Space, the Final Frontier: In the Scientific Pursuit of Extraterrestrial Life Away from Earth

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(Dated: 9 April 2020)

For decades we have been searching for an answer to the knotty question, "do aliens exist?". Other questions in line are: "where are they?", "are they like us, sophisticated intelligent beings?" or "do they exist in the form of simpler lifeforms?", "Have they ever visited us?", "Why haven't we encountered them yet?", "or have we?" To satiate this curiosity, astrophysicists and astronomers have come up with innumerable theories and ideas, engaged in building facilities and institutes and come up with a planet-wide effort for the search of extraterrestrial intelligence - SETI@home. This article will take a ride through time, from the first documented idea to look for extraterrestrial beings to the current exploration of this field.

Keywords: *Drake equation*, *SETI@home*, SETI, Astrobiology, Astrophysics, Astronomy, Extraterrestrial life, Fermi paradox

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I. INTRODUCTION

The well-known intro from the Star Trek franchise, *Space: the final frontier. These are the voyages of the starship Enterprise. Its continuing mission: to explore strange new worlds, to seek out new life and new civilizations, to boldly go where no one has gone before*, has been deeply imprinted in our hearts since the beginning of the 60s. We will always be mesmerized by the imagination of its creators and never stop wondering whether, indeed, a time comes when we will be advanced enough to engage in interstellar and intergalactic exploration and meet new life forms, with possibly equally advanced intellect and technology and whether we will ever receive a message from them, if indeed they are somewhere out there.

The first written account reflecting the thought process related to the presence of extraterrestrial life dates to 400 BC. In his book 'On Natura', Metrodorus of Chios doubted the likelihood of the existence of one living world only in the infinite universe.[1] Later, in 50 BC, the Roman philosopher Lucretius in his book 'On the nature of things' reflected on the possibility of the existence of many Earths with many worlds, conceivably different from us.[2] Giordano Bruno noted in the 15th century, "there must be an infinite number of suns with planets with life around them", a notion for which he was prosecuted.[3]

Later in 1690, physicist Christian Huygens wrote in his book 'Cosmotheoros, "that life can exist on any other planets".[4] Hence, for centuries our intellect has driven us to question the presence of extraterrestrial life out there, somewhere, maybe on an Earthlike planet in the Milky way or other galaxies. This question has led to a zealous search for extraterrestrial life for decades now. Physicists, astrobiologists and engineers alike have developed many theories and are in a constant strive to prove their validity. Scientists have even developed tools and machines to send out signals to look for life far away from Earth.

In this exploration for extraterrestrial life, mankind has developed a peculiar interest towards finding its own counterpart, an intelligent lifeform in outer space. One such initiative was the development of the Drake equation in 1961 by American astronomer and astrophysicist, Frank Drake.[5] The equation puts forward a probabilistic argument of finding radio-communicating extraterrestrial intelligence based on certain parameters considered helpful in predicting the number of intelligent life forms in the Milky way galaxy and is founded on a paper published by physicists Cocconi and Morisson on the search for interstellar communication. These two fundamental constructs have inaugurated the official journey of the Search for Extraterrestrial Intelligence aka SETI.

Through this article, we will embark on an expedition in the quest for extraterrestrial life and intelligence. The opening section will unfold the events that materialized over the years, from the beginning of the 19th century up till now, in the search for living beings away from Earth. We will then, through the latter sections, take a closer look at the landmark events and theories that opened new horizons to this pursuit. Such will include the already mentioned famous Drake equation, the Fermi paradox, including explanations to the Fermi paradox by way of a paper written by Michael Hart and the great Filter hypothesis. We will then take a brief walk through the biggest SETI experiment of all time, SETI@Home ("SETI at home"). We will conclude this article with a glimpse at the future of the search for extraterrestrial life.

II. CHRONOLOGICAL ACCOUNT

The idea of the existence of aliens has evidently perplexed and mystified the human mind for centuries. However, the first scientific thought to communicate with extraterrestrial intelligence was made circa 1830 by the famous German astronomer and mathematician, Carl Friedrich Gauss. He proposed that using the Pythagoras Theorem, we could create a strong visual message for the aliens who might be observing us through their strong telescopes. Gauss suggested erecting a large right triangle in the Siberian forests. As per his vision, the triangle was to be constructed of large pine trees on the outside borders while having wheat piled on in on the inside. This colossal right triangle was supposed to be bordered by squares of giant wheat fields[6], thus forming the shape as depicted in Figure 1. Gauss' intention was to convey to those aliens out there the message that our Earth is inhabited by intelligent beings familiar with the Pythagoras Theorem. One of his other ideas to communicate with our intelligent counterparts was to reflect sunlight towards our neighboring planets[7] using his invention, the Heliotrope.

At the end of the 19th century, Nicola Tesla claimed that he had received alien radio signals.[8] According to him, while experimenting in his laboratory in Colorado Springs with high-frequency electricity and wireless energy transfer, he received cosmic radio waves on one of his instruments. After analyzing and searching for the origin of the received signals, he declared that the signals were sent by intelligent Martians from the planet Mars in an attempt to contact us.[9] The scientific community dismissed those claims. Nevertheless, Tesla's idea of communicating with extraterrestrial intelligent beings had already spread amongst scientific communities. It was only after five decades, in the mid-20th century, that Tesla's idea was accepted by the scientific community and further embraced in the form of a search for extraterrestrial intelligence (SETI).

