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Drake-Equation

or: How many Aliens are there? 1

This very question was answered as early as 1961 by the astrophysicist Frank Drake: He formulated the Drake equation. With its help, we can calculate how many extraterrestrial civilizations there are. It tells us, therefore, how many *types of aliens* exist in the Milky Way.

And the beauty of it is: The Equation is very simple!

Look here:

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

- N: Number of extraterrestrial civilizations – the number we are looking for!
- R^*: Star formation rate per year in the Milky Way
- f_p: Of these, the proportion of stars with planets
- n_e: Per star, planets in the habitable zone
- f_l: Of these, the proportion of planets with life
- f_i: Of these, the proportion of intelligent life
- f_c: Of these, the proportion of civilizations willing to communicate
- L: Average lifespan of a civilization in years

The parameters on the right-hand side are all multiplied together. **R*** is a rate, the parameters f_p , n_e , f_l , f_i and f_c are probabilities, and thus numbers from the interval [0 – 1]. **L** has the dimension of time.

The Drake-Equation tells us, using the number **N**, how many extraterrestrial technological civilizations exist in the Milky Way with which we could, in principle, make contact.

Okay – now let's see … 2

Approximately 1.5 G-class stars are formed in the Milky Way each year. These are stars that shine long enough for life to even be possible. And they are stars that are large enough to allow for a stable habitable zone. Thus, we have:

$$R^* \;=\; 1.5 \text{ per year (Milky Way)}$$

Almost all stars have planets. However, half of all stars are binary or even multiple star systems. These systems cannot have stable planetary orbits over long periods. Therefore, the proportion of star systems potentially supporting life is:

$$\mathbf{f_p} = 0.5$$

Since almost all stars have many planets, it makes sense to assume that there are about 2 planets per star in the habitable zone:

$$\mathbf{n_e} = 2$$

Now we come to the question:

On how many of these planets does life actually arise?

This includes the chemical evolution of complex hydrocarbons, proteins, and coding. It signifies the emergence of the first self-replicating cell. We don't know for sure, but we assume — given the very long timeframe of billions of years — that this scenario occurs on 30% of all eligible planets.

$$\mathbf{f_l} = 0.3$$

If such first cells form, what is the probability that complex life (multicellular organisms, complex cognitive brains) with intelligence will develop over the course of evolution? We assume that this occurs in 10% of cases:

$$\mathbf{f_i} = 0.1$$

Furthermore, we assume that half of these intelligent beings also want to communicate and send signals into space:

$$\mathbf{f_c} = 0.5$$

Finally, the question remains:

How long does such a civilization of intelligent beings typically live?

Let's optimistically assume that civilization can ward off all possible dangers (nuclear war, climate change, biosphere poisoning, resource depletion, etc.) and lives for a long time, e.g., 100 million years:

$$\mathbf{L} = 100 \text{ million years}$$

If we **multiply all** of that, then …
Taa-daa! … we arrive at the result:

