Lesson outline

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Cosmic civilizations

Key words:

Cosmic civilizations

Life

Cosmos

Exoplanets

Topic: Searching for life in the Universe.

Students' age: 15-19

Time: 🕓 2 lessons

Subjects:

physics

computer science

LESSONS IDEA

Enrico Fermi noticed that if the Galaxy contains such an amount of technologically developed civilizations, how come we can't observe any traces of their existence, e.g. signals they send, probes, spaceships, or representants of those civilizations. This is the so-called *Fermi paradox*.

If we haven't observed any tracks of the aliens yet, this means that either:

- the assumptions concerning extraterrestrial civilizations are wrong and life is far more scarce;
- alien civilizations send different signals to space, however our civilization is not developed enough to detect them.

There are many reasons why we have not noticed any traces of alien space civilizations, for example:

- Annihilation of civilizations:
    - ❖ *Civilizations' destruction due to global conflicts*. Sources of conflicts on planets: shrinking resources of food, water, valuable minerals. Nuclear, thermonuclear, biological, or chemical weapons as potential sources of destruction of a civilization.
    - ❖ *Global ecological crisis*. Consequences of polluting the environment: lack of drinkable water, sterilization of soil, emission of glasshouse gasses, destruction of the layer of atmosphere protecting against radiation. Environmental pollution as one of the reasons for blocking (or utterly destroying) a civilization's development.
    - ❖ *Ice age*. An ice age could bring destruction to a space civilization. Causes: changes in the orbit position's parameters, change in the inclination between the equator and the ecliptic, others? Ice ages have caused massive changes in the amount of species inhabiting Earth.
- The Earth holds the only life in the universe.
- The distance between stars near which alien civilizations live. The distances between two stars around which life exists can reach hundreds, thousands, or even more light years.
- The two civilizations might fall before they can contact one another.
- The ZOO hypothesis, which states that other cosmic civilizations intentionally avoids communication with Earth to allow humans to evolve without interference. Exemplary reasons: they don't want to interfere with our civilization, or it is too primitive for them. The ant analogy: we prefer to watch ants thus researching their behaviors, rather than trying to "talk" with them. Weak point of this hypothesis: if the amount of developed civilizations is high, then some of them might intend to meet us instead of just observing.
- The planetarium hypothesis, which states that humanity is in a simulation, and the aliens are the ones running it.

There are many proposed solutions of the Fermi paradox:

- ➲ 30 such solutions are described at the webpage
- ➲ 18 solutions are described at the webpage

- 31 solutions at the webpage

In the proposed lesson we will explore the hypothesis, that alien civilizations have been born randomly in time and their lifetime is finite. The proposed lesson will consist of the theoretical introduction necessary to work in the practical part. In particular, students will learn (and discuss in practical part) about reasons why cosmic civilizations (if existed/exist) may fall. During this exercise, it is worth mentioning to student that these reasons may also apply to our civilization.

In the next set of exercised titled “Probability of contacts between communicating civilizations” students will assume certain conditions regarding the lifetime of hypothetical cosmic civilizations, their number in space etc., and with these assumptions will calculate the probability that the civilizations exist in the same time and may meet.

The first lesson

Presentation, which contains important information needed to understand and work of students in the practical part (slides 1-4). Before starting the first lesson, the teacher asks students to watch the movie(s) (links to the movies are in the part “Additional materials (online)”. The first lesson in the series finishes with comparing students' answers to questions about the film(s) and presentation. This can be done in form of a exercise titled ***Fall of cosmic civilizations*****.**

The second lesson

Presentation, which contains important information needed to understand and work of students in the practical part (slides 5-12). During the second lesson, students will experiment with simulation exercises titled “**Probability of contacts between communicating civilizations”**, discuss the obtained results etc.

Fall of cosmic civilizations

This exercise can help you to learn about reasons why cosmic civilizations (if existed/exist) may fall. Complete the table by entering in appropriate columns possible causes of the collapse of civilization. Divided these causes into three parts: self-inflicted disasters, natural inflicted disaster and external disasters.

