is so positioned that the chance is more than two out of three that currently we are not even bathed in the EM transmissions from a sapient ETI in our galaxy. Moreover, there is only a one in four chance that we could detect a single transmitting planet were we fortunate enough to look in the right place in the sky. Inspection of Figure 4 suggests that search resources should be minimized in the direction of the central bulge. Factoring in search schema (out of scope of the present investigation) would yield probabilities of finding such detectable transmissions which would further reduce the above probabilities of actually detecting an ETI.

It should now be clear how our galaxy can be abundantly populated with intelligent life, and still yield the observational experience of the 50+ year-old SETI program. Unfortunately, the sound of silence that we hear is to be expected.

Related Thoughts

Readers interested in cosmology will no doubt recognize this little dissertation as an expansion of the eponymous Drake Equation (q.v.) that first suggested how we might compute the number of sapient civilizations in our galaxy. The early applications of Drake usually yielded a paltry number of potential ETI out there. Thanks to recent researches into the existence and nature of exo-planets, we now know that the potential for intelligent life is abundant throughout the Milky Way.

From a report in the 12nov18 *Aviation Week & Space Technology* we learn –

"Before we launched Kepler we didn't know if planets were common or rare," says Paul Hertz, chief of NASA's astrophysics division. "Now we know that planets are more common than stars in our galaxy. We know there are billions of planets that are rocky like the Earth and are orbiting their stars in the habitable zone … where their temperatures might be conducive to water on the surface," bolstering chances for life.

The question of interest that demands attention at this point in such a discussion concerns post-Singularity civilizations – their number, nature, organization, and possible means and modes of interest in emerging primitive civilizations like ours. From the copernican perch we are comfortable with the high likelihood that thousands of successful post-Singularity civilizations have already transcended their temporary bio-evolutionary beginnings. What form do they now take, how are they living, what manner of pursuits are of interest to them, what thoughts do they think, …?

Do any of them live in magnificent Dyson spheres that encompass brown dwarfs; spheres configured entirely into computronium and the energy capturing/conversion system that milks the encapsulated star. In such domiciles existentially 'immortal' super-intelligent beings can exist in virtual universes they have constructed within their massive computronium spheres, doing what? Or are some of them travelers of the galaxy and beyond, taking advantage of notions and knowledge of space/time that are real, yet far beyond our comprehension. If so, then it's also likely that unbeknownst they have been living among us as what? tourists? shepherds? gamers?, practicing A.C. Clarke's "any sufficiently advanced technology (that) is indistinguishable from magic."

I'll end these rambling with an overarching question - what can humans do to show them that we are worthy of being saved from destroying ourselves? Are they already communicating with some of us whom they consider worthy? Have they already answered John Wheeler's last question, 'Why existence?', or will a serious human quest in that direction somehow qualify us as at least an interesting species worth observing, and therefore preserving?

