Cosmological Time Lime

Rosa M. Ros, Beatriz García, Ricardo Moreno, Pilar Orozco, Juan Antonio Prieto, Ivo Jokin

International Astronomical Union, Polytechnical University of Catalonia, Spain, ITeDA and National Technological University, Argentina, Colegio Retamar, Spain, Diverciencia, Spain, Municipal Center for Extracurricular Activities, Dolna Mitropolia Municipality, Bulgaria.

Abstract

The history of the Universe spans 13.8 billion years. In that period of time, the Universe transformed energy into atoms of primordial elements in record time. The atoms formed stars and these, in turn, transformed the material to produce the approximately 100 elements that make up the Periodic Table. The chemical elements were organized, but to get the prebiotic material that later led to the various forms of life that we know on Earth, the process was long and complex. We can say that life is the consequence of a series of factors that produced it and allowed it to evolve. Knowing moments that were fundamental milestones for the appearance of life throughout the history of the Universe, approaching the tools that astronomers devised, built and installed, even outside Earth, to study the possibility of existence of life beyond the only place in the Universe where it was detected, and to discover the theories that try to explain how, when and where life originated, is the mission of this Workshop.

Objetives

• Visualize the history of the Universe through a time line
• Understand the importance of the process that was necessary to arrive at the formation of life.
• Understand the adaptation of life to very varied conditions

Cosmological introduction

The Universe is the only system isolated from nature: it does not exchange energy or matter with the environment, because it is the environment.

It is estimated that the universe arose 13.8 billion years ago, as a consequence of a release of energy. The process of birth and evolution of the universe, as well as the possible scenarios for its final destiny, were addressed in the Universe Evolution Workshop.

Beyond the study of the Universe as a whole, it is interesting to expand the proposal related to scale models that allow us to glimpse what the age of the Cosmos means, but at the same time, introduce a fundamental concept for the human species: that of life, one of the unique characteristics or properties of the Universe.

The question of the origin of life, and its corollary, the existence of intelligent life, is the main focus of exo and astrobiology; It constitutes an unusual event, which can be studied from a scientific point of view, with the aim of understanding how it happened on Earth and how it could happen elsewhere.

The search for life is a common goal in astronomy and astrophysics and hence, putting the subject on a cosmological scale allows us to understand the long time interval that separates the origin of the Universe with the appearance of the most primitive forms of life.

For the search for life, we have some tools that are the basis of work in Astrobiology and Astrochemistry.

In the process of formation and birth of a star from the gravitational collapse of a cloud of interstellar gas and dust, a planetary system can be formed with the remains of material from said cloud.

In the same way that we can know the composition of the star considered by studying its spectrum, it is possible to know the existence and chemical composition of a planetary atmosphere, in the case of the Solar System, or of exoplanets, in the case of Exoplanetary Systems or extrasolar. Each chemical element, each molecule, presents a specific and unique spectrum.

If a planet or exoplanet has an atmosphere, and if the spectrum of the star is known, when light from that star passes through the exoplanet's atmosphere, it will be partly absorbed by the chemical elements in that atmosphere. In this way, we will be able to determine the chemical composition of any atmosphere.

An example of this is the recent discoveries of the James Web Telescope, regarding various exoplanetary systems.

An example: of how it is possible to approach the search for life, would be the following. in the detailed modeling of the exoplanet WASP-39b, made thanks to the observations of the Web Telescope, revealed that the SO_2 in its atmosphere is produced by photochemistry, which is extremely important because photochemistry is essential for life on Earth to thrive, since it is linked to the production of O_3 (ozone), with photosynthesis and with the production of essential vitamin D for the human organism.

From moment zero in the time line that we will propose, only about 100 seconds elapsed until the transformation of what was all energy into atoms. For the appearance of life, the galaxies must have arisen first, then the stars, these must have transformed the chemical elements, enriched the intergalactic and interstellar medium, and the conditions must have been given for disordered molecules to be ordered to form complex structures that could be replicated. themselves and finally gave way to life.

In the next sections we will see this long process that is not miraculous, it is a consequence of the evolution of the Cosmos.

Activity 1: Timeline

It is about visualizing the time line of the history of the Universe on a tape, using a meter as a unit of measurement equal to a billion years (1m = 10^9 years, that is, 10 cm = 10^6 years).

As science advances and more precise instruments become available, the determination of such important magnitudes for the history of the Universe, such as time and distance, can lead to certain changes in the periods in which the most important events occur. significant in the Cosmos. Let's remember that what we know about the Universe is statistical, more and better observations can force us to review all our results.

The Big Bang, the great explosion, took place 13.8 billion years ago (13.8 10^9 years), then, for a short period of time of 10^{-45} sec, it is not very well known to explain what happened because it cannot be not even apply Einstein's theory of relativity, this is the so-called Era of Planck.

After 10^{-35} from the Big Bang, INFLATION begins, which responds to an exponential expansion of the Universe. One microsecond (10^{-6} seconds) after the Big Bang, the formation of the primordial soup (consisting of various elementary particles) begins.

After 3 minutes of the Big Bang, the Primordial Nucleosynthesis of the “H” begins. All this first part cannot really be represented on the time line due to a scale problem, since we are considering 1 millimeter equivalent to a million years, the seconds or minutes are invisible. For this reason, it is not displayed on the time line, but rather is presented separately.

Fig. 1: Simple presentation of the timeline on a 13.8 m long tape. Some objects appear sewn that facilitate the relation and comparison of values and allow to set the scale.

After 100 million years (after 10 cm), that is, 13.7 billion years ago, the first primordial elements were formed. After another 100 million years, that is, another 10 cm, 13.6 10^9 years ago, the first molecules were formed, and among these, the first water molecules.

Approximately, also in this lapse of time, 13.6 billion years ago the first stars were formed and a little later, 13.1 billion years ago, the first galaxies. After a hundred million years, the early Milky Way (13.0 10^9 years) was formed (figure 1).

For about 8.4 billion years (8.4 meters: on our scale, 10^9 years equals one meter) a series of simultaneous phenomena take place. The first stars are evolving, giving rise to different explosions that expel different types of atoms and the diversity of primordial elements of the periodic table is appearing. At the same time, new stars continue to form, which also evolve, and various types of objects emerge, at different stages of evolution.

Fig. 2: 4.6 billion years ago, the Sun was formed and with it the different bodies of the solar system appeared, in particular the Earth and the rocky planets were formed 4.56 billion years ago. About 20 million years later the Earth's magnetic field arose, which serves as protection against various radiations dangerous to life as we know it.

After the aforementioned 8.4 million years, that is, 4.6 10^9 years ago, the formation of our Sun takes place, as well as the formation of the first alcohols. The OH groups are necessary later because they appear in the formation of many molecules that will be important in achieving the constitution of DNA.

About 3 cm later, 4.57 billion years ago, the solar system was born, 4 mm later, 4.566 billion years ago, the gaseous planets were formed, and 6 mm later, 4.56 billion years ago, the Earth and the other rocky planets were formed (figure 2).