In 1959, two physicists, Cocconi and Morisson at Cornell University, published an article in Nature titled "Searching for Interstellar Communications", arguing that radio telescopes had then become sensitive enough to receive radio transmissions broadcasted from other star systems.[10] They also stated that those messages might be transmitted at a wavelength of 21 cm (1420 MHz), corresponding with a wavelength at which neutral hydrogen emits radio signals. They argued that as Hydrogen is the most abundant element in the universe, intelligent extraterrestrial beings might consider it a feasible wavelength at which to send

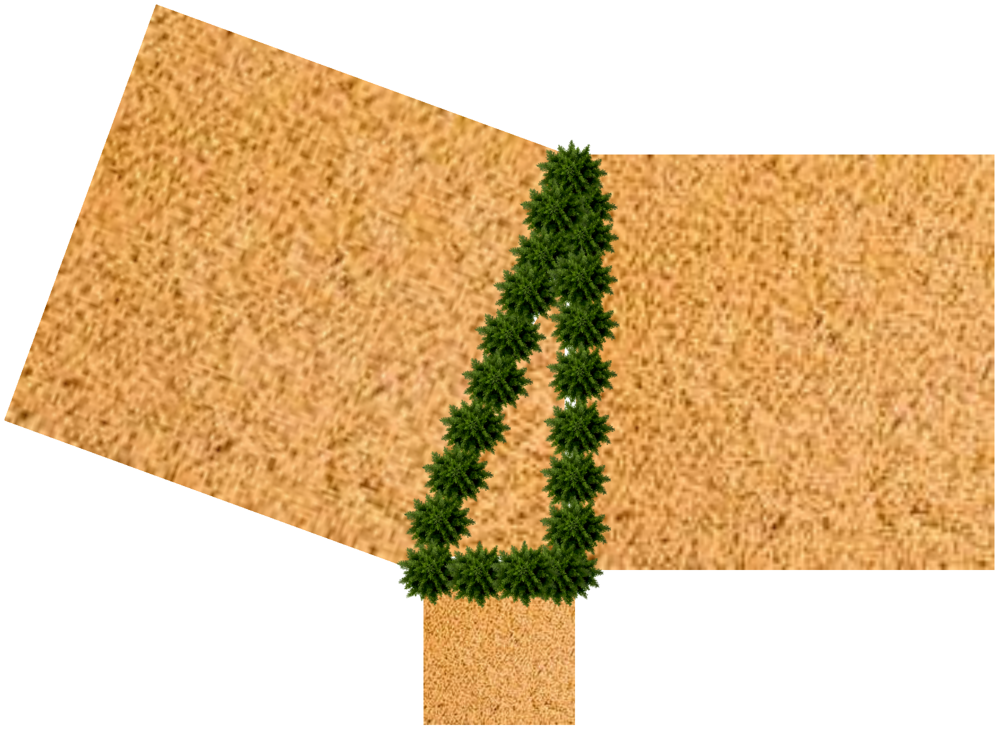

FIG. 1. Artist's rendition of the Gauss' vision to communicate with the aliens using Pythagoras theorem. The pine trees line the right triangle enclosed by the squares of wheat plantation.

signals to be picked up by other civilizations.

To experimentally test this theory, Frank Drake did the first SETI survey, known as Project Ozma, using 25 meters radio dish, utilized to monitor two nearby sun-like stars, Epsilon Eridani and Tau Ceti, at the National Radio Astronomy Observatory in Green Bank, West Virginia. The dish was enabled to monitor at frequencies close to 21 cm (1420 MHz) for six hours a day, between April and July 1960. These attempts to receive radio transmissions from extraterrestrials were unsuccessful.[11]

In 1961, Frank Drake organized the first official meeting for SETI at Green Bank Facility. It was to be a promising meeting, as Drake was fresh out of Project Ozma. But the problem was, in the words of Nadia Drake, Drake's daughter, "the meeting's scientific agenda was in disarray. Drake, who was 31, had been busy acting as a one-man organizing and hospitality committee and had been distracted by meeting logistics".[12] The meeting's attendees included esteemed personalities such as Philip Morrison, Melvin Calvin and Carl Sagan. A day before the meeting, Drake came up with a thought-provoking agenda for the conference in the intention of occasioning a vigorous discussion. In the proposed schedule, he listed seven allimportant factors he thought were crucial for finding intelligent alien civilizations capable of radio communication (N). Drake reasoned, "If I plug in numbers and multiply the terms together, it should give me the value of N". On November 1, he commenced the meeting by writing the equation on the board of the conference room.[12] Little did he know that the equation would become the basis of all SETI research, and be known, half a century later, as the Drake equation.

Even after those pioneering efforts by Frank Drake, the 60s didn't prove to be as fruitful for SETI as anticipated. The SETI was regarded by the scientific community as a science fiction outfit. Such a conservative outlook led to a significant downfall in SETI research, with only a few out-of-the-box thinking scientists producing work in this field. Those scientists continued to conduct radio searches with little or no support from their parent institutions or their governments. Significant works that resulted from this humble research were the classic book 'Intelligent Life in the Universe', 1966 by I.S. Shokolovski and Carl Sagan,[13] and First Soviet-American Conference on Communication with Extraterrestrial Intelligence held from November 5-11, 1971 in the Soviet Union in Byurakan Astrophysical Observatory. Its proceedings were published by the MIT (Massachusetts Institute of Technology) Press in 1973.[14]

During the late 70s however, the SETI began pacing itself . The late 70s also saw the rise of a revolt within the SETI community due to a paper published by Michael Hart in 1975[15] which questioned the presence of intelligent extraterrestrial beings due to the apparent lack of evidence. This argument culminated in the form of the conference 'Extraterrestrials - Where Are They?' held in 1979 at the University of Maryland.[16]

Later, at the request of Michael Papagiannis, the International Astronomical Union held a one-day session on 'Strategies for the Search for Life in the Universe' during the 17th IAU General Assembly in Montreal in 1979.[17] The meeting turned out to be a huge success with more than 1000 astronomers from around the world attending the Open Evening Session, where Drake and Papagiannis presented the results of the meeting. One of the very significant discussions of the meeting was the possible number N of the advanced civilizations in our galaxy, whose value was presented by Michael Hart, T. Kuiper, F. Drake, and M. Papagiannis respectively, with four possibilities: very small N, very large N, neither very small nor very large N, and either very small or very large N. Those very arguments, seen as the potential cause for the early demise of SETI, ignited a new spark in the SETI community as more people joined in. It was also because of those debates that the SETI community concluded it was impossible to reach unequivocal statements concerning extraterrestrial intelligence without backing them up with considerable amount of data, thus pushed research forward with alternative experimental efforts for SETI.

