The Fermi Paradox: 'Where Is Everybody?'

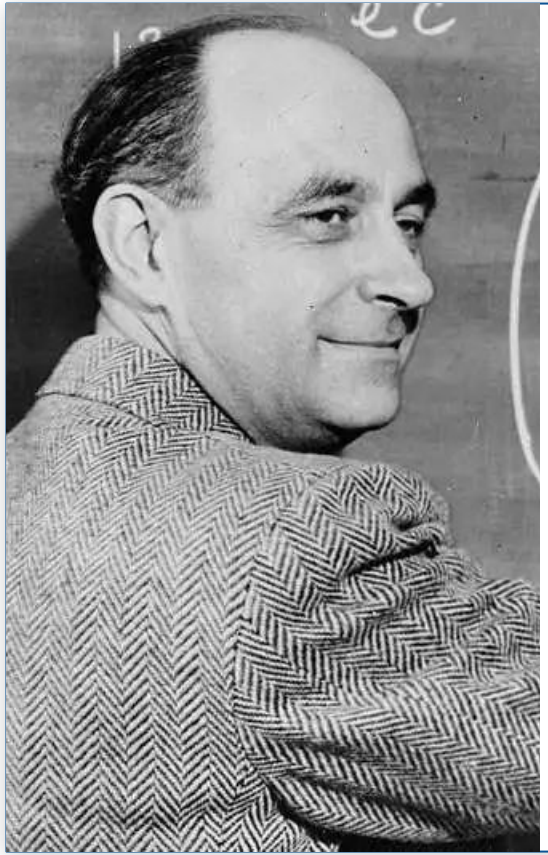
The Fermi paradox is the contradiction between the absence of clear, apparent evidence for alien life and the high estimations of its presence.

Space Facts

- The age of the Milky Way galaxy is **13.61 billion** years with estimated **100-400 billion** stars.
- In 2020, using Kepler's data, it was calculated that the Milky Way potentially may have **6 billion** Earth-like planets.
- Another study indicated that over **300 million** possibly habitable planets exist in our galaxy.
- Astronomers have already confirmed over **5,000** exoplanets with **24** superhabitable planet (planets with better conditions than on Earth).
- The age of the observable universe is **13.77 billion** years (+/- 40 million years).
- The number of stars in the observable universe is estimated to be around **10^{22}-10^{24}**.
- The universe is estimated to have around **100 billion** galaxies.
- There are approximately **50 sextillion** Earth-like planets in the whole universe.

Taking into account the fact that the universe is old and enormously big, there should be significant number of intelligent civilisations capable of long-distance communication. So, **where is everybody?**

The Fermi Paradox: Reasoning



The Milky Way contains billions upon billions of stars that are quite similar to our own sun.

Some of these stars are likely to have Earth-like planets in their circumstellar habitable zone.

The planets of several of these stars are significantly older than the Sun. If Earth is typical, intelligent life may have been there for a very long time.

Some of these civilisations may have developed interstellar travel, a step humans are investigating now.

The Milky Way galaxy might be entirely travelled in a few million years, even at the modest speed of currently proposed interstellar travel.

Furthermore, given that many stars like the Sun are billions of years older, alien civilisations – or their probes – should have previously visited Earth.

However, there is no solid proof that this has taken place.

The Fermi Paradox

There are many approaches that scientists use or could possibly apply to explore our universe for the existence of extraterrestrial life or even an intelligent one. Studying technosignatures, electromagnetic emissions, direct observation of systems, and conjectures about interstellar probes still requires an answer to the question: **'Does extraterrestrial life exist out there, or why haven't we spot it yet?'**

The Fermi paradox is the conflict between the lack of clear, obvious evidence for extraterrestrial life and various high estimates for their existence. There are different hypothetical explanations for the paradox:

Discovery of Extraterrestrial Life is too Difficult

- Humans have not listened properly
- Humans have not listened for long enough
- Intelligent life may be too far away
- Intelligent life may exist hidden from view

Sociological Explanations

- Colonisation is not the cosmic norm
- Alien species may not live on planets
- Alien species may have only settled part of the galaxy
- Alien species may isolate themselves

Willingness to Communicate

- Everyone is listening but no one is transmitting
- Earth is deliberately avoided
- Communication is dangerous
- Earth is deliberately isolated

Evolutionary Explanations

- Intelligent alien species have not developed advanced technologies
- It is the nature of intelligent life to destroy itself
- It is the nature of intelligent life to destroy others
- Civilisations only broadcast detectable signals for a brief period of time
- Alien life may be too alien

Economic Explanations

- Lack of resources needed to physically spread in the galaxy
- It is cheaper to transfer information than explore physically

Rarity of Intelligent Life

- Extraterrestrial intelligence is rare or nonexistent
- Periodic extinction by natural events

Alien Life is already here Unacknowledged

The Fermi Paradox: Possible Solutions

1. There is no other intelligent civilisation in the universe.
2. Other civilisation have already visited Earth, but it was before humans.
3. The galaxy is full of other civilisations, but Earth is too far from other colonised planets to contact with them.
4. The concept of physical colonisation as a whole seems laughably primitive to a more sophisticated species.
5. Predator civilisation exists, and most intelligent life knows better than to omit any outward signals that reveal its whereabouts.
6. Once sentient civilisations reach a certain level, a super predator species starts eradicating them.
7. There is a lot of movement and noise around, but because of our obsolete equipment, we are listening for the incorrect things.
8. Higher civilisations are studying us, yet they want us to evolve organically.
9. Our unique moon is necessary for maintaining stability; however, its formation requires unusual circumstances.
10. We are all just completely wrong about the nature of reality.
11. We are the first in our galaxy, and it will be a very long time before another civilisation comes.
12. There may be advanced civilisations, but they began very recently and have not yet produced better technology.

