WHERE IS EVERYONE?
THE SEARCH FOR LIFE IN THE VAST UNKNOWN

BY SHREYA RAMESH

Aliens are everywhere in modern science fiction. From H.G. Wells's first description of alien life in *The War of the Worlds* to the diverse landscapes in George Lucas's Star Wars universe, these foreign lands help us escape life on Earth and imagine one of space travel to galaxies far, far away. Yet sometimes we forget that these bustling metropolises filled with diverse creatures and landscapes are only fictional since life outside of Earth has not yet been discovered. Despite scientists' efforts, we still have not discovered organisms—even as simple as tiny bacteria—on planets that our rovers, like Perseverance and Curiosity on Mars, now call home. We live in a universe with trillions of galaxies, many of which have solar systems with the ideal conditions to sustain life, yet we have not discovered any signs of extraterrestrial life. So, where is everyone?

THE PARADOX

This very question is the same one Italian physicist Enrico Fermi supposedly asked his colleagues at Los Alamos National Laboratory in New Mexico[1]. In fact, his query became the motivation behind the Fermi paradox. The Fermi paradox is merely a question of probability and highlights that despite the age of our universe and the almost infinitely large number of planetary systems that could inhabit life, humans have yet to encounter extraterrestrial life forms.[2]

Fermi is not the only one to ponder this existential question.[3] Dr. Frank Drake, a prominent astronomer and astrophysicist, developed a formula to estimate how many alien societies could theoretically exist. In his formula, Drake theorized that there are a multitude of astronomical factors that influence where and how civilizations would form. For example, most civilizations most likely require stars of a certain size to provide enough light and thermal energy for biological functions, such as photosynthesis. Additionally, planets must have the proper conditions to sustain life, which include having enough carbon to build biomolecules and water for organisms to survive. However, the lack of observed life forms does not match up with the high numbers of civilizations that the Drake equation could theoretically yield. Consequently, astrophysicists have pondered this question of probability over the years and have developed different explanations for this disparity.