Meanwhile, NASA's hope for communicating with the extraterrestrial intelligence transpired in the form of spacecrafts, Pioneer 10 (launched on March 2, 1972) and 11 (launched on April 5, 1973). These spacecrafts were the two in the series of 8 spacecrafts in the project Pioneer designed to explore the space beyond our solar system and contained plaques made up of Gold coated Aluminum (Figure 2) bolted to their mainframe. Each plaque contained line drawings of human male and female (symbolic of the intelligent human race on Earth) standing before the outline of the Pioneer spacecraft.[18,19] Also, the plaque contained an illustration of the element Hydrogen on its left-hand side in the schematic form, showing the transition of neutral atomic hydrogen. As Hydrogen is the most common element in the universe, it was regarded as a convenient choice in the hope that should someday, indeed, intelligent and scientifically-educated aliens stumble upon it, they will be able to comprehend and translate the message.[19] At the bottom of the plaque there was a symbolic depiction of our solar system, with the trajectory of Pioneer spacecraft drawn in the form of an arrow protruding from the third symbol, Earth. The spacecraft behind the male and female human forms was drawn in the same scale as in real life to help deduce the relative size of human beings as compared to the Pioneer spacecraft. These drawings were designed by Carl Sagan and Frank Drake and drawn by Linda Salzman Sagan.[19,20]

Although the drawings on the plaque were created in good faith and with the vision to represent humanity as a whole, they were received with a fair share of criticism. Art historian Ernst Gombrich condemned the use of an arrow to illustrate the trajectory of Pioneer as he thought the arrow might be meaningless to the aliens and could also be a cause for misinterpretation and misrepresentation.[21] Another accusation claimed the human male and female bodily representations were of a Caucasian depiction only,[22] thus leaving out other races such as blacks and Asians. Whereas the original design intended to depict all races on the planet by including features of African, Asians and whites, the final drawings on the plaque were mere outlines, lacking shades and nuances, thus giving an impression of Caucasian human race.[23] Another issue with the human figures on the plaque was their sheer nudity, as some deemed it obscene pornographic drawings.[24] Pioneer 10 passed by

Jupiter on December 3, 1973, sending first close-up images of the planet. By the year 1983, Pioneer 10 left our planetary solar system. The signals from Pioneer 10 started weakening during the late 90s and a complete signal loss occurred in 2002. Pioneer 11 made its flyby near Jupiter in December 1974 and Saturn in September 1979 and left our solar system in 1990. The last contact with Pioneer 11 was in November 1995. Those spacecrafts were the first ones to leave our solar system.[19]

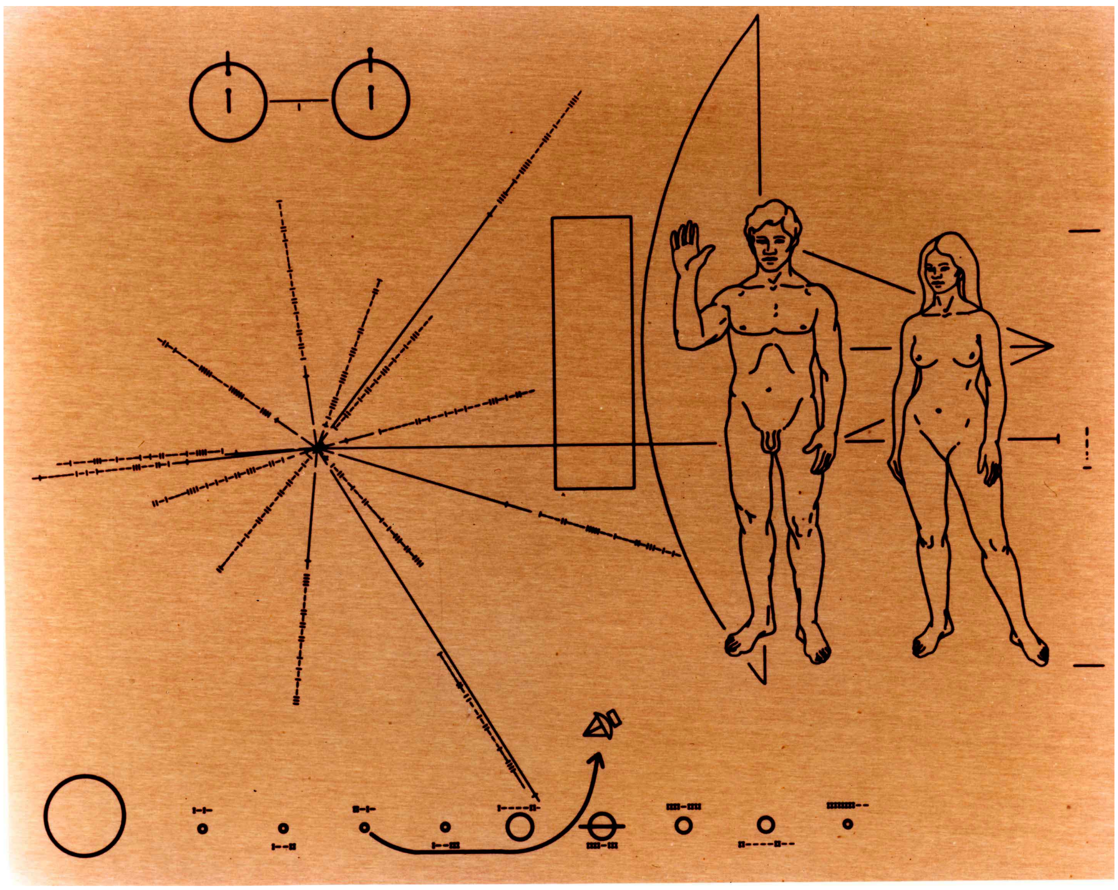

FIG. 2. The plaque onboard Pioneer 10 and 11. The drawing consists of the human male and female figures standing in front of the Pioneer spacecraft, scaled same as in the reality, the Hydrogen element on the left-hand side showing its transition, the solar system at the bottom of the plaque and the trajectory of the Pioneer spacecrafts from Earth as represented by an arrow. Credit: NASA Ames[20]

Later, in 1977, NASA's Voyager mission launched Voyager 1 and Voyager 2 to probe the planetary systems of Jupitar, Saturn, Neptune and Uranus.[25] Like their predecessors, Pioneer 10 and 11, both Voyagers contain messages from Earth (Figure 3), in the form of golden records containing images and sounds from Earth, for the extraterrestrials who might someday, even in a very distant future, encounter them.[26]

The contents of the records were selected by a committee headed by Carl Sagan. The messages contained over 115 photographs and diagrams,[26] encoded in analog form, of our solar system and planets, DNA, human anatomy, reproduction systems, animals and birds, insects, plants, landscape, photographs of humans with broad range of cultures having food, their architecture, their portraits. Scale of size and time was included in on these images. It also contained music sounds and vibrations. Compositions of Bach, Mozart and Beethoven played by various artists were included along with music recordings from various cultures such as Chinese music, gospel blues, American rock, Indian classical music, Bulgarian and Azerbaijani folk music along with electronic music compositions. Spoken greetings of 55 ancient and modern languages. Also, sounds of footsteps and laughter were added. It also covered recordings of brain waves pertaining to various emotions and memories such as Earth's history and problems faced, feelings of falling in love and happiness. US President Jimmy Carter's message included in the recording read:

This is a present from a small, distant world, a token of our sounds, our science, our images, our music, our thoughts and our feelings. We are attempting to survive our time so we may live into yours.