About 2 cm later, the terrestrial magnetic field arose, from this 4.540 billion years ago, with what it represented as protection against various types of radiation harmful to life on our planet.

Later, at 6 cm, the formation of the Moon began, about 4.48 billion years ago, constituting the Earth-Moon system within our planetary system.

Only 3 cm later, 4.450 billion years ago, the Primitive Terrestrial Atmosphere was formed.

4.1 10^9 years ago, that is, after 45 cm, the Late Heavy Bombardment took place, which affected the bodies of the solar system, as well as the Earth and the Moon.

4.000 billion years ago (4.0 10^9 years), that is, 10 cm later, the First Prokaryotic Cells (without a nucleus) appear and the DNA molecule appears.

After 2 meters, this is 2000 million years ago, life begins that breathes Oxygen O_2.

After 40 cm, 1.6 10^9 years ago, the appearance of green plants on our planet begins, that is, the chlorophyll function comes into play (figure 3).

Fig. 3: In white the Line from its beginnings to the appearance of the first green plants. In pink from this point to the present.

Beyond 90 cm or 90 million years, that is, 700 million years ago (0.7 10^9 years), the first specialized tissues and organs begin to appear.

After 18 cm, for 0.52 10^9 years, those of Trilobites appear, fossils well known to all of us.

After 5 million years, that is to say 5 cm later, for 470 million years the first exit of animals from the water to the terrestrial zone takes place.

After only 7 cm, 400 million years ago, the Ammonites (known fossils) appear.

3 mm later, 397 million years ago, the first vertebrates appear on Earth.

If we move 14.7 cm, about 250 million years ago, Nautiluses appear, animals that can still be found on our planet.

Only 5 million later, that is 5 mm later, 245 million years ago, the first dinosaurs appear.

After 4.5 cm, 200 million years ago, the first mammals appeared, initially they were small, although later the larger ones appeared.

5 cm later, 150 million years ago, the first feathered dinosaurs appear, the ancestors of our birds. In fact, one of the least evolved and one of the closest to the ancient winged dinosaurs are the simple chickens that we have in our pens (figure 3).

Beyond 14.75 cm, that is, after 14.75 million years, 0.0025 10^9 years ago = 2.5 million years = 2,500,000 years, the first Humanoids appeared.

After only 2.2 mm, that is, only 0.0003 10^9 years = 0.3 10^6 years = 300,000 years ago, Homo Sapiens appears.

Cannibal Galaxies

Galaxies are groups of stars bound by gravity that rotate on themselves. The various groups of galaxies form filaments where the activity of the formation of new galaxies is very active.

All galaxy clusters are included in a great cosmic ballet where they meet, collide and the cannibalism of the larger ones over the smaller ones makes the young galaxies compete to get the free gas that is left to promote the formation of new stars (figure 4).

This is how the richest areas of star formation correspond to areas of large collisions, where the big winners are always the largest galaxies. All this activity takes place in the filamentous zones of the universe, leaving large spaces freer of matter (figure 5).

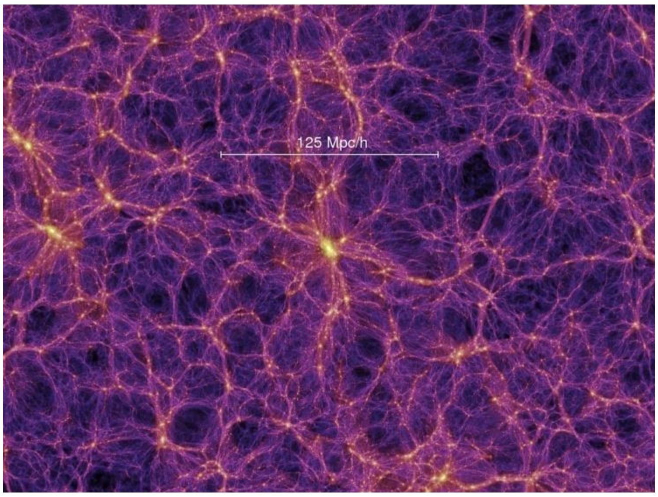



Fig. 4: Collision of Cannibal galaxies (Credit: ESO). Fig. 5: Modeling of the filamentary structure of the universe (Credit: Springel et al.)

Activity 2: Filamentous model

The filamentary structure of the universe can be simulated with a tray or a plate where you can place water with detergent. By inserting a pair of straws to sip soft drinks, the action is reversed, blowing air through them and thus achieving a good number of bubbles in a very short time.

As can be seen in the model with large soap bubbles, most of the soapy liquid is located in the areas where the bubbles intersect, giving rise to areas with a more or less filamentary appearance.

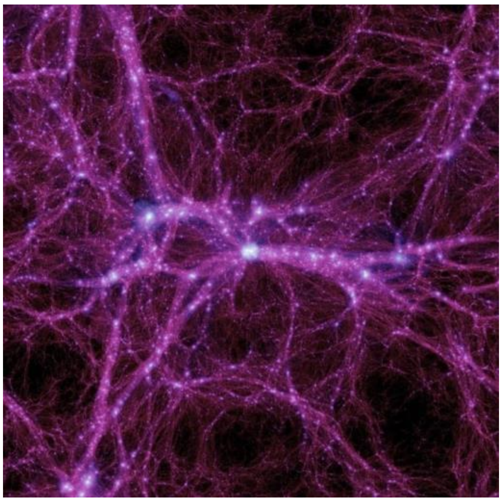



Fig. 6: Modeling the filamentary structure of the universe (Credit: Illustris Project). Fig. 7: Modeling the mentioned structure in filaments using water and detergent

Galaxy Classification

There are spiral, barred, elliptical, spherical, and irregular galaxies, which are usually classified according to their morphology in the well-known Hubble sequence. As mentioned before, this classification attends only to its form and does not correspond to their evolution.