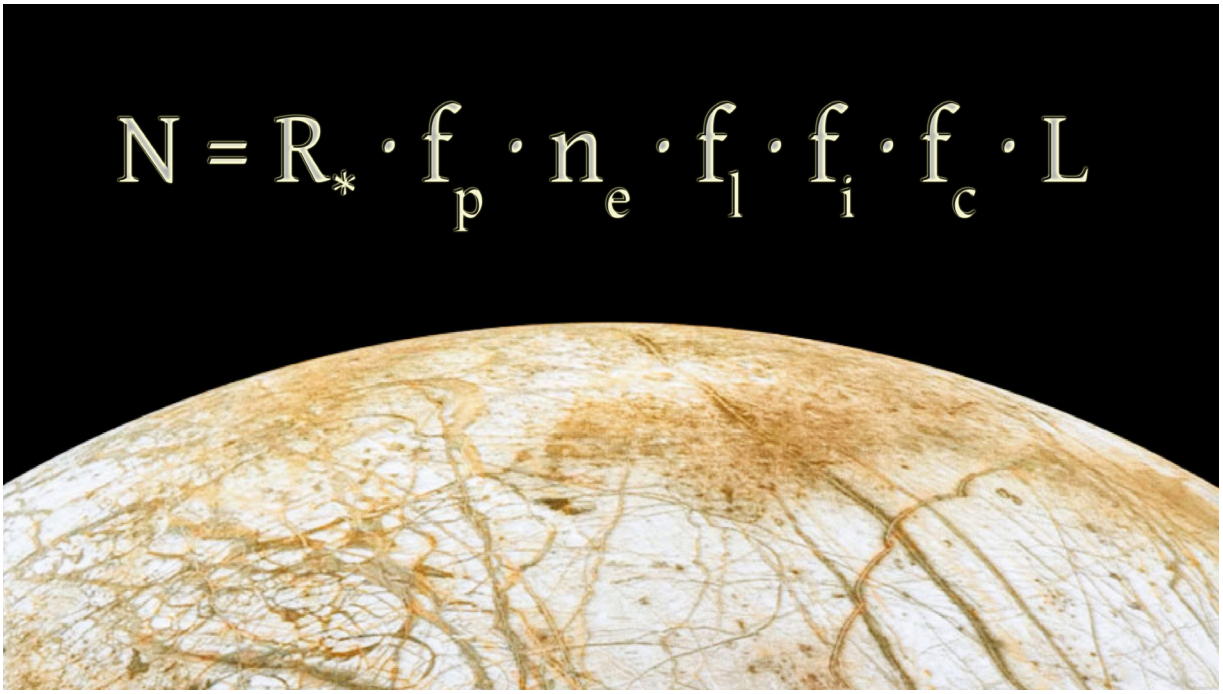

Figure 1: The Drake Equation. *A formula that can be used to estimate the number of possible extraterrestrial civilizations, where N = number of civilizations with which humans could communicate, R_* = average rate of star formation, f_p = fraction of stars with planets, n_e = number of planets that could host life, f_l = possible planets that could develop life, f_i = planets where intelligent life could develop, f_c = planets where life could communicate, L = amount of time that civilizations can communicate.*

ANSWERS TO AN UNANSWERABLE QUESTION

A seemingly obvious answer is that extraterrestrials simply do not exist in our universe. Developed by Frank Tipler and Michael Hart in the early 1980s, the Tipler-Hart solution postulates that aliens have not contacted humans because they simply do not exist.[4] Another explanation is that they exist but are not technologically advanced enough to detect our presence or to reach out to us yet. For all we know, life outside of Earth could consist merely of simple microorganisms. Alternatively, some scientists speculate that aliens have already visited us in the past, but life on Earth was not advanced enough to understand or recognize them as extraterrestrial organisms. However, there is no evidence that such advanced civilizations have visited Earth, and we still have not detected any signs of alien life from advanced radio telescopes.

One of the most recognizable solutions to this paradox is known as "The Great Filter".[5] Robin Hanson, the researcher who coined this idea, speculated that fundamental barriers prevent some civilizations in the universe from expanding. Potential barriers could include uncontrollable ones such as the initial atmospheric composition of a planet and its distance from the sun. But they could also include problems that civilizations can control such as pollution and global conflict. These barriers would then theoretically prevent civilizations from advancing past a certain point of their development. Perhaps humanity is the only civilization in our universe's 14 billion-year history that has overcome the Great Filter. Or, perhaps, we are the only civilization left in the universe that has yet to encounter the Great Filter.

SEARCHING

As we have developed new technologies to explore space, we have also created new projects that may begin to help us answer these hard questions that space exploration has created. One early example of such a project is the Voyager missions. In the 1970s, NASA launched the first probes that were to reach interstellar space beyond the reaches of our solar system.[6] With this in mind, scientists included records onboard which could provide to any alien civilization proof that other life in the universe exists. These "Golden Records" contain greetings in various languages, music from around the world, and photos representing our planet and the accomplishments of those living on it, such as images of technological innovations and of the Earth itself taken from outer space. On the cover of the record, NASA included valuable information that aliens could use to learn more about life on Earth, including our location relative to 14 known pulsars and visual directions which could be used to better understand the contents of the record.[7] Hopefully, one day, the Voyager probes will be found by some distant extraterrestrial civilization who will discover that they are not alone in the universe— and who may then in turn provide humans with a similar sense of clarity.

Another ongoing project that NASA and other organizations have been working on is the search for exoplanets—which are planets that inhabit star systems outside of our solar system. Currently, there are nearly four thousand confirmed planets in our galaxy, although astronomers predict that nearly trillions may exist in our galaxy alone.[8] Astronomers are currently searching for plan-