Along with this was added the inspirational Latin phrase, *Ad astra per aspera* (through hardships to the stars), encoded in Morse code.[27] Currently, both Voyager probes are sailing adrift away from our solar system, in the interstellar space. Voyager 1 has become the first human-made object to go that far in space.[28] We must keep in mind, however, that Pioneer and Voyager missions are far from agile messenger services for messaging between the stars: even with the most optimistic estimates, it will take hundreds of thousands of years, maybe even millions of years, for the spacecrafts to pass near some star, and who knows what remains of them by then. If by some miracle, a space faring extraterrestrial species encounters these vessels, and this might take who knows how long, the message conveyed will be pretty straightforward: the spacecraft's origin, the time it has left Earth, and how the creatures, and their technology, that sent it, looked like.

Additionally, a small group of scientists at NASA, led by John Billingham continued with the efforts for SETI via meetings, workshops and publications and the development of new instrumentations for SETI despite the lack of support by the U.S. Congress. Jill Tarter of

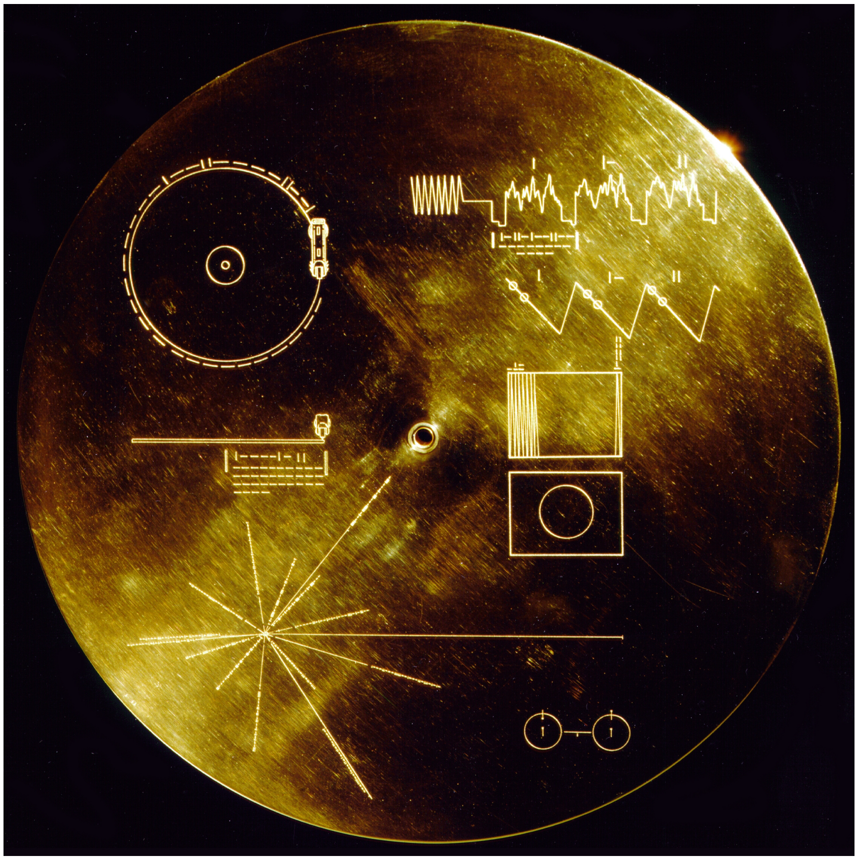

FIG. 3. The cover of identical records onboard Voyager 1 and 2. The cover is made of Gold-plated aluminum for protection. It also contains a key to play the record, both on the outside and the inside, in order to keep the key intact in case the exterior erodes over time. Credit: NASA[29]

this group made a significant contribution to this field during that time by initiating radio communication attempts all around the world and keeping logs of those attempts.

Early 80s saw a significant development and stirring of this field in terms of scientific credibility. In its report for the allocation of resources for Astronomy and Astrophysics research, the Astronomical Survey Committee of the U.S. Academy of Science, for the first time prioritized SETI and recommended the allocation of 2 million USD for research during the 80s. Similarly, the U.S. Congress in 1982 allowed NASA to fund SETI at the rate of almost 2 million USD per year.

Another significant landmark for SETI was the establishment of IAU Commission 51 – Search for Extraterrestrial Life by International Astronomical Union in its 18th General Assembly at Patras, Greece in 1982. IAU commission 51 held its first IAU symposium in Boston during June 18-21, 1984, and was attended by 150 prominent scientists and many others from 18 countries around the world.[30] The launch of SETI Institute, California in November 1984 was also one of the significant milestones for SETI research. The institute started operating on February 1, 1985. The inaugural officers of the institute were CEO Thomas Pierson and scientist Jill Tarter and its board of trustees included eminent figures such as Frank Drake, Andrew Fraknoi, Roger Heyns, William Welch, Carl Sagan, Lew Platt, and Nobel Prize laurates Baruch Blumberg and Charles Townes.

SETI institute was founded subsequent of profound funding concerns regarding the search of extraterrestrial intelligence. Those concerns led to the conception of a dedicated non-profit research organization whose focus was to be research and education of the factors that hinge on the Drake equation.[31] Jill Tarter, who is currently the Chair Emeritus of SETI Research at the institute, was active in raising funds for the SETI institute. Project Phoenix was conceived after the U.S. Congress cancelled the NASA SETI project in 1993 . It was the world's first most sensitive and comprehensive search for extraterrestrial intelligence based on detecting radio signals beamed directly towards Earth or unintentionally transmitted.[32] Phoenix's first observations began in 1995, using Parkes 210 feet radio telescope, the largest radio telescope in the southern hemisphere, placed in New South Wales, Australia. Over sixteen weeks, almost 200 stars, not visible from the Northern hemisphere, were observed using this telescope.