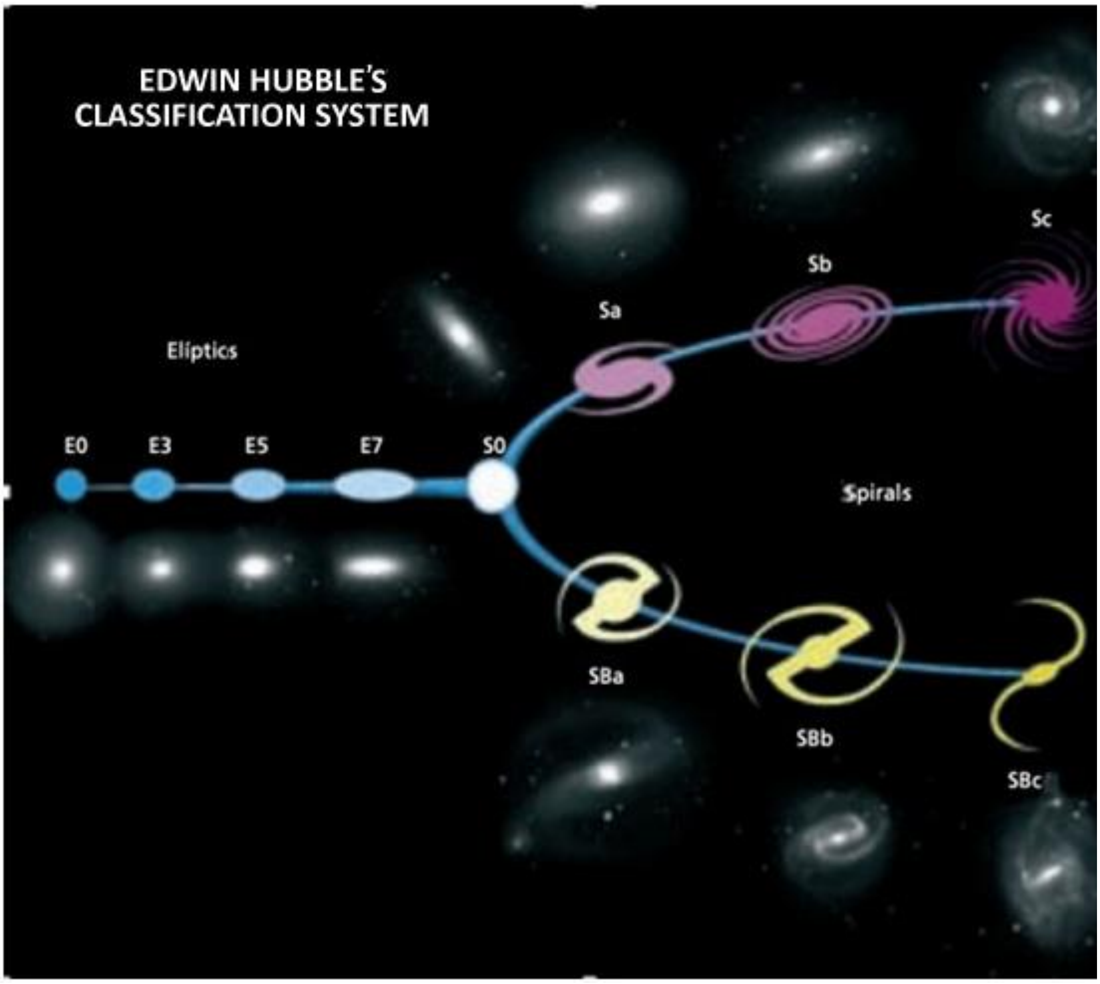


Fig. 8: Edwin Hubble's classification system (Credit NASA-ESO)

Activity 3: Simulation of the formation of spiral galaxies

A model of spiral galaxies (Fig 9a) can be made with a full glass of water and a product that has very fine grains, for example sodium bicarbonate (Fig 9b), table salt (NaCl), although it dissolves more easily in water, and sand (Fig 9c), as long as it is very fine, even passed through a sieve.

Fig. 9a. Galaxy NGC 5457 (ESA/Hubble)

Fig. 9b. Galaxy of sodium bicarbonate

Fig. 9c. Galaxy of sand.

Stir the water in the glass vigorously with a teaspoon, stop stirring, add a tablespoon of the product and wait for the grains to settle. A central pile and some spiral arms are achieved, very similar to those present in galaxies.

Looking at the glass from the side, the model also simulates the shape of galaxies seen edge-on, with the central bulge (Fig. 10 a, b and c).

Fig. 10a, Sand galaxy model, seen from the side.

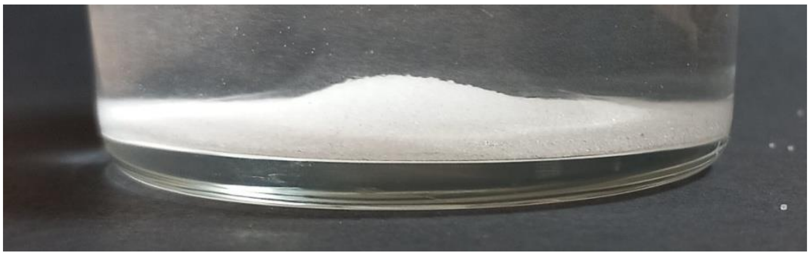


Fig. 10b. Baking model, also seen from the side.

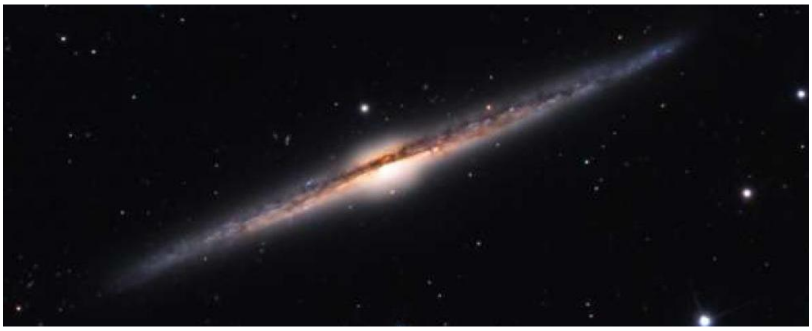


Fig. 10c. Galaxy NGC 4565, with the central bulge (Credit ESO/NASA)

If you keep stirring slowly, you can go modeling the spiral arms, and end up getting something similar to elliptical galaxies, another of the types of galaxies in the Hubble sequence (Fig. 8). Our model just fails to reproduce barred galaxies.

Habitable zone in galaxies

In the central zone of galaxies there is a high level of energy, there are massive gamma-ray bursts and huge, very energetic and violent events that make life impossible. On the other hand, in the zone of the edge of the galaxy there is a lack of atoms heavier than Hydrogen and Helium, which are necessary for life, so the habitable zone corresponds to a circular zone like the chamber of a car tire. and corresponds to the zone where the Sun moves. The habitable zone in galaxies is normally located in a radius of between 23000 l.y. and 30,000 l.y. from the center of the galaxy (the Sun is at 27000 l.y.).

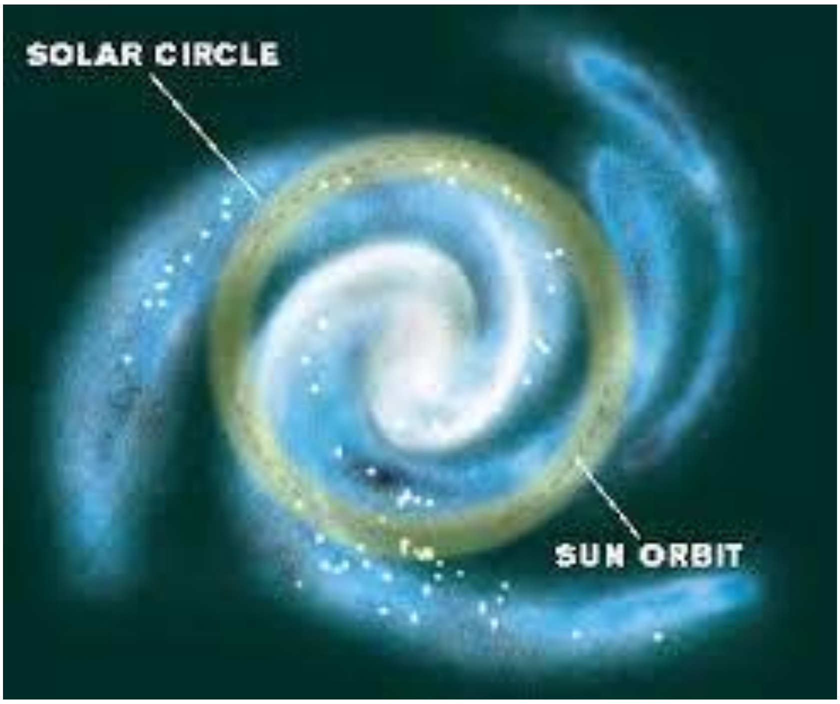


Fig. 11: Galaxy habitable zone (Credit: NASA)

Plasma and Magnetic Field

En el medio intergaláctico, en el medio interestelar y en las propias estrellas, la materia suele estar en estado de plasma. Este plasma está formado por electrones, protones, partículas de alta energía y gas ionizado.