No	Self-inflicted disasters	Natural inflicted disasters	External disasters
1			
2			
3			
4			
5			

- Examples of self-inflicted disasters:
    - World wars covering a large part of a planet and using weapons of mass destruction, for example:
        - Global (or almost global) nuclear warfare
        - Chemical warfare
        - Biological warfare
    - Ecological collapse and/or global climatic change (global warming or new Ice Age) caused by:
        - Deforestation and biodiversity loss. An example of a significant decrease in the number of inhabitants, on a local scale, are the Easter Islands. The decline in the number of inhabitants was probably caused by the depletion of the island's natural resources and the cutting down of all trees.
        - Global warming caused by accumulation of greenhouse gases in the atmosphere of the planet. These gases are for example: carbon dioxide, methane, nitrous oxide, water vapor, and synthetic fluorinated gases.
        - Global cooling caused by for example large scale nuclear warfare.

- Examples of natural inflicted disasters:
    - Geological:
        - Planetquakes
        - Volcanic activity
    - Meteorological:
        - Tornadoes and Severe Storms
        - Floods

Examples of external disasters:

- Collision with asteroid
- Stellar explosion

More examples can be taken from the webpage

Probability of contacts between communicating civilizations

As the introductory exercise students can experiment with different input parameter values for the algorithms to obtain probabilities larger than for example 1%. It is worth paying attention to students that the input parameters should be more or less realistic, e.g. the time when alien civilizations began to appear cannot be longer than the lifetime of the Universe, etc.

Algorithms used in the exercises are probabilistic. Thus, when students run the same algorithm second time, with the same input parameters, obtained probability may differ. Similarly, when we toss a fair coin 100 times, we should expect to get roughly 50 “Heads” and 50 “Tails”. In practice, in one experiment we can obtain for example, 45 “Heads” and 55 “Tails”, in the second one - 52 “Heads” and 48 “Tails”.

Short description of algorithms used in the exercises:

❖ *Algorithm 1: probability of simultaneous existence of at least two civilizations - version with uniform civilizations time existence*

In this scenario we assume, that technical civilizations started to born **T.tot** years ago. Each of these civilizations lives **T.ext**. During the time **T.tot** exactly **n.civ** civilizations can be born. We assume, that the civilizations can be born in random (uniformly distributed) moments of time.

The algorithm is implemented as follows:

1. Input parameters: T.tot, T.ext, n.civ
2. Initialize "event counter" L=0
3. Generate randomly n.civ positive numbers, t_i, smaller than T.tot, where t_i is a time when i civilization started to live. It means that i civilization lives in a time interval [t_i, t_i+T.ext].
4. For i civilization check if another civilization, j, started to live in the time interval [t_i, t_i+T.ext]. If yes, increase even counter, L, by 1.
5. Repeat points 3 and 4 N times.
6. Output: probability = L/N.

Algorithms 2 and 3 are implemented similarly.

❖ *Algorithm 2: Probability of simultaneous existence of at least one civilization*

Probability of simultaneous existence of at least one civilization with ours (or any that has been existed) for **T.ear** years. We assume, that technical civilisations started to born **T.tot** years ago. Each of these civilizations lives **T.ext**. During the time **T.tot** exactly **n.civ** civilizations can be born. We assume, that the civilization can be born in random (uniformly distributed) moments of time.