Source: Futurism.com

The Drake Equation

The Drake equation is a probabilistic reasoning is used to estimate the number of active, communicative alien civilisations that exist in the galaxy containing the Milky Way.

$$N = R^* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

How It Does Work?

R^*	f_p	n_e	f_l	f_i	f_c	L	$= N$
the average rate of star formation **every year** in our galaxy	the fraction of those stars that **have planets**	the average number of planets that can **support life** in a star that has planets	the fraction of planets that **actually develop life**	the fraction of planets with life that actually go on to **develop intelligent life**	the fraction of intelligent life that replaces detectable **signs of existence in space**	the expected lifetime of such a civilisation for the period that it can communicate across the space	The number of civilisations in our galaxy with which communication might be possible

The numbers employed in several parts of the Drake equation are not well established; hence, the Drake equation can provide a very broad range of values, depending on the assumptions. Specifically, the outcome might be N<1, indicating that we are probably the only civilisation in the galaxy, or N>1, indicating that there are many other civilisations that we might meet. One of the few areas where there is a broad agreement is that the existence of humans presupposes a probability of the emergence of intelligence that is larger than zero.

The Drake Equation: Current Estimates

- **The average number of planets that can potentially support life per star that has planets**: in the habitable regions of Sun-like stars and red dwarf stars in the Milky Way galaxy, there may be as many as 40 billion Earth-sized planets. It is possible that 11 billion of these planets are revolving around Sun-like stars. This means that fp*ne is around 0.4, given that the galaxy contains about 100 billion stars

- **The fraction of planets that could support or actually develop life at some point:** Earth's geology provides indications that fl may be high (approximately a probability of 1). Abiogenesis may be very frequent once the conditions are appropriate as life on Earth seems to have started about the same time that favourable conditions emerged

- **The average rate of star formation in our galaxy:** R∗ is about 1.5-3 stars per year (NASA, European Space Agency [ESA])

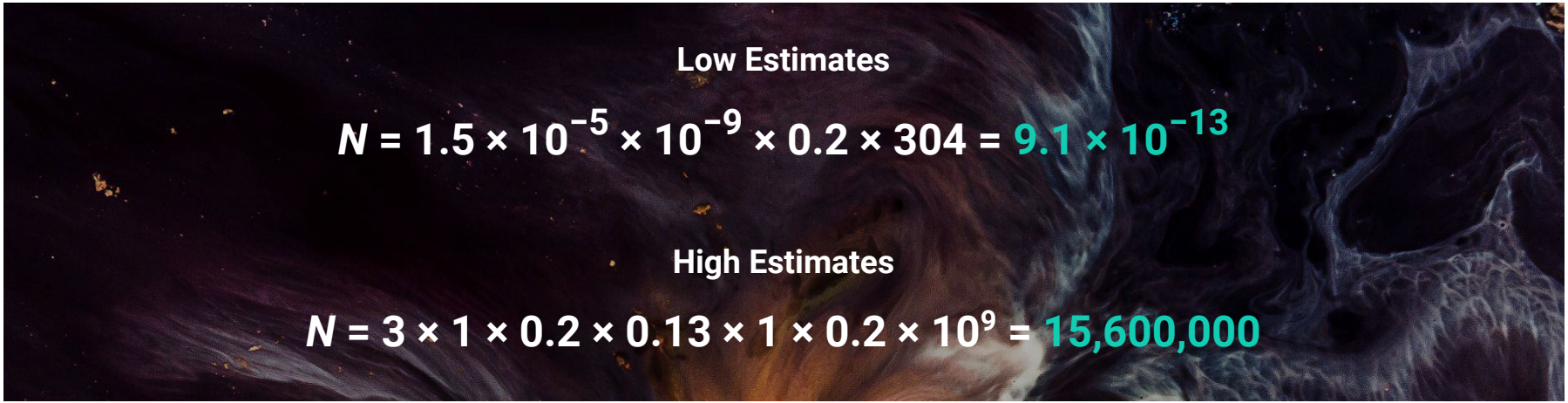
- **The fraction of civilisation that develops a technology which releases detectable signs of its existence into space:** Calculations imply that present or future Earth-level technology may be observable by civilisations not too superior than ours

- **The fraction of those stars that have planets:** fp may approach 1, which means that planets orbit stars as a norm rather than an exception, and each Milky Way star has one or more bound planets

- **The length of time for which such civilisations release detectable signals into space:** Using 28 civilisations more recent than the Roman Empire, the L is estimated to be 304 years for 'modern' civilisations

- **The fraction of planets with life that actually go on to develop intelligent life (civilisations)**: This is still a very controversial value. It has been suggested it it to be very low (0.0002) or very high (approaching 1). The low estimates come from how long it took for intelligent life to appear on Earth (4.6 billion years have passed since Earth's formation compared to a million years for Homo erectus to develop). People who prefer higher values notice that life gets more complicated over time and come to the conclusion that intelligence is almost inevitable

The Drake Equation: Results



Low Estimates

$$N = 1.5 \times 10^{-5} \times 10^{-9} \times 0.2 \times 304 = 9.1 \times 10^{-13}$$

High Estimates

$$N = 3 \times 1 \times 0.2 \times 0.13 \times 1 \times 0.2 \times 10^{9} = 15{,}600{,}000$$

The result of the Drake equation using low estimates suggests that we are probably alone in the Milky Way galaxy, and possibly in the whole observable universe. The seeming contradiction between high estimates of the likelihood that alien civilisations exist and the absence of evidence for their presence is known as the **Fermi Paradox**. Importantly, it is more appropriate to view the Drake equation as an approximation than as a genuine attempt to calculate an exact value.