Fig. 12a: Veil Nebula, (Credit Hubble), Fig. 12b: Comet C/2002 E3 (Credit Rykis Babianskas and Carlos Viscasillas)

On Earth there is matter in this state such as lightning, the interior of fluorescent tubes or low consumption lamps, monitors and television screens, plasma balls or the flame of a candle.

Fig. 13a, 13b and 13c: There is matter in the plasma state in the plasma ball, in a flame and in a fluorescent tube

Plasma is also the solar wind, a stream of charged particles that is released from the Sun's corona into the entire solar system, in all directions. The flow of these particles is variable, greatly influenced by solar activity, which produces spots and solar flares. The solar wind can deform the plasma in comet tails, which always point away from the Sun.

On Earth it can generate geomagnetic storms, and gives rise to auroras (lights in the north and south). Particles from the solar wind travel at high speed and with a lot of energy, have great penetrating power and can damage the DNA of cells. The Earth's magnetic field forms the magnetosphere, which acts as a protective shield, like an umbrella, deflecting charged particles that are so dangerous to life from reaching the Earth's surface.

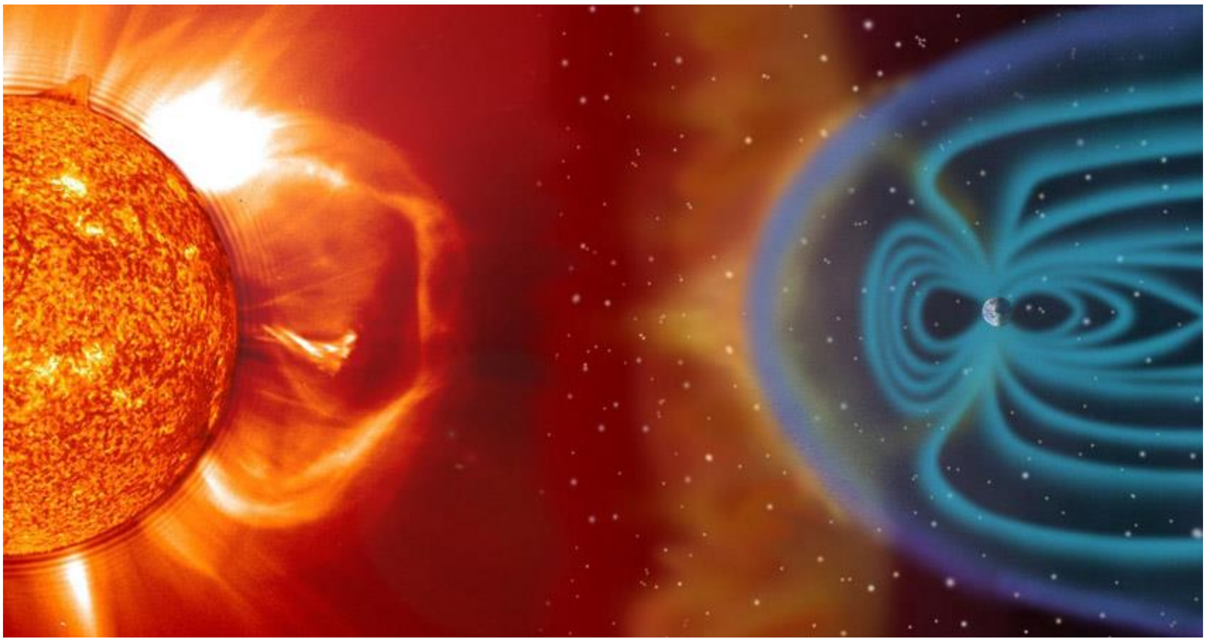


Fig. 14: The Earth's magnetic field serves as a shield or umbrella against the solar wind.

When there are strong coronal ejections on the Sun, the intensity of the solar wind increases greatly, and it can pierce the Earth's magnetosphere. On those occasions, part of the solar wind reaches the atmosphere in the areas near the poles, generating beautiful northern lights (in the northern hemisphere) and austral lights (in the southern hemisphere).

The energy of these particles excites the atoms in the atmosphere, causing their electrons to emit photons of different wavelengths. If the particles are high energy, oxygen produces a green/yellow light, and if they are low energy, red/purple light. In the case of nitrogen, it produces a bluish, or red/purple light at the lower edges of the aurorae.

Fig. 15a and 15b: The various colors in the aurorae depend on the ionization of oxygen and nitrogen. (Credit: S. Ekko, Finland)

Activity 4: Earth's magnetic field

We can visualize the Earth's magnetic field with a magnet, which represents the Earth's magnetic field, and a compass, with which we go along the lines of force of the field. It is enough to understand that the needle of the magnet is located "tangent" to the lines of the magnetic field (Figures 17a, 17b and 17c).

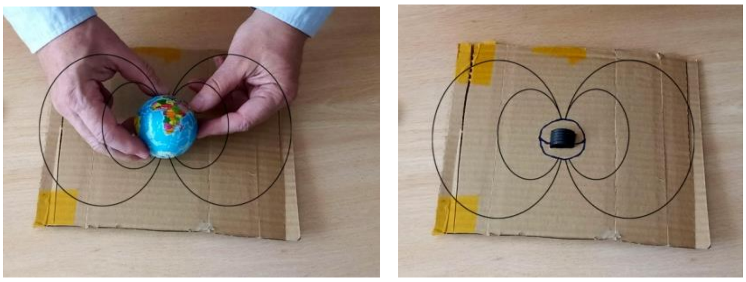


Fig. 16a, 16b: Model of the Earth's magnetic field with some lines of force represented.

