Astronomy 1010 Lab – **Life in the Universe** – V2.0

NAME:

Learning Objectives:

▶ **Science Processing Skills**: Interpreting data along with applying and evaluating mathematical relationships.

→Learning about the Drake Equation and SETI.

→Learning about the Fermi Paradox.

→How all of the points above tie together in the search for life.

Introduction: *In space there are countless constellations, suns and planets; we see only the suns because they give light; the planets remain invisible, for they are small and dark. There are also numberless earths circling around their suns, no worse and no less than this globe of ours.* – From *De l'Infinito Universo e Mondi*, by Giordano Bruno, 1584.

Pre-Lab Exercises

Take a few minutes to answer the questions below thoughtfully (not simply yes/no). Integrate as much material from class as you can when answering and justify your responses.

1)Do you believe there is life outside of Earth? What about "intelligent life"?

2)Do you believe there is life outside of Earth but within our own Solar System?

3)Do you believe/suspect, that Earth has been visited by extraterrestrials?

Drake Equation

In 1961, astronomer Dr. Frank Drake wrote down a simple formula for determining how many intelligent civilizations exist in our Milky Way galaxy. Today, the formula is known as the **Drake Equation** –

$$\mathcal{N} = \mathcal{R}_* \times \mathcal{F}_p \times \mathcal{N}_e \times \mathcal{F}_l \times \mathcal{F}_i \times \mathcal{F}_c \times \mathcal{L}$$

N is the number of technologically advanced civilizations.
$\mathbf{R}_*$ is the rate of star formation per year.
$\mathbf{F}_p$ is the fraction of those stars with planets.
$\mathbf{N}_e$ is the number of habitable planets in a solar system.
$\mathbf{F}_l$ is the fraction of habitable planets in which life forms.
$\mathbf{F}_i$ is the fraction of life-bearing planets where intelligent life emerges.
$\mathbf{F}_c$ is the fraction of intelligent civilizations that send detectable signals.
L is the length of time a civilization sends detectable signals.

4)Explain why the Drake Equation is different from asking "How prevalent is life in the Universe?"

5)Take your best shot! Calculate **N** using what you believe are reasonable values. Note that you are not expected to know these values – use what you have learned from class and estimate what you think are reasonable values for the variables in the equation.

6)Supposedly the original values that Drake used were as follows: $\mathbf{R}_* = 10$, $\mathbf{F}_p = 0.5$, $\mathbf{N}_e = 2$, $\mathbf{F}_l = 1$, $\mathbf{F}_i = 0.01$, $\mathbf{F}_c = 0.01$, and $\mathbf{L} = 10{,}000$. How does your answer to (5) compare with Drake's original number?

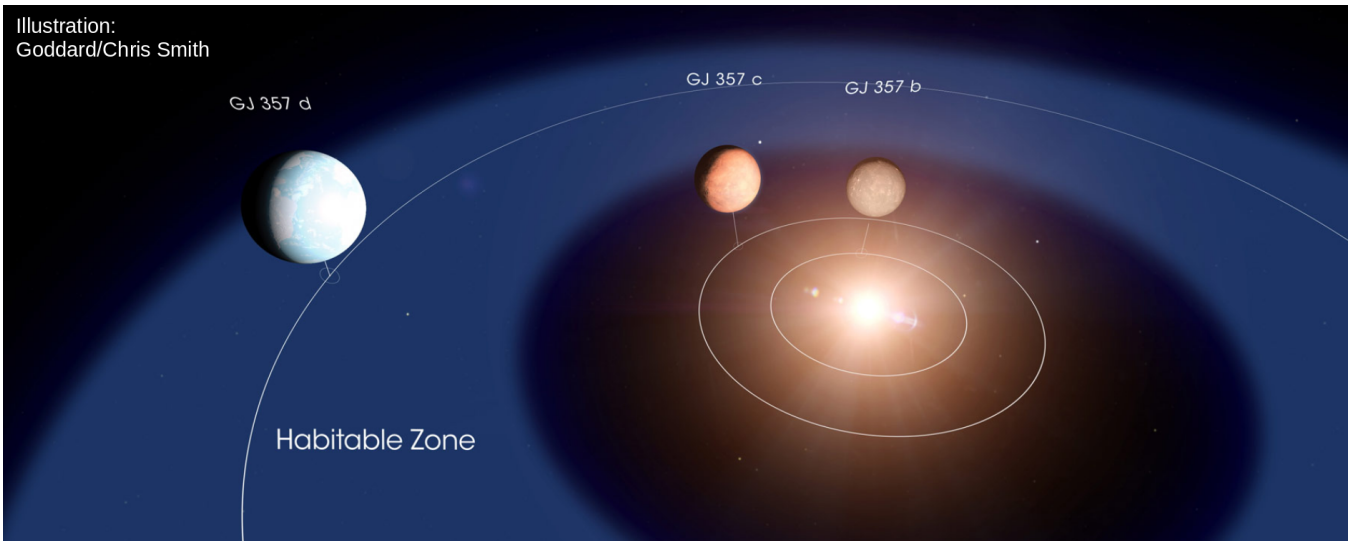
7)Today, we know that the *observable Universe* is not infinite (this theory will be discussed in detail in 1020)! While there are not "numberless earths" we suspect that there are so many planets that they are seemingly *countless*. We have confirmed over 5100 **exoplanets** – planets beyond our Solar System. While this number is small, we have truly only begun searching for them, and we believe there are at least 100 billion planets in our Milky Way. While we currently do not know how many planets may be habitable, many scientists believe the answer might be astoundingly large.