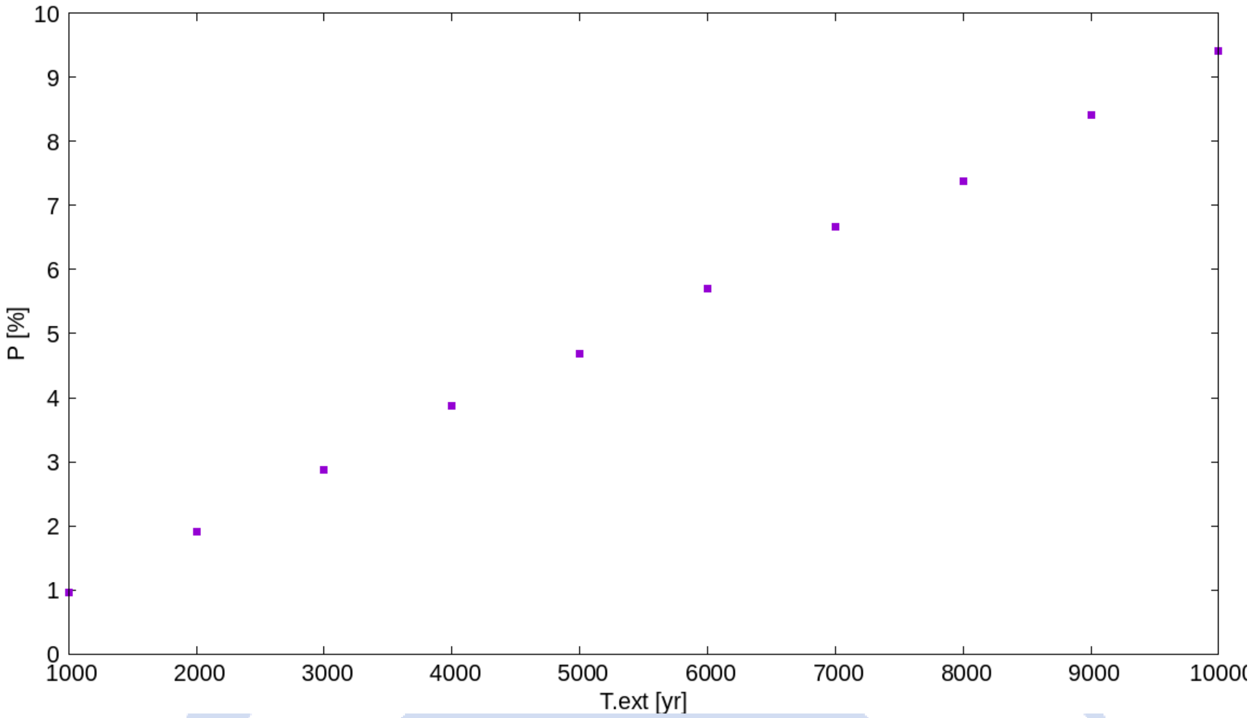
❖ *Algorithm 3: probability of simultaneous existence of at least two civilizationsII - version with civilizations time existence diversity*

In this scenario we assume, that technical civilizations started to born **T.tot** years ago. Each of these civilizations exists for a certain non-constant number (uniformly randomly distributed) of years. During the time **T.tot** exactly **n.civ** civilizations can be born. We assume, that the civilization can be born in random (uniformly distributed) moments of time.