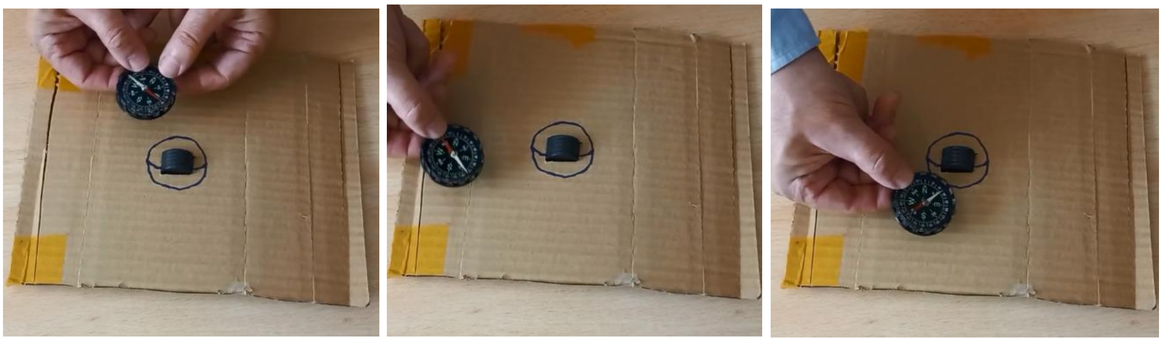


Fig. 17a, 17b, 17c: With a compass, the field lines are “drawn” (the compass needle is always tangent to the field lines).

Inside a plastic sphere, we put a magnet wrapped in a paper napkin. It represents the Earth. We sprinkle iron filings near the poles, which visualize very well the magnetic field lines in that area.

Fig. 18: A magnet inside a plastic sphere, as a model of the Earth's magnetic field.

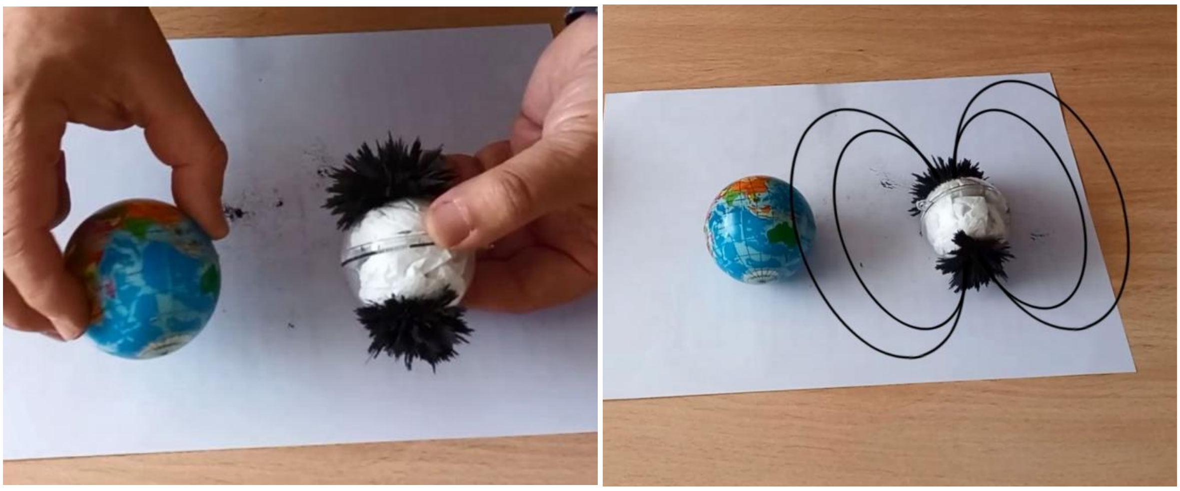


Fig. 19a and 19b: With iron filings the field lines in the polar areas are visualized. It is in these areas where the auroras occur.

The origin of life on Earth

The origin of life on Earth is accepted to date back more than 3 billion years, evolving from the most basic microbes to great complexity over time. But how did the first organisms develop in the only known home of life in the universe?

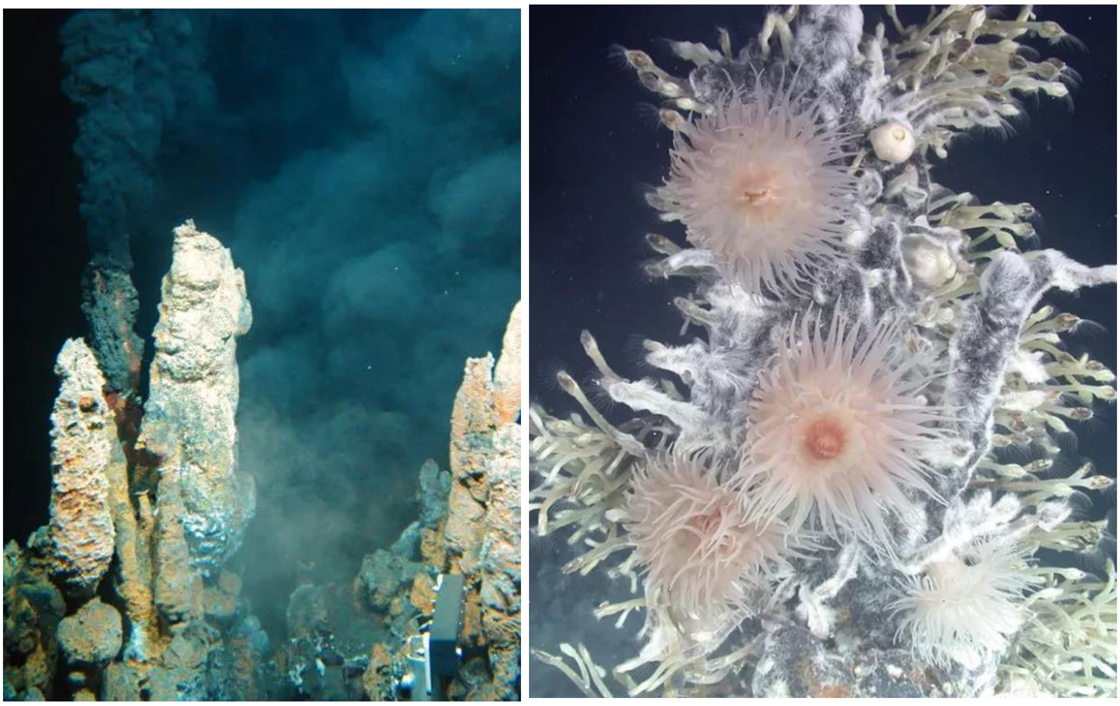
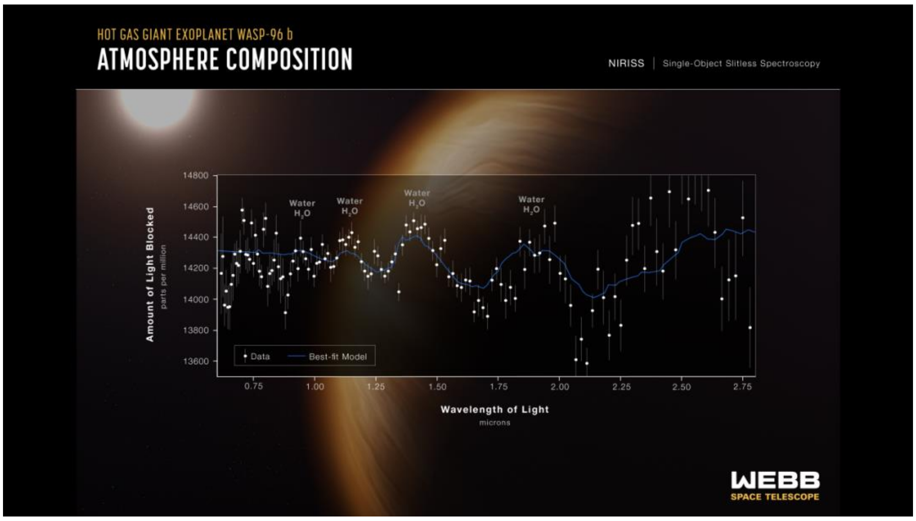