In September 1996, the project moved back to its roots at the SETI National Radio Astronomy Observatory in Green Bank, West Virginia. Incidentally, the 140 feet observatory telescope is situated only a short distance from the telescope used by Frank Drake in the 60s in Project Ozma. Project Phoenix continued its observations at the site until April 1998. During that period, the telescope was utilized half the time by Project Phoenix and the remaining time for other astronomical observations. In August 1998, the project moved to Arecibo, the world's largest radio telescope. Due to the high demand for the telescope, Project Phoenix could only operate for a limited number of hours, primarily at night, between 17:00 hours to 08:00 hours, two seasons a year. In total, the project ran for only 100 days at the Arecibo, from August 1998 to March 2004 before ending its operation. The project was primarily dependent on private funding. While the project was still operational, scientists, engineers, and technologists were actively seeking out ways to best pursue SETI research in the coming decades.

During the various workshops held from 1997-99, the idea of Allen Telescope Array was conceived.[33] The scheme involved an array of small antennas with a random arrangement over an area exceeding 1 Sqkm. The project began developing in 2001 as a collaboration between SETI Institute and the University of California, Berkeley after a generous donation made by Paul Allen, co-founder of Microsoft. After the completion of the first phase of construction, the antenna array became operational in October 2007. Since then, it saw many ups and downs in terms of funding. The SETI institute began its uninterrupted research using the Allen Telescope Array from 2016, operating daily between 18:00 hours to 06:00 hours. However, the technical challenges facing researchers are not straightforward. Not only do they have to scan the sky methodically and systematically over a long period of time, they also need to tune in to the exact frequency at which the message is broadcast: it is not enough to observe that very part of the sky from where the message is sent at just the right time; we also must tune in to the appropriate frequency. If not, the message will be lost. Moreover, interference from television or radio broadcasts on earth does not make it easy for scientists to differentiate a historical message sent by another culture from the TV series "Friends".

While SETI research had already kicked off in the 80s, the idea of SETI@home was conceived by computer scientist David Gedye in 1995 only, and led to the involvement of the masses with SETI operations. SETI@home officially launched at Berkley on May 17, 1999, as a result of the efforts of David Gedye,his graduate school advisor, David Anderson and SETI scientist at Berkley, Dan Werthimer. This was the first planet-wide effort to communicate with aliens.

While the efforts for SETI were actively pursued, NASA had been constantly busy looking for planets outside our solar system (exoplanets). Found in 1992, and although inhabitable, the first exoplanets in this endeavor gave rise to the hope that there are innumerable more out there, waiting to be unveiled.[34] After the discovery of a few more exoplanets, the researchers in 2001 came upon HD 28185 b, an exoplanet existing in a habitable zone, around the same distance from its sun as Earth is from our sun.[35] The planet is nearly six times as big as Jupiter, which is 16 times bigger than Earth, and because of its existence in the habitable zone, is capable of supporting life.

In 2003, Spitzer Space Telescope was launched and began observing exoplanets and their atmospheres.[36] Using the telescope, atmospheres of various exoplanets were being observed via spectral scans and analysis. This method of observation has been used to detect life on those planets. On March 2009, Kepler planet-finding mission took off with the launch of NASA's Kepler space telescope from Cape Canaveral Air Force Base in Florida.[37] It operated on its primary mission for 4 years, finding more than 1000 confirmed exoplanets, in the habitable as well as the non-habitable zones, before running into a malfunction in 2013. In 2011, Kepler found its first rocky exoplanet. In April 2014, first Earth-size planet, named Kepler-186f, was discovered. Only 10 percent larger than Earth, the planet orbits a star about half the size of our sun in the habitable zone.[38]

After some technical corrections were made to the space telescope, the Kepler mission was renewed as K2 that same year .[39] In July 2015, Kepler discovered a bigger and older Earth-like planet with 385 days rotation around its sun and a possibility of water on its surface.[40] In 2018, another space telescope TESS was launched.[41] That same year, Kepler ended its mission due to fuel exhaustion, after operating for 9 years.[42] By 2019, more than 4000 exoplanets have been found.[43]

III. THE MIGHTY YET SIMPLE DRAKE EQUATION FOR THE ESTIMATION OF EXTRATERRESTRIALS IN THE MILKY WAY GALAXY

$$\mathcal{N} = \mathcal{R}_{*} \cdot f_{\mathrm{p}} \cdot n_{\mathrm{e}} \cdot f_{\mathrm{l}} i \cdot f_{\mathrm{i}} \cdot f_{\mathrm{c}} \cdot \mathcal{L} \tag{1}$$

Where,

$\mathcal{N}$ = the number of intelligent alien civilizations in the Milky way capable of radio communication right now.

$\mathcal{R}_{*}$ = the rate of star formation in the Milky way.

f_{p} = fraction of those stars having planets.

n_{e} = number of those planets per star that could support life.

f_{l} = fraction of those planets where life evolves.

f_{i} = fraction of those lives that evolve into intelligent beings.

f_{c} = fraction of that intelligent life that develops radio communicative technology.

$\mathcal{L}$ = the average length of time these civilizations send detectable radio signals into the space.

A. Estimates, predictions and assumptions for each variable

From section III, we know the variables in the Drake equation that should be considered while looking for extraterrestrial intelligent civilizations. Frank Drake and colleagues in 1961 estimated the values of these variables as given below:

- $\mathcal{R}_* = 1/\text{year}$
- $f_\text{p} = 0.2$ to 0.5 of all stars formed will have planets
- n_e stars with planets will have between 1 and 5 planets capable of developing life
- $f_\text{l} = 1$, All of these planets will develop life
- $f_\text{i} = 1$, All of these will develop intelligent life
- $f_\text{c} = 0.1$ to 0.2 of which will be able to communicate
- $\mathcal{L} = 1000$ to $100,000$ years

These values as predicted in the 60s by Frank Drake and colleagues were more like educated guesses because, at that time, the only parameter with reasonably known value was $\mathcal{R}_*$. Based on these values, there would be between 20 to $50,000$ intelligent alien civilizations in the Milky Way capable of radio communication.

Let us now analyze each parameter briefly and discuss their current values as predicted based on the recent progress in space and SETI research.