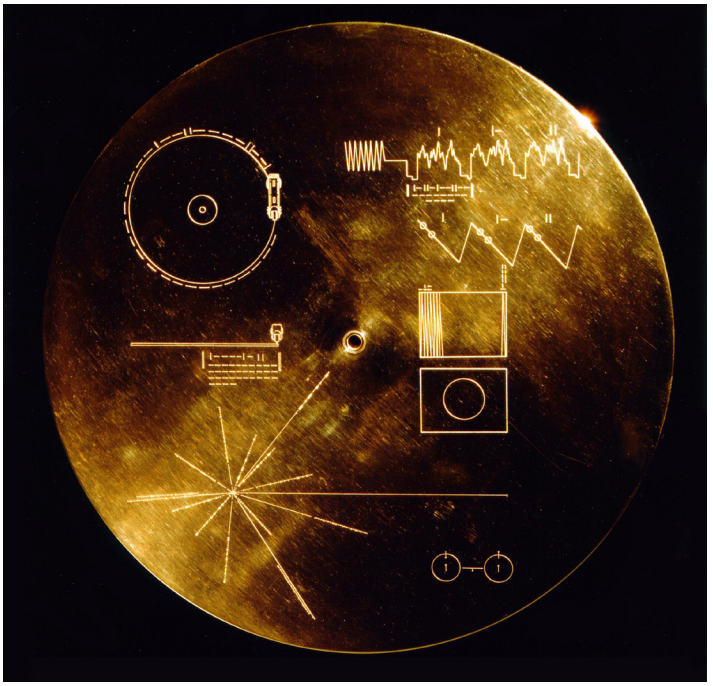

Figure 2: *The cover of the Golden Record on board the Voyager missions.*

ets with conditions similar to those of Earth since these conditions have clearly proven the possibility to sustain life. For example, astronomers have analyzed the atmosphere of countless planets by examining the light they emit or absorb, splitting this light into a spectrum of different bands of colors, and then using these band arrangements to determine the atmosphere's chemical composition.[9] Any signs of oxygen, carbon dioxide, or methane in these bands are regarded as potential signatures of life or as indicators that life could develop on these planets in the future. Similarly, astronomers analyze the star systems hosting these exoplanets; stars that are slightly cooler than our Sun combust for slightly longer, meaning that they can burn for tens of billions of years, increasing the chances that life has time to evolve.[10] If a planet is the ideal distance away from these types of stars, they may be potential hosts for life.

An alternative method to search for life is by scanning the skies for radio waves. Radio waves are a great way to communicate across space since they travel at the speed of light and are not absorbed by the dust in space.[11] As a result, the Search for Extraterrestrial Intelligence (SETI) Institute set up various projects to detect alien life as advanced as us using this technology.[12] For example, the Allen Telescope Array, located in Hat Creek, CA, is one of SETI's first arrays of radio telescopes. It includes a series of forty-two large antennas containing specialized receivers designed to detect any radio signals that other civilizations may transmit from their own technology or activities. These antennas are set up in such a way that internal mirrors within the large dishes reflect and amplify the incoming signals that scientists can use to make observations.[13] With this arrangement of radio telescopes, researchers can observe multiple star systems at any time of day, maximizing the chance of observing life. Additional SETI projects, such as the Breakthrough

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Listen project, use similar technologies to survey nearly a million nearby stars and star systems as well as nearly 100 galaxies that are close to the Milky Way.[14] The radio telescopes used for this project are located all around the world, from West Virginia to Australia. These telescopes are linked together in order to conduct a deep and comprehensive search of all the various radio waves that can be found throughout outer space. Despite not yet having found any signs of life, these projects symbolize scientists' optimism for discovering that we are not alone in the universe.

ANSWERS

Searching for life in our universe is difficult, especially when the only evidence of life that we have is our own existence. There are numerous research projects to address Fermi's original question, yet, after nearly seventy years of research, we still have no answer. In the end, we may never get answers in our own lifetimes or even during humanity's existence simply due to factors beyond our control and the sheer vastness of outer space. Is humanity doomed for a solitary existence in our universe? Or can we revel in the fact that our presence may be truly special? Our existence in the universe may be something extraordinary; against all the odds and barriers that the universe may throw at us, humanity still exists and thrives.

Figure 3: *Allen Telescope Array, a SETI initiative to detect radio signals*

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