Fig. 20a: Life may have started at hydrothermal vents where acidic seawater met alkaline fluid from the Earth's crust (Credit: Woods Hole Oceanographic Institution). Fig. 20b: Anemones thriving in the warm waters of the vents (Credit: NERC ChEsSo Consortium)

Science remains undecided and in conflict as to the exact origin of life, even the very definition of life is questioned and rewritten. Some of the many scientific theories about the origin of life on Earth that are in force are:

- One of the most accepted theories is the one that proposes that life could have started in hydrothermal vents that can be found in the ocean depths, generally on divergent continental plates and that spew key elements for life, such as carbon and hydrogen. The expelled fluids cool as they cross the earth's crust, absorbing gases and dissolved minerals, such as carbon and hydrogen. We now know that these vents, rich in chemical and thermal energy, hot and alkaline, support a wide variety of species (Figures 20a and 20b).



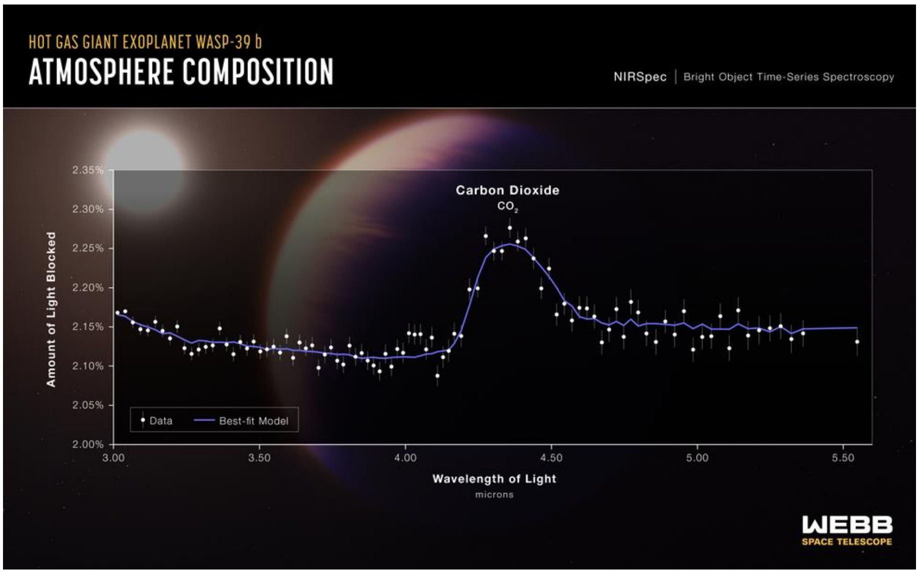


Fig 21a. Spectra of exoplanetary atmospheres, acquired with the James Web Telescope. WASP-96 b (top). Fig 21b: note the presence of the water molecule; WASP-39 b (bottom): the Carbon Dioxide band in the center of the spectrum. Note that these spectra are transmission and the wavelengths correspond to the near infrared, that is, the bands appear outside the visible region of the electromagnetic spectrum.

- Lightning may have provided the spark necessary for life to begin. Electrical sparks can generate amino acids and sugars from a charged atmosphere of water, methane, ammonia and hydrogen. Over millions of years, larger and more complex molecules could form. Although research since then has revealed that Earth's early atmosphere was actually hydrogen-poor, scientists have suggested that volcanic clouds in the early atmosphere could have contained methane, ammonia and hydrogen and electrical discharges, The first molecules of life could have been found in the clay, mineral crystals in the clay could have arranged organic molecules in organized patterns. However, this theory could not be categorically demonstrated (Figure 21a and 21b).

- 3 billion years ago, ice could have covered the oceans and facilitated the birth of life, since it is believed that organic compounds are more stable at low temperatures. The ice could also have protected fragile organic compounds from ultraviolet light and cosmic impacts. Today we know that in the frozen ground, known as permafrost, there are forms of life in a dormant state.

But, it would also be possible to argue that life begins outside the Earth and would have arrived by the exchange of rocks over millions of years thanks to the impact of comets, asteroids, meteorites, within the framework of the theory called panspermia. Protected from the conditions of outer space, microbes could survive trapped in rocks, but the issue must be taken very seriously, because it is also possible that upon arrival on Earth, the extraterrestrial material could be contaminated with pre-existing life on the planet, such as occurred with the famous meteorite ALH 84001 (Fig. 22), for which recent research, funded by the NASA Astrobiology Program, shows that the organic material in it was not formed biologically, but by geochemical interactions between water and the rock.

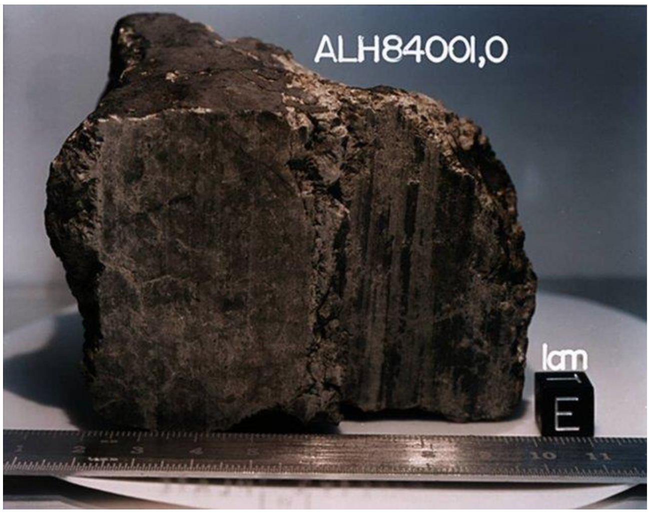


Fig. 22 . ALH 84001 meteorite: arrived from Mars, it was the protagonist of the premature announcement of life arriving from that planet. Today we know that what is detected as organic matter does not have a biological origin.

However, even if panspermia were true, the question of how life began on Earth would only shift to how life began elsewhere in the Universe.

Exploration of extreme environments on Earth has led to the discovery of numerous habitats that had been considered uninhabitable only a few years ago. The interest in the diversity and ecology of extreme environments has grown for various reasons, not only because of the potential use of extremophiles and their components in biotechnological processes (such as bio-mining, bio-remediation), but also because of the search for limits to the existence of life.

The first living species must have been simple life forms that served as a connection between the first organism (as bacteria) and life as we know it today.

As is well known, it is not possible to simply put some chemical elements in a test tube and hope that a new type of life will appear spontaneously. The origin of life is an event that takes millions of years to occur, but once it begins, life can multiply exponentially and adapt to areas of a planet that may be very different from where it originated.