$\mathcal{R}_*$: This represents the number of stars formed each year in the Milky way galaxy. Today, the estimates for the number of stars in the Milky way vary from 100 billion to 400 billion. Also, the age of the Milky Way has been estimated to be from between 800 million years to 13 billion years. According to Jim Plaxco, President of the Chicago Society of Space Studies, if we take the lowest star count, i.e., 100 billion and the upper age limit of the galaxy, i.e., 13 billion years, the average rate of star formation turns out to be 7.7 new stars per year.[44] Conversely, if we take the highest star count, i.e., 400 billion and the lower age limit of the galaxy, i.e., 800 million years, the average rate of star formation becomes 500 new stars per year. As the galaxy ages, the calculations above display, the rate of star formation decreases. So, the current estimates for the overall rate of star formation range from 5 to 20. Plaxco also states that not all stars created are considered suitable because not all of them are blessed with reasonable longevity and size. Evans et al, estimate this value at 1.5 to 3 stars per year. Some critics, however, argue that instead of considering the rate of yearly star formation, it would be best to consider the number of stars currently in existence. In light of this, one of the modifications to the Drake equation includes the Seager equation to be discussed later.

f_{p}: The fraction of those stars with planets. The only known planets at the time of the creation of the Drake equation were the ones in our solar system. Since then, more than 200 exoplanets (planets outside our solar system) have been discovered. At the time of the creation of the Drake equation, it was believed that only single star systems can have planets because the gravitational disruptions in multiple star systems would prevent the formation of planets. That viewpoint caused the exclusion of almost 50 percent of the stars from consideration. As a result, theories have been otherwise confirmed. The current estimated range is 5% to 90%. Jim Plaxco gives a value of 0.4 to this parameter.

n_{e}: The average number of habitable planets per star for those stars with planets. For this parameter, a value of 1.0 means that every star with planets will have one habitable planet, while a value of 0.5 means that there is one habitable planet for every two stars with planets. To arrive at a value for this parameter, factors such as the chemical composition of the solar nebula that forms the planets, the presence of necessary elements in adequate quantities and the range of distance at which a habitable planet can exist, must be considered. Current estimates suggest the value 0.4 for this parameter.[45,46] We must also consider that life might not necessarily require Earth-like conditions. We must keep our minds open to a possibility as such.

f_{l}: The fraction of these habitable planets, where life actually emerges. For this variable, a value of 0.01 means that only 1 for every 100 habitable planet and a value of 1.0 means life develops on every habitable planet. This is one of the biggest unanswered questions of all, basically because as of now there is only one specimen in front of us, i.e., life on Earth. Many questions pop up while trying to estimate the chance of life emerging on a planet: How does life originate in the form of simple biomolecules, and if so, how do these biomolecules are then directed to form a basis for life? Where does this primitive life stem from? Does life emerge on a solid surface, in the oceans or in the atmosphere? What if it originates in interstellar space and only later on settles down on a planet capable of providing nutrition for its propagation. Astrophysicists and astrobiologists have pointed out that in our own solar system, of 8 other worlds, including Mars and the moons of Saturn and Jupiter, a possibility of life may exist, most probably a primitive one. Such possibility, of course, could never be declared a certainty until being proven. Optimistically, it is possible to predict a 10 percent chance of life emergence, but even that is a long shot. At present, any value considered in regard to life emergence parameter will be considerably far from accurate. Maybe in the future, when we are technologically advanced enough to pick up biosignatures, that is, the presence of methane, molecular oxygen, etc., as suggested by Astronomer and planetary scientist Sara Seager, we would then be able to define the value of this parameter with a bit more accuracy than today. Though not big, it would still be a remarkable step forward to use life emergence parameter to infer the presence of life in those planets. Case in point, when deciding the value of life emergence parameter, as per Plaxco, is that the Earth is 4.5 billion years old and that the oldest fossil evidence of cyanobacteria dates to 3.5 billion years. The question is whether those conditions are profuse enough on other planets occasion life. Current estimates suggest the value of 10^{-5} to 0.2.[47]

f_{i}: The fraction of planets with life where intelligent life appears. A value of 0.001 means that intelligent life will appear only on 1 of the 1000 planets with life. We can again be guided by one example only, i.e., Earth. Of all the millions of species ever to inhabit Earth, mankind is the only one who has been capable of evolving to a higher intelligence, particularly to develop technological capabilities. Although primitive life formed on Earth relatively quickly, it took way longer to develop its complexity, let alone intelligence. Catastrophic events like meteor showers and other environmental calamities may have proven hinderance in the way of the development of intelligence. On the other hand, those events might also have aided in the evolution of intelligent life. Currently the value of this parameter is given as 0.05.

f_{c}: The fraction of intelligent civilizations that develop radio communication technology. A value of 1.0 indicates that every civilization develops radio technology, while a value of 0.001 means only 1 in 1000 civilizations develop radio. Those intelligent beings may be advanced enough to build necessary amenities such as buildings and roads but may not ever be able to develop radio technology or other means of communication. There is an abundant range of possibilities of whether intelligent life is capable of developing radio communication. It may be that only 1% of intelligent life develops technology. In this light, we must also consider the issue of frequency of radio signals used to communicate. Scientific communities from Earth and the extraterrestrials need to pitch exactly to the same frequency in order to communicate.

$\mathcal{L}$: The length of time during which intelligent life remains detectable. This parameter turns the equation from a rate into a number. Again, we can only be led by the example of Earth. Some astrophysicists believe that the value is 450 years, others believe 50 years and Drake himself, being an optimist, believed it to be around $10,000$ years.

Now, we have better technology than we did 60 years ago, to predict the values of the Drake equation parameters more realistically than ever. The current estimates, as per these predictions, suggest that there are between zero (which means that we are alone in the Milky way) to 21 intelligent alien civilizations in the Milky Way capable of radio communication.

Some of the unspoken assumptions made by Drake, while writing the equation, are:

- That intelligent, technologically advanced civilization will not colonize other worlds. We need to keep an open mind to the fact that a technologically advanced civilization has a chance of spreading or colonizing other planets. Thus, scientists must consider this parameter as well while making estimates and modifications to the Drake equation.

