# Drake’s equation: estimating the number of extraterrestrial civilizations in our galaxy

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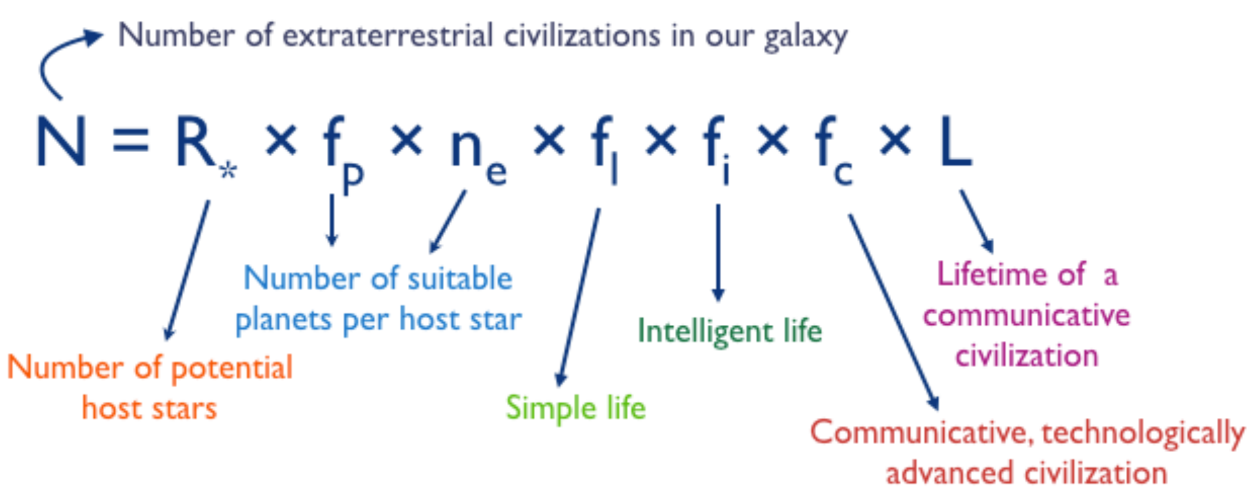
*This activity was largely inspired from an outreach project developed by Exscitec members at Imperial College London, UK.*

**Goals**

In this workshop, we estimate the number of communicating civilizations in our galaxy! In this first session you will go through the different ingredients required. You will make estimates for each of the variables using both results from recent scientific studies and your best guesses. Next week we will go over each variable in more detail -- make a note of any questions you may have so that we can discuss them. We will compare and discuss everyone’s estimates of N, and will discuss their implications for finding life as well as for the survival of our own species.

**Outline**

Estimating the number of extraterrestrial civilizations out there may at first seem like a daunting task, but in 1961 Prof. Frank Drake found a way to break this problem down into a series of much more manageable steps. This is neatly summarized in the following equation, where each of the variables relates to a specific topic:



$R_*$: Number of Sun-type stars that form each year in our galaxy

$f_p$: Fraction of Sun-type stars that host planets

$n_e$: Number of Earth-like planets per planetary system, so that $f_p$ x $n_e$ is the fraction of Sun-type stars that have Earth-like planets

$f_l$: Fraction of Earth-like planets where life develops

$f_i$: Fraction of life-bearing planets where intelligent life evolves

$f_c$: Fraction of planets hosting intelligent life where a communicative, technological civilization arises

L: Lifetime (in years) of technologically-advanced, communicating civilizations

To obtain N, we simply estimate each of these parameters separately and then we multiply them together.

You may have noticed that each of these parameters relates to an entire scientific field in itself! The first three ($R_*$, $f_p$ and $n_e$) are determined through astrophysics research, while the next two ($f_l$ and $f_i$) are from the realm of biology. The last two ($f_c$ and L) are big questions that relate to society, technological advances and even ethics (eg. *should* we communicate with aliens if we found them?). The first parameters in the equation are fairly well constrained by empirical research (eg. the number of potential host stars). The last parameters of this equation, however, are much less well constrained (eg. how easy is it for simple life such as bacteria to evolve into complex and even intelligent life?). You will see that your guesses are pretty much as good as anyone else's (eg. how long will a civilization like ours last?).

**$R_*$: Number of Sun-type stars that form each year in our galaxy**

Stars are essential for life. They provide the building blocks for it (eg. carbon, oxygen), and they are very important energy sources that life can use to sustain itself. However, not all stars can sustain life "as we know it"; for the purposes of this activity, we will assume that roughly only stars that have a similar temperature and lifetime as our Sun are appropriate.