Micrometeorites

The original solid material of the solar system, was forming the moons and planets. That accretion has not ended, and about 5 tons of material from space continue to fall on Earth. These meteors cross the exosphere and thermosphere at high speed without difficulty because these layers are not very dense. But when they reach the mesosphere, the density is greater and great friction occurs that can melt the material. When cooling in the stratosphere and troposphere, they eventually have a spherical shape, sometimes with striations and sometimes small bubbles, the effect of rapid solidification.

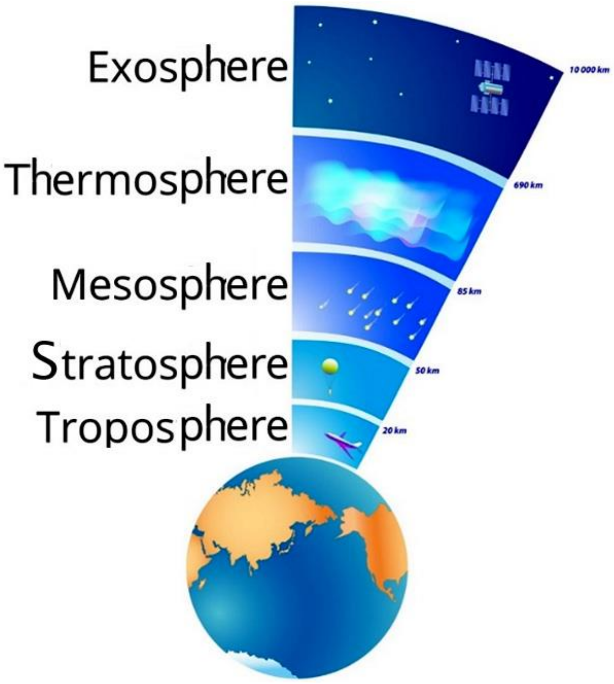


Fig. 23: Layers of the atmosphere. (Credit: Lifeder).

Activity 5: Simulation of spherical micrometeorites

We fill a tall, transparent cylindrical container with sunflower oil as a column. With the help of a syringe (Figures 24a and 24b), a few drops of water or cola are dropped (because their color can be seen better that way). The initial physical state of the water or soft drink causes small spheres to form immediately, which are seen to slowly fall down the column of oil.

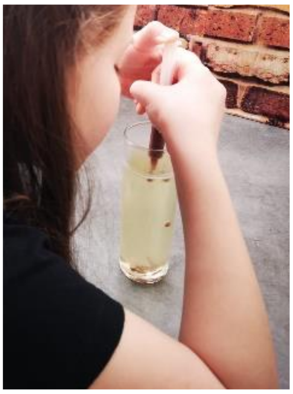



Fig. 24a: Making the drip with a syringe, Fig. 24b: Column to form the spheres.

Activity 6: Search for micrometeorites

Micrometeorites can be obtained in the material that is continuously deposited on roofs, roads, etc. When it rains, the water drags them down the gutters on the roofs and in the gutters of the streets or routes. A little bit of sand from those places is collected on a sheet of paper with a brush.


Fig. 25a: On public roads you can find ditches or gutters with sand where we can locate meteorites. Fig. 25b: We collect this grit with a piece of paper to analyze it.

Next, a magnet is passed under the sheet of paper with the material: it will be clearly seen how small particles of ferrous material are attracted by the magnet (Figure 26). Without pulling the magnet apart, flip the paper over, and all the sand will fall out, except for those fine dark particles, which will be attracted to the magnet's magnetic field. Flip the paper over and remove the magnet. There may be possible micrometeorites there.

Fig. 26a and 26b: Passing the magnet under the sheet of paper, it drags the ferromagnetic material

When viewing the sample with the mobile phone camera at maximum zoom, the particles that are micrometeorites have a spherical shape, like small marbles.

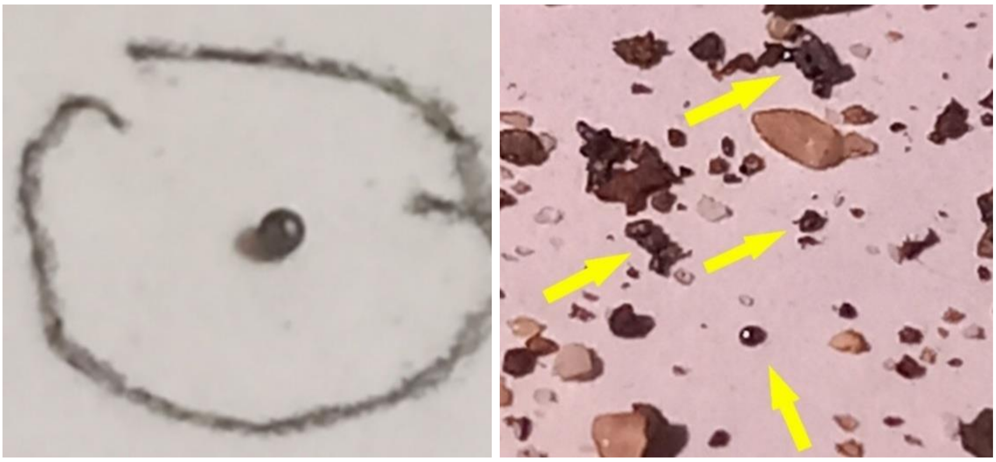


Fig. 27a: Photograph of a single isolated micrometeorite with the mobile camera, Fig. 27b: Photograph with several micrometeorites using the same camera;

You can also build simple "traps". For this you need the following items: a kitchen tray and transparent cellophane paper (kitchen wrap). Cover the tray with the cellophane paper by folding the edges or gluing the cellophane underneath, to prevent it from blowing away (Figures 28a, 28b and 28c).

Fig. 28a: Tray, cellophane and tape, Fig. 28b: Gluing the cellophane to the back of the tray, Fig. 28c: Micrometeorite "trap" set up in the garden.

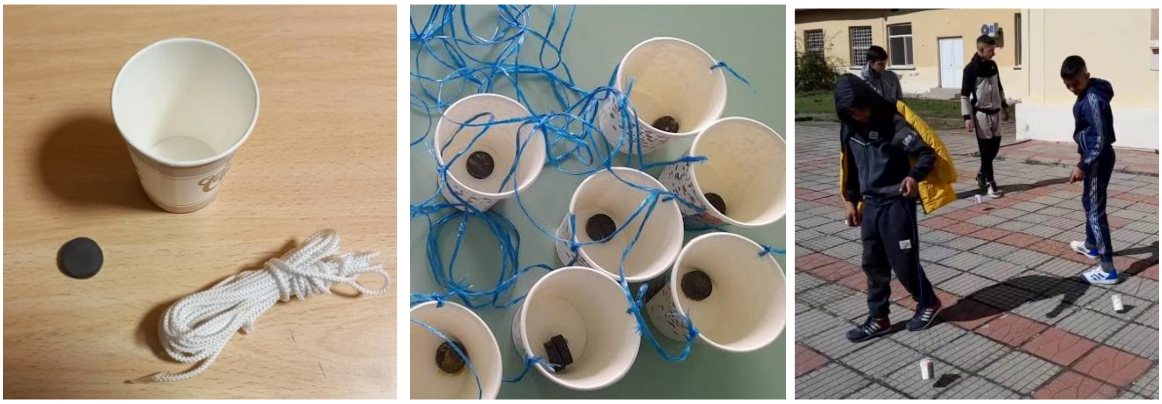


Fig. 29a and 29b: The glass tied with a thread and a small magnet inside. Fig. 29c: Student using the beaker, searching for micrometeorites.