- And that broadcasting-and-listening-for radio signals are the methods by which an intelligent species would choose to communicate across interstellar space. We need to be flexible to the possibility that these civilizations might develop alternative communicative technology along with the radio communication or not rely on it entirely. Their technology might be way advanced in comparison to ours. There is also a possibility that they might be trying to communicate with us using entirely different media and technology and that their efforts might have gone futile just like ours.

B. Where is the Drake equation leading us?

According to some scientists and mathematicians, the Drake equation is broken for it does not account for evolutionary effects, nor considers the history of the galaxy.[48] The equation was written before the Big Bang theory was validated. Therefore, it does not account for many other phenomena that might have affected the emergence of habitable planets and life on those planets. The last four parameters in the Drake equation f_{l}, f_{i}, f_{c} and $\mathcal{L}$ are no more than wild guesses for now because, as we mentioned earlier, we can only be led by the example of Earth. According to Paul Sutter, an astrophysicist at the Ohio State

University, we have no idea how uncertain the estimates of values for each variable might be. Failing to correctly estimate the value of even one parameter is a waste of years of hard work. As Sutter himself noted, "Until you know all of it, you know none of it".[49] As earlier discussed, the Drake equation makes a significant number of assumptions. But perhaps we need to look at this equation not as a blueprint of a strict estimate, but more of a guide to our approach towards the search of life beyond Earth. Yet, is it as useful today, as it was years ago, to further our understanding of life beyond Earth? SETI researchers had initially based their work on the Drake equation, some still do, but many of them have gone past it to develop many variations of the equation. Those variations are far from perfect, but they are better in some sense than the Drake equation in eliminating unnecessary assumptions or looking at the problem from a different angle. Maybe in the future, when we have better technology, we will be able to turn those wild guesses into solid estimates. Until then, the equation remains broken.

C. Modifications to the Drake equation by Sara Seager

Astronomer and planetary scientist, Sara Seager, in 2013, developed another version of the Drake equation.[50] Her equation focuses on estimating the number of extraterrestrial civilizations based on planetary biosignature, i.e., the biogases accumulated in the planetary atmosphere to detectable levels, rather than listening to radio signals.[51] Thus, her approach is based on finding life outside of Earth, however intelligent. In an interview, Seager asserted, "This equation is a purposeful take-off on the Drake equation, which was about the search for intelligent extraterrestrial life".[52]

$$\mathcal{N} = \mathcal{N}_* \cdot f_Q \cdot f_{HZ} \cdot f_O \cdot f_L \cdot f_S \tag{2}$$

Where, $\mathcal{N}$ is the number of planets with detectable signs of life, $\mathcal{N}_*$ the number of stars observed, f_Q the fraction of quiet stars (M class dwarf stars which are dimmer and cooler). Those are the most common stars in our galaxy. It is easier to look for planets transiting those stars because they are less noisy in terms of brightness. f_{HZ} is the fraction of stars with rocky planets in the habitable zone, f_O the fraction of those planets that can be observed, f_L the fraction that have life, and f_S the fraction on which life produces a detectable signature gas.

Seager considered M-type dwarf stars to look for habitable planets because those are the most common stars in our galaxy. Those stars are less luminous and smaller than regular stars like our sun. Previously, scientists neglected those stars when searching for planets that can support life.[52] Recently, many rocky planets have been found orbiting those M stars that have exhibited Earth-like conditions. Scientists thus are now focusing their hunt toward those star-classes, looking for habitable planets and signs of life. One such example recently discovered is M-star Ross128, which is orbited by a rocky planet, 128Rossb with a distance of about 0.05 AU (astronomical unit = 150 million km). Discoverers have estimated that equilibrium temperature on that planet is somewhere between -60 and 20°C, which is similar to that on Earth.[53,54]

Seager proposes to use Transiting Exoplanet Satellite Survey to find rocky planets. This survey relies on transit photometry in which the dimming of a star due to a transiting planet is observed to infer the presence of a rocky planet. She then plans to use the James Webb Space Telescope to observe the atmospheres of those planets, during transit. Observing the atmosphere of those planets and searching for biogas accumulations, enhances the chance of detecting extraterrestrial life.

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IV. FERMI PARADOX

A. The Fermi Paradox

The Fermi paradox, named after physicist and 1938 Physics Nobel laurate Enrico Fermi, illustrates a contradiction between the high probabilistic estimates for the presence of extraterrestrial life and the apparent lack of evidence for one. In other words, because of the presence of a large number of stars in the universe, some even billions of years older than ours, there is a high probability for the presence of intelligent species, perhaps even highly technologically developed. Nonetheless, there has been no evidence of life out there. This argument was put forth in 1950, during a conversation related to the subject of UFOs and ETI between Fermi and some colleagues while he was working at the Los Alamos National Laboratory, where Fermi famously asked, "Where is everybody?"[55,56]

B. Explanation for the absence of extraterrestrials by Michael Hart

In 1975, astrophysicist and white separatist advocator,[57] Michael Hart published a paper, "An Explanation for the Absence of Extraterrestrials on Earth" in the Quarterly Journal of The Royal Astronomical Society. That paper prompted a division within the SETI community, breeding a rather pessimistic view on the subject as compared to other articles of the era. The paper puts forward arguments to support the claim that if extraterrestrials are not here, than they do not exist.

In the paper, Hart points to various explanations, given by his colleagues, for the absence of extraterrestrials on Earth and tries to prove them inadequate. He explains the invalidity of each explanation in separate sections, dividing them into three main categories: physical explanations, sociological explanations and temporal ones. Physical explanations deal with the physical, biological, astronomical or engineering difficulties that might come in the way of space travel.

Hart suggests many alternatives to deal with the physical obstacles, concluding that "neither the time of travel nor the energy requirements create an insuperable obstacle to space travel". Sociological explanations involve the view that perhaps the intelligent extraterrestrial beings did evolve but have chosen not to contact us because of a shear lack of interest or because of destroying themselves in a nuclear war or that they have set Earth aside as a human zoo.According to Hart, it is highly unlikely that a technologically advanced species has never been curious enough nor developed the urge for space travel. He disregards the zoo hypothesis, deeming it a highly unscientific view.

Temporal explanations are based on the possibility that advanced civilizations evolved pretty recently and haven't had the time to reach us yet. Hart concluded that the presence of intelligent life in our galaxy is highly unlikely and we might as well be the first ones to evolve to that level. He argued that to extensively dive through radio signals is a waste of time and money and that our decedents in some far future would be the ones to colonize habitable planets in our galaxy.