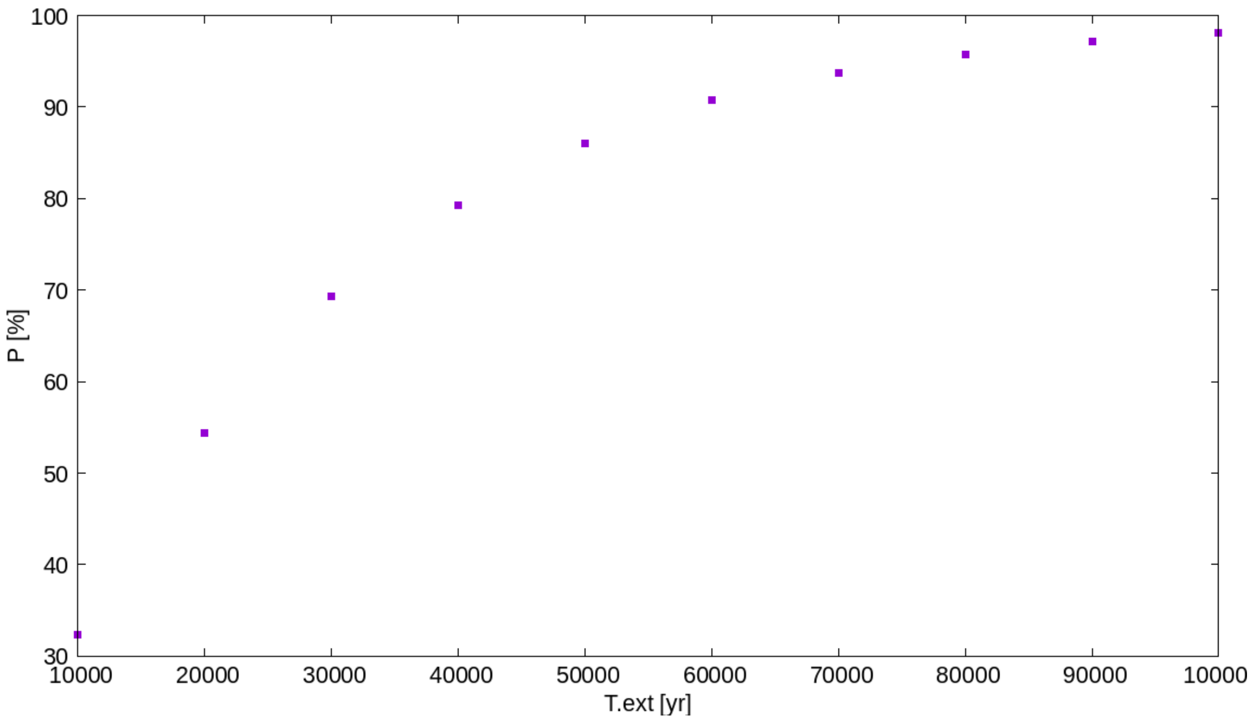
✍ Exercise 1

Check, by using algorithm 1, that for a given number of civilizations, the probability of contact is the larger, the larger is life time of these civilizations. Assume, that T.tot=1 Gyr, n.civ=100 and T.ext=1, 2, 3, ..., 10 kyrs. Plot the probability as a function of T.ext. Is it a linear function? Test your hypothesis for other values of the input parameters, for example use n.civ=200 and T.ext=10, 20, 30, ..., 100 kyrs.

❖ Solution for T.tot=1 Gyr, n.civ=100 and T.ext=1, 2, 3, ..., 10 kyrs:



❖ Solution for T.tot=1 Gyr, n.civ=200 and T.ext=10, 20, 30, ..., 100 kyrs:

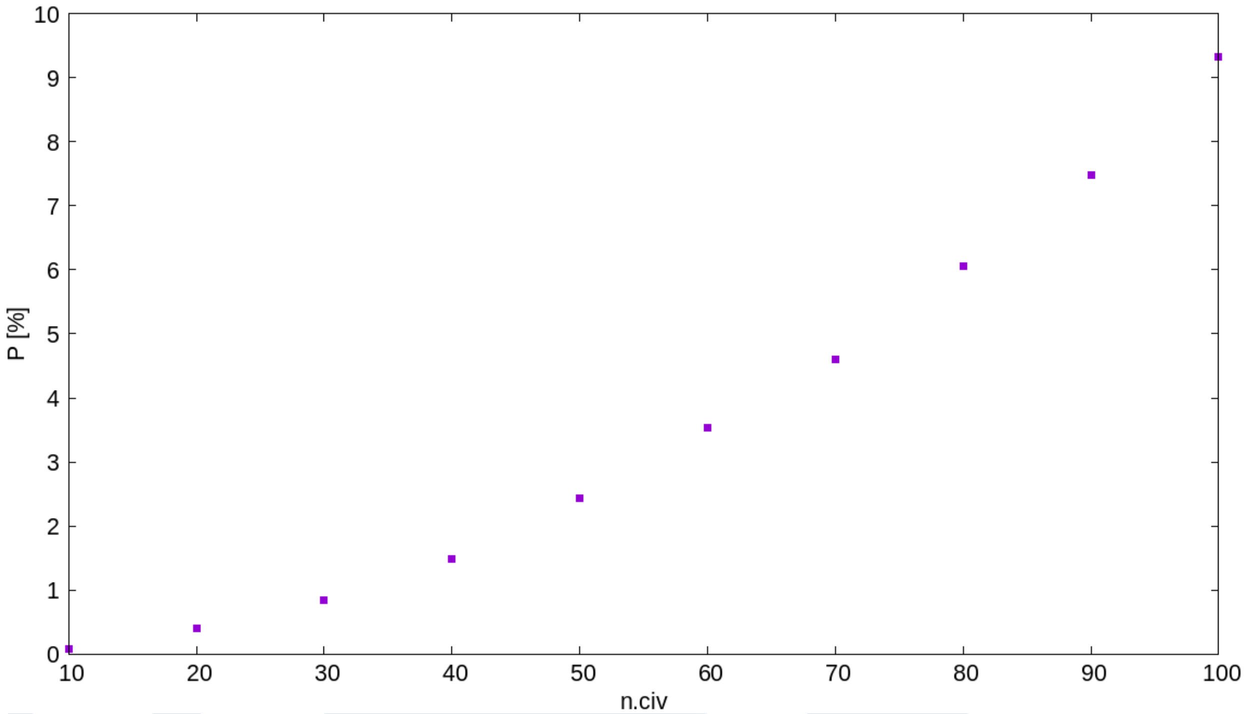


In general, the smaller the product n.civ*T/ext/T.tot is, the more the graph of P, as a function T.ext, is similar to a linear function.

✍ Exercise 2

Check, by using algorithm 1, that for a given constant life time of the civilizations, the probability of contact is the larger, the larger is the number of these civilizations that have occurred in the universe. Assume, that T.tot=1 Gyr, T.ext =10 kyrs and n.civ=10, 20, 30, ..., 100. Plot the probability as a function of n.civ. Is it a linear function? Experiment with different input parameters.

- ❖ Solution for T.tot=1 Gyr, T.ext =10 kyrs and n.civ=10, 20, 30, ..., 100:



In general, P as a function of n.civ is not a linear function. If the product n.civ*T.ext/T.tot is small (i.e much smaller than 1.), P is proportional to n.civ*(n.civ-1).

✍ Exercise 3

Check if the following hypothesize is true or false: probability of contact between two civilizations is the same if the time of life of the civilization is 10 times larger and the total number of civilizations is 10 time smaller.

<u>Use algorithm 1.</u>

- ❖ Solution: It is not true, for example, for T.tot=1 Gyr, T.ext =10 kyrs and n.civ=100 we have P=9.3 %, for T.tot=1 Gyr, T.ext =100 kyrs and n.civ=10, P=0.9 %.

For small values of n.civ*T/ext/T.tot we have approximately P=n.civ*(n.civ-1)*T.ext/T. It implies that if T.ext is 10 times smaller, we should have about 100 times more civilizations to obtain near the same value of P.

✍ Exercise 4

Calculate the probability of contact between our and alien civilization, by assuming that T.tot=1Gyr, T.ext=10000 years, n.civ=50, T.ert=1000 years?

- Solution: P=0.05%

✍ Exercise 5

Calculate the probability of contact between our and alien civilization, for constant values of T.tot, T.ext, T.ert as a function of n.civ? It is a linear function? Test your hypothesis for different values of input parameters.

For small value of (T.ert+T.ext)/T.tot (i.e much smaller than 1.) the probability is proportional to n.civ.

✍ Exercise 6

Use algorithm 1 to find the probability of contact between civilizations for T.tot=1Gyr, T.ext=100 kyr and n.civ=100. Use algorithm 3 to calculate the same probability for civilizations that live between 50 and 150 kyrs. In this case we can expect that the mean lifetime of civilizations is 100 kyr. Is the probability the same as calculated by using algorithm 1?

- In both cases we get P=63%.

✍ Exercise 7

The ancient Egyptian civilization began to live about 5000 years ago, on the other side, dinosaurs lives about 100 million years. Calculate probability that 2 civilizations can live in the same time assuming that T.ext equals 5000 and 100 million years respectively by assuming different values of n.civ and T.tot.

Use algorithm 1 to obtain the solution.

Summary of lessons

Discussion of student work results. It is worth noting that the probability of coexisting at the same time of cosmic civilizations is very small. It's also worth noting that the lifetime of civilizations may be restricted by global disasters, asteroid impacts etc. Advanced technical civilizations can possibly defend themselves against many disasters but those at the beginning of technological development may not survive many of these events.

Even if two or more of cosmic civilizations coexist at the same time, it may not be possible to contact each other. They can exist at different parts of galaxy (distance between these civilisations can be of order hundred thousand light years) or even they can live in different galaxies.

ADDITIONAL MATERIALS:

- Presentation in pdf format titled *Cosmic civilizations*
- Worksheet document Worksheet_1.docx
- Worksheet document Worksheet_2.docx

- The Fermi Paradox — Where Are All The Aliens?

- The Fermi Paradox II — Solutions and Ideas – Where Are All The Aliens?

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