To set up the trap for each student, we tie the glass with string and stick a small magnet inside the glass. Students move around the schoolyard area with the magnetic cups. Then they remove the magnet, and if there are iron particles (micrometeorites), they will fall on the white sheet of paper. Students look with their phone cameras to find micrometeorites, identifying them as small spheres.

Extremophile Classification

An extremophile is an organism, often a microorganism, that lives in extreme conditions, that is, in those circumstances that are very different from those in which most terrestrial life forms live.

Until recently, it was thought that in the places where we now know extremophiles grow, it was impossible for life to exist. For example, in the extremely cold areas of Antarctica, in the highly acidic and metal-containing waters of the Rio Tinto, or in the extremely dry and heavy-metal-containing Atacama desert. But it has been shown that there are organisms that live in all these areas.

NASA and ESA astrobiologists study on the ground (Antarctica, Atacama Desert, Ríotinto Mines, etc.) how life evolves or adapts to understand how it originated.

Antarctica, for the most part, is cold and desolate, yet several groups of scientists have managed to find a great deal of life below its surface. They have found extremophile microbes living at depths of 36m with temperatures of -20ºC in salt water (which does not freeze due to the high concentration of salt), another group has found an entire ecosystem at a depth of 800 m in the total absence of light (figure 30).

Fig. 30: Different scientific groups find extremophiles under the surface of Antarctica

Some extremophiles live in the absence of water or are able to withstand desiccation by living with very little. Like the microbes in the soil of the Atacama Desert.

There is a very spectacular phenomenon: the flowery desert. This is the driest desert in the world, in years when there is more rainfall than normal and then a cold front, a large number and diversity of flowers appear (up to 14 varieties) that last for a few months.

The mining area of Riotinto has been exploited by the Roman Empire since the 1st century BC and the current situation, after hundreds of years of surface mining where heavy minerals have been extracted, is of great interest to study life in extreme conditions.

Fig. 31: Photograph of August 2022 after several years of dryness, the last years were 2015 and 2017

Other extremophiles develop in environments of high acidity and high metal concentrations (Iron, Copper, Cadmium, Arsenic, Zinc, Lead). The reactions in this river are catalyzed by acidophilic bacteria, so that if the acidity is reduced, the bacteria population multiplies, which generates more oxidation of sulfides and more acidity in a process that feeds back. The inhabitants of the area know when it is going to rain because of the changes in color of the river (bacteria generate more acidity to maintain the ph during the flooding of the river).

Fig. 32: The red waters of Rio Tinto where acidophilic bacteria live.

Fig. 33: Erica Andevalensis spreads throughout the area, whose roots in acid soils and with very little nutrients

There are extensive areas of Erica Andevalencis bushes or “mining heather”, distributed along the riverbed. These plants have their roots in highly acidic soils with few nutrients. Some plants even grow on the banks of the river with their roots partially submerged in acidic water and soils with high concentrations of Copper and Lead.

Space research requires the work of astrobiologists in extreme areas such as Antarctica, the Atacama Desert or the Ríotinto Mines. The first step of many of the protocols that are carried out to discover extremophiles consists of the DNA extraction process and for this reason this activity is carried out next.

Activity 7: DNA extraction

After observing that there is life in very extreme conditions, it has been decided to do the DNA test when it is desired to detect the existence of life. The remains of DNA allow to detect the existence of life (current or past), and this is used to search for life in space. The DNA molecule is a very long molecule and is packed with protein (like a ball) inside cells. Thus, in order to detect the presence of DNA remains, it is necessary to prepare a solution with which we can break the cell's enveloping membrane.

As an example, we will proceed to extract the DNA from a ripe tomato because it is very easy to liquefy it.

Solution to break the cell.
In half a glass of water, dissolve a teaspoon of salt (Sodium Chloride) to loosen the proteins and thus release the DNA that will appear white due to the presence of salt. Three teaspoons of Sodium Bicarbonate, to keep the pH of the solution constant and that the DNA does not degrade. Next, dishwasher is added until the water is the color of this, to break the membrane of the fatty cells. It is necessary to mix without foaming to be able to see the DNA well.

Prepare the "tomato" cell juice
We will start by extracting two tablespoons of tomato pulp, crushing it with a spoon and mashing it with a fork until we have a more or less liquid puree (figure 34).

Pour the cell-breaking solution over the tomato puree. Twice the volume of solution as tomato puree. To break the cells, shake taking care not to make foam and strain to remove large pieces. The content inside the cells is in the juice and that is where the DNA that we want to extract is located.

Fig. 34: Preparing the liquid tomato puree, to proceed to add twice the membrane-breaking solution to extract the DNA.

Make DNA visible
When there are many strands of DNA, it looks like a white cloud (salt gives it a whitish color). We let alcohol fall down the wall of the glass of juice, because we want a layer of alcohol to remain on top of the juice without mixing with it. In three or four minutes a white cloud of DNA is formed that is gathering and becoming visible (rises up). Alcohol is added because DNA is not soluble in alcohol and the cloud of DNA that is clearly visible is formed (figure 35).

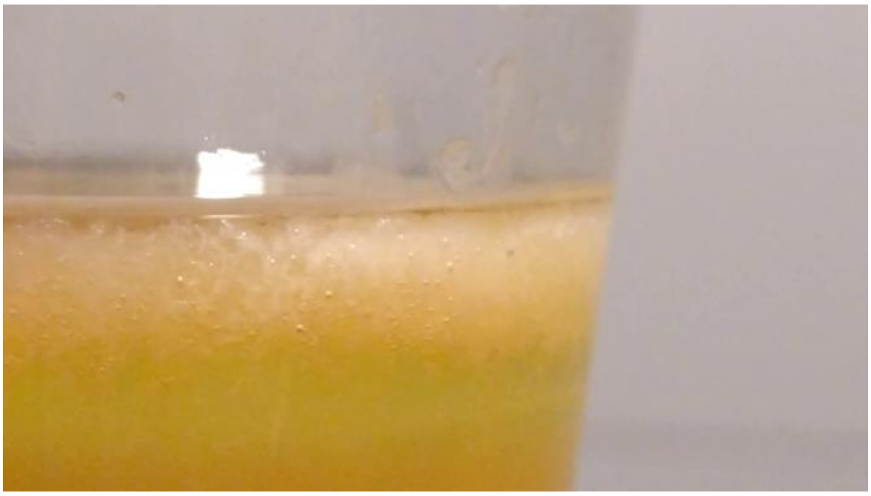


Fig. 35: The DNA cloud is highly visible floating above the mixture

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