Current estimates are: $\mathbf{R}_* = 1$, $\mathbf{F}_p = 1$, $\mathbf{N}_e = 0.2$, $\mathbf{F}_l = 1$, $\mathbf{F}_i = 1$, and $\mathbf{F}_c = 1$. You will notice that the only value not included and arguably the most "controversial" number is the lifetime of a technologically advanced civilization. The famed astronomer and science communicator, Carl Sagan, noted that an advanced civilization, such as our own, might "extinguish" itself through war. Hence, perhaps **L** is only 10,000 years. However, other scientists believe the value is far larger. Some have argued that **L** is in fact closer to the age a star could sustain life, and this could be 10 billion years (or more)! If we are optimistic, what value do we get for **N**?

https://www.seti.org/press-release/seti-institute/press-release/biography-seti-pioneer-jill-tarter-making-contact

Renowned astronomer Jill Tarter has spent her career studying the possibility of life existing beyond our own planet Earth!

Meet Gliese 357 d



Located only 31 light-years from us, GJ 357 d, is a **super-Earth** or planet that is more massive than the Earth but less massive than Neptune-like planets. It is located within its host-star's **habitable zone**, which is the region around a star where liquid water could survive on a planet's surface.

8)The planet receives as much energy as Mars. Mars, as you learned, has no detectable liquid water on its surface. Why might the situation be different for GJ 357 d?

9)Currently there are very few confirmed "potentially habitable exoplanets". A list of such planets can be found in various data sets, including in **Wikipedia**. Look at one such planet in the list, and compare it with the Earth and GJ 357 d. What are some similarities and differences? Furthermore, if there are potentially hundreds of millions of such habitable planets, why are they so difficult to detect?

Where are all the aliens???

If the Universe is teeming with life, why is it so quiet in our neck of the woods? That question is commonly referred to as the **Fermi paradox**. Here are a few things to consider:

A)Most galaxies are so far away from us that even if we had advanced technology to travel between galaxies, millions to billions of years would pass by the time we got "there"! Thus, galaxies might be teeming with life far beyond the Milky Way, and we will almost certainly never know.

So let us focus on our galaxy:
B)The Milky Way is believed to be around 13.5 billion years old. The Earth is about 4.5 billion years old. Therefore in principle, there should have been a long period of time for other civilizations to evolve before humanity.

C)While we are currently "a long way" from colonizing the Milky Way, studies suggest it could actually be very quick, just a few million years! Again, consider that the galaxy is 13,500 million years old, and you can see this is, relatively speaking, very quick.

Despite (B) and (C), there currently is no direct evidence for intelligent civilizations outside of Earth. Why might that be?

10)Can you come up with some ideas? Discuss it with your group.

Maybe aliens???

In June of 2021, the Pentagon released their preliminary assessment on **Unidentified Aerial Phenomena** (misnamed across the media as the "Pentagon UFO report"). One unnamed senior official noted "we have no clear indications that there is any non-terrestrial explanation for them - but we will go wherever the data takes us". With this notion of *let us trust the data*, let us consider some possibilities. One very well known scientist proposed that an object that flew by our solar system in 2017, an object known as 'Oumuamua, and one which the vast majority of scientists accept as an elongated asteroid - might actually have been an alien artifact! NOT a spacecraft, but an artifact. It is also very important to note that the "alien explanation" for 'Oumuamua is a possibility that needless to say has come across a lot of skepticism from much of the scientific community. That said, it has not been ruled out.

Read this short article on 'Oumuamua
https://www.thedailybeast.com/why-harvard-astronomer-avi-loeb-believes-the-oumuamua-interstellar-asteroid-is-an-alien-ship

11)After reading the article, discuss whether one argument is more convincing than another and why? Do you feel the "alien" hypothesis warrants more study or is it safe to discard it?

12)Based on this lab, has your thoughts on any of the following changed: **Do you believe there is life outside of Earth? Do you believe there is intelligent life outside of Earth?**

It is always important to be both critical, and open-minded at the same time. Just because we have not found any life outside of Earth, as of yet, certainly does not rule it out. That said, one very enjoyable aspect of all this is imagination – "I wonder what aliens might act and look like?"

13)Sketch below (or describe if your artistic skills are not up to task) an alien living on another planet! Explain why the alien is the way it is – for example, perhaps the alien's planet is orbiting a star much dimmer than the Sun and therefore needs big eyes! Be creative, have fun in your final Astronomy 1010 Lab Question ★

Questions, suggestions? – **Dr. Idan Ginsburg** – iginsburg@gsu.edu