N = 2,250,000

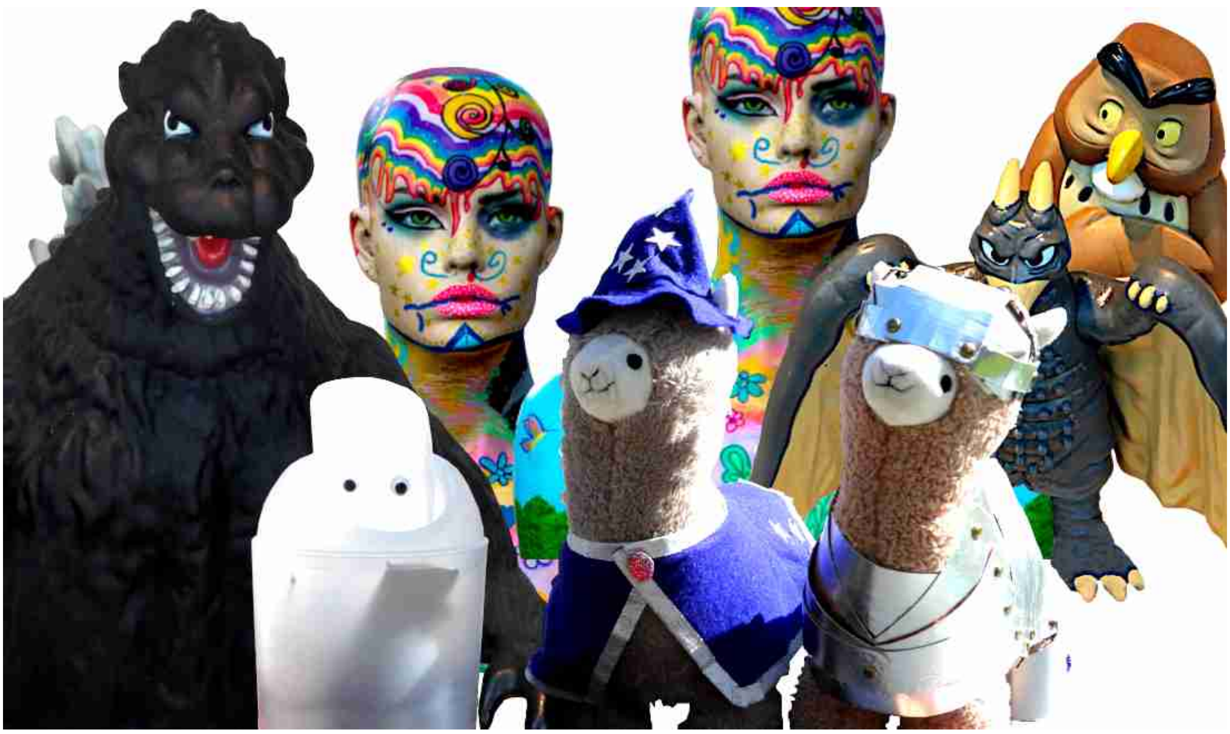
And that means … 3

… that there are 2.3 million (rounded) extraterrestrial civilizations in our Milky Way!
So we are surrounded by

N = 2.3 millions

aliens!

It's teeming with aliens!



If we take into account the size and shape of the Milky Way – it is a disk with a diameter of 100,000 light-years – then the average distance between two civilizations is about 300 light-years.

Our alien neighbours are therefore 300 light-years away from us. That's actually – when we consider the vast distances in space – pretty close.

We have **neighbours** – and they are not far away !

Average lifespan L

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Let's go back and look at the Drake equation again:

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

Here we see: Our result for **N** depends very sensitively on the last factor, namely **L**. This is precisely the “average lifespan of a civilization”.

Using our own civilization, that is, humanity on Earth, we can see how uncertain **L** is:

Civilization can only last a long time if it:

- can permanently prevent their self-destruction through a nuclear war
- can manage their resource consumption through a circular economy
- can permanently prevent their extinction through climate change and biosphere destruction

These catastrophes are called „**Big Filter**“ by astronomers, because they could be a „**Big Stopper**“ as a regular law, which stops every civilization – if a certain level of evolution is reached – (meaning full extinction).

We see that if the “Big Filter” is a regular law, if it *always* strikes, then the average lifespan of a civilization would only be a few hundred years:

$$L = 200 \text{ years}$$

This gives us for **N**:

$$\mathbf{N} = \mathbf{4.5}$$

This means there are only 5 other civilizations in the Milky Way. In the vastness of the Milky Way, the nearest civilization would therefore be on average 30,000 light-years away. That is extremely far away – and contact would be virtually impossible.

The habitability n_e 5

Let's recall the factor n_e: This factor indicates the number of habitable planets in an average star system. We had assumed:

$$\mathbf{n_e} = 2$$

Here we assume that all planets orbiting their central star at a distance at which liquid water exists on their surface are "habitable". We therefore assume that such planets would have a life-friendly, stable atmosphere.

But …

… could it be that this number “2” is far too optimistic?

Because it's probably not enough to simply orbit the central star at a certain distance. For example, in the case of Earth, we experienced an extremely random event:

The Earth was rammed by the protoplanet "Theia" 4.5 billion years ago during its formation. This collision created our present-day Earth and the Moon. The Moon is just as large and orbits the Earth at such a distance that it stabilizes the Earth's axis. This stabilization gives our Earth consistent seasons and a consistently habitable ecosystem.

Therefore, if habitability is tied to an event that only arises through extreme chance (collision with another planet), then such habitability is much, much rarer.

This means that the value of n_e is *extremely* low. It would then have to be:

$$\mathbf{n_e} = 0.0001$$

This means that only 0.01% of all stars
have *even a single* habitable planet.

How large would **N** be then? So we substitute the above n_e into the Drake equation and get:

$$N = 0.00023 \sim 0 \; !$$

We see:

There is *not a single* extraterrestrial civilization in the Milky Way.

We are alone!

Summary 6

This table shows what we have estimated:

supposition	habitability n_e	lifespan L	number N	∅ distance
optimistic	2	100 mio. years	2.3 mio.	300 ly
pessimistic	2	200 years	5	30,000 ly
very pessimistic	0.0001	200 years	0	–

Depending on our hypothesis about the number of habitable planets n_e, and depending on our conjecture of the average livespan **L** …

… we get for **N** a result between millions and zero.