Hart's paper has been considered to be one of the explanations to the Fermi paradox, now sometimes known as Fermi-Hart paradox.[58] Some scientists drop the paradox part completely and rather regard it as Hart-Tipler argument.[59] Although his scientific endeavors are appreciable, the fact that Michael Hart was a sheer racist should neither be ignored nor be overlooked. The naked beauty of science and its aspiration for truth should not be tarnished by people like him.[57]

V. THE GREAT FILTER HYPOTHESIS

Formulated by economist Robin Hanson in 1996 and updated in 1998,[60], the great filter hypothesis tries to answer the question why, despite a high probability of the presence of life in the universe, we haven't been able to encounter any extraterrestrial lifeforms at all.[60,61] According to the hypothesis, life, during one of the stages of its emergence, undergoes the great filter of elimination. That filter can manifest as a planet in the habitable zone, presenting no materials necessary for the formation of life. The filter can also manifest at the first stages of life, when certain conditions prevent a biogenesis (formation of living organisms from non-living organic matter, such as organic compounds). Likewise, the filter can also eliminate life at later phases of development. Hanson provides a list of those possible stages of life emergence. For example, the filter can be a natural calamity that totally wipes out a living species, such as the one that led to the annihilation of dinosaurs. Similarly, the filter can simply be an impediment to the development of complex brain structures that form intelligence.

Life on Earth has undergone a fair share of filtration, but it has, until now, thrived through thick and thin. Yet, out of a billion of living species on Earth, only one, i.e., the human race has evolved into intelligent beings. Scientists argue whether the Great Filter is behind us or still ahead of us. Whether we are to face a mass obliteration in the times to come or are we past that and will eventually develop into a highly advanced space-faring species. What if we are still to face the Great filter? What form will this filter take? Will it take the shape of a global natural calamity or will an asteroid hit Earth or might it simply come in the form of a disease or a viral infection that will claim millions of lives and finally engulf all of humanity. Fate is a mysterious lady.

The Great Filter hypothesis thus, explains the Fermi paradox. Maybe the alien species did emerge on some planet but was wiped out before evolving into a higher form or maybe they evolved into highly intelligent and technologically advanced species only to later meet with a deadly fate.

VI. SETI@HOME (”SETI AT HOME”)

During his birthday party, on December 11 1994, computer scientist David Gedye was talking to a friend, discussing what can be the next big thing in science; something to the effect of the launch of Apollo 11 back in 1969. How could computer science create the same effect? Gedye was an astronomy amateur enthusiast and SETI turned out as an obvious idea. Back then he was working with a small company on network gaming. It was the time when internet was not yet a public domain. Gedye came up with an idea to ask people using internet to volunteer to remotely lend their computer hard drives for the use of SETI data analysis. Enlisted for the experiment was astronomer Dan Werthimer, a SETI scientist from UC Berkeley. Also recruited was David Anderson, formerly an assistant professor at UC Berkeley, who at the time was the chief technical officer at Tunes.com.

Gedye's plan was to unfold thus: a software would mine the data from the Arecibo radio telescope, convert it into processable bits, send it to the user desktop, command it to be processed upon to hunt for alien signals while the computer is idle and send the results back to Berkeley home base. That would thus work as distributed computing, virtually acting like a supercomputer due to the immense collective computing power provided by the volunteer computers. By the fall of 1995, the proposal was ready. Anderson would work in his company during daytime and code the software during the evenings.

By May 17, 1999, they were up and running. Gedye and team thought more or less a thousand people might join the project. As a result, they set up only one desktop for lending out data and receiving back the results. But apparently the idea of lending out your computer for a search for aliens was so alluring that at the launch over a million people signed up for SETI@home. The lone data-serving desktop suffered immense load. Sun microsystems then donated computers to act as a collective server end. The project got back up and since then, more than 4 million people have used SETI@home. An early analysis in the year 2000 showed that a million volunteer computers had processed the amount of data that would otherwise take a single desktop a thousand years to process. Currently, the collective computing power of those volunteer computers exceed 2008's premier computer.

As of now, there is an enormous amount of data from Arecibo that has been sent over from volunteer computers to UC Berkeley home server, data that has been examined over 21 years of operation and still needs to be analyzed. As such, the researchers at UC Berkeley have decided to halt the public-facet of the SETI@home project by discontinuing to send more work to the volunteer computers and, according to Dr. Eric Korpela, director of SETI@home, the project, while not dead, is going into hibernation. Situated before the team , comprising of a 4 full-time researchers, is a huge amount of 2 decades worth of collected data that needs to be analyzed .[62] Once the data analysis is over, SETI@home might be relaunched sending the data from other telescopes such as MeerKAT array in South Africa or FAST telescope from China. SETI@home might be over but the search for extraterrestrial intelligence continues. For all we know, our galactic neighbors did leave us a message; let us wait and see what is unveiled once the data analysis is over.

VII. EPILOGUE

What the estimates shown above clearly indicate is that there is most likely an alien civilization somewhere out there capable of communicating with us. However, the vast size of the galaxy, let alone the universe, strongly nullify the alluring possibility of alien past or near future visits. Compared with the immensity of the universe, the search for extraterrestrial intelligence, even after 60 years of operations, is still in its infancy due to its technological limitations. Not only that, but it is anyone's guess when this research will come to fruition in actuality.

Finally, if we put it as captain Picard's log entries, "Captain's log, supplemental. To gain knowledge of the existence of other life forms on other planets in the Milky Way galaxy has been one of the prime incentives of humanity's space quest. We are taking necessary measures to keep each step forward in this quest for life. Maybe someday in the near future, we will learn that there are complex organisms somewhere out there. Maybe, a time will come when we will make the first contact with a highly advanced, intellectual beings or maybe we will be visited by them. Or maybe they are there, observing us, waiting for us to make an evolutionary breakthrough so that they can contact us, and we can exchange knowledge with them which would forever change the course of humanity. We must, however, keep in mind that the universe and the galaxy are vast and gigantic, beyond anything we humans can perceive. Hence, it might take millions of years to make such a galactic journey. For that we must keep moving forward with hope and optimism, taking strong educated steps towards technological advancement. We have a long way to go, there is still so much to do. However, slowly but surely, we will get there."

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