There are approximately 400 billion stars of all different types in the Milky Way. Of these, 90% are not hot enough; of the remaining 10%, around 25% have lives too short for intelligent life to evolve.

*Based on these numbers, estimate how many stars in the galaxy could be suitable for life.*

This is the number of stars in the galaxy at present. The Galaxy formed 10 billion years ago. *Based on this, how many stars suitable for life form each year?*

**$f_p$: Fraction of Sun-type stars that host planets, and $n_e$: Number of Earth-like planets per planetary system**

In the last two decades we have found thousands of planets orbiting other stars than our Sun. They are known as extra-solar planets or exoplanets. I am an expert in the detection and characterization of small, rocky exoplanets that are potentially similar to our Earth, so I will be happy to discuss this particular topic in more detail with you next week.

NASA's *Kepler* mission discovered the majority of exoplanets known to date. One of its main goals was to measure the fraction of Sun-like stars that have Earth-like planets, i.e. $f_p$ x $n_e$. Several teams have analysed the full *Kepler* dataset in order to measure the occurence rate of Earth-size planets in the habitable zone, including Petigura et al. (2013). Their paper is available here: https://arxiv.org/pdf/1311.6806.pdf

*What is the "habitable zone"? What is Petigura et al.'s estimate of $f_p$ x $n_e$? What do you think of this estimate -- do you find it surprisingly big or small?*

**$f_l$: Fraction of Earth-like planets where life develops**

The following questions are intended to help you estimate $f_l$. Answer them based on your knowledge, experience or simply your gut feeling. Feel free to discuss the questions and your answers with your classmates.

How would you define life? Do you think it is easy for basic life to emerge on a planet, if all the necessary conditions (eg. liquid water, food and shelter) are present?

We know from fossil records on Earth that the first forms of life appeared relatively soon after the Earth formed; does this mean that life can form very easily?

*Based on your answers to these questions, rate how likely you think simple life (such as bacteria or microbes) can form, assuming the ideal conditions are present. You can use a scale from 0 (impossible) to 10 (will definitely happen) and then divide your answer by 10 in order to have a fraction between 0 and 1.*

**$f_i$: Fraction of life-bearing planets where intelligent life evolves**

Assume that simple forms of life emerged on a planet, such as bacteria or fungi or microbes. How likely is it that some of these species will evolve into complex, intelligent beings? What is intelligent life -- how common is it on Earth? Which species would you say have some form of intelligence?

Do you think this step should be easier or harder than the previous step of forming simple life?

*Based on your answers to these questions, rate how likely you think intelligent life can form, assuming that simple life already exists. You can use a scale from 0 (impossible) to 10 (will definitely happen), and then divide your answer by 10 in order to have a fraction between 0 and 1.*

**$f_c$: Fraction of planets hosting intelligent life where a communicative, technological civilization arises**

Do all intelligent species develop communication skills, such as language? Do they all develop technology? Will they necessarily want to communicate with other species or even aliens?

Do you think we should communicate with an extraterrestrial species if we found one? What would you want to tell them? How would you communicate -- what language would you use (English? Latin? Mathematics?)?

*Based on your answers to these questions, rate how likely you think intelligent life will turn into a technological civilization that is able and willing to communicate. You can use a scale from 0 (impossible) to 10 (will definitely happen), and then divide your answer by 10 in order to have a fraction between 0 and 1.*

**L: Lifetime (in years) of technologically advanced, communicating civilizations**

Assume that all these previous steps happened and you now have an intelligent, technologically-capable civilization that is willing and able to communicate with other species across the galaxy. How long will they be able to do this for?

Humans on Earth are one such example of this. How long do you think our current (communicative) civilization will last for? 200 years? 2 million years? 10 billion years?

**Putting it all together to obtain N**

Finally, compute your estimate of N using Drake's equation. Don't worry if your result is wildly different from your classmates'; the experts can't agree either -- their values typically range from 1,000 to 100,000,000! Most values outside this range are not fundamentally impossible either. Next week we will compare everyone's values and try to understand how and why you each got the estimates (big or small) that you did.

Science does not always have the answer to every question, and sometimes we need to make rough estimates or informed guesses. These can still be helpful, in order to formulate a hypothesis or design an experiment that will help us get the actual answer. For example, estimating the number of potential extraterrestrial civilizations in the galaxy can help us decide on the best way to go look for them. If we are confident that N is very big, i.e. extraterrestrial civilizations are very common, we might choose to simply wait for them to contact us. Or we could decide to send a probe to our nearest Sun-like neighbour because it is very likely it will host a planetary system that harbours such life. What else can we do to search for extraterrestrial life? What would you do if you had substantial evidence that N is very small, i.e. that extraterrestrial civilizations are very rare?