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Feature Article

The Universe, the Light, the Earth, the Life: the Reality is Greater than We Are

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Abstract. The pandemic caused by Covid-19 locked us at home for several weeks. Some clever town councillors took this opportunity to offer their citizens cultural pills. In my little town I was asked to present a few short lectures on general scientific concepts. I tried to link together four entities of reality (Universe, Light, Earth and Life) showing that reality is much more complex than we think and much greater than us. E.g.: age of the Universe vs age of human civilization ($\sim 1.3 \times 10^{10}$ vs $\sim 1 \times 10^4$ years), size of universe vs human size ($\sim 1 \times 10^{25}$ m vs ~ 1 m), velocity of light vs velocity of sound (3×10^8 vs 3.5×10^2 m/s), number of stars in the sky ($\sim 1 \times 10^{23}$), number of molecule in a drop of water ($\sim 3 \times 10^{21}$), number of atoms in a human body ($\sim 1 \times 10^{27}$). Although we know reasonably well *how* Universe, Light, Earth and Life “work”, we are still surrounded by profound mysteries related to the *why* questions, i.e., the “questions of meaning”, that science cannot answer. Such questions, e.g., why is there the Universe? Why is there Life in this insignificant fragment of the Universe called Earth? Why did the evolution of Life lead to human? What’s the meaning of my life? What is the meaning of the Covid-19 pandemic? The answers to these “questions of meaning”, that cannot be given by science, are discussed in the encyclic *Laudato si’* of pope Francis in relation to the ecological and social crisis we are going through.

Keywords. universe, light, earth, life, reality, complexity, mysteries, unbelievable numbers, stars, atoms, time, energy, human, questions of meaning, talents, spiritual energy.

Premise

During the pandemic caused by Covid-19, I was asked by the cultural center of my town to present a series of short lectures of general interest for students as well as for citizens locked in their homes. I thought it was a good opportunity to recall some fundamental concepts on the Universe, the Light, the Earth and the Life, to show that the world is full of mysteries, that is, things that are not understood or that, if they are understood, are so strange as to seem incredible: incredibly large, incredibly small, incredibly organized, incredibly efficient. The Reality is much, much greater than we are.

The Universe

Let's start from the Universe.¹ What is the Universe, which we sometimes call the world? Has there always been? No. Science tells us that the world was "born" 13.8 billion years ago. Scientists are unable to say what was before. We are faced with a first mystery, we will see many others. According to some scientists, before there was nothing. Other scientists think that there are not only one universe, ours, but that there are many: and to say that there are many, the word multiverses is used. But these are only hypotheses, in which science borders on the field of philosophy.

The most accredited scientific hypothesis on the Universe is that everything started with the so-called Big Bang, a big explosion (better: a great expansion) of a very small "thing" in which an incredible amount of energy was concentrated (Figure 1). We do not know what was before this Big Bang, but we know, at least in broad terms, what happened after, that is, during the 13.8 billion years of "life" through which the Universe came to us. At the beginning there was only a very small volume of incredibly concentrated energy at very high temperature; then, a great expansion in the space occurred and the Universe cooled down. Energy began to condense forming matter, matter aggregated to give galaxies, stars and all other celestial bodies, including our Earth, which formed 4.5 billion years ago (when the Universe already existed for 9 billion years). Then life originated on Earth about 3.5 billion years ago (how life originated, it is not known: another mystery), then the evolution of life led to human. Our civilization is only 10,000 years old!

What else do we know about the Universe? As we can see with our eyes, there are many material objects: stars, planets, satellites, meteorites, and there are phenomena such as gravitational attraction, heat, and light: that is, there are matter and energy. According to scientists, in addition to matter that is seen and energy that manifests itself, there is also a large amount of matter that we do not see (the so-called dark matter) and there is energy that we do not perceive (dark energy). As we will see below, we know a lot about the Universe, but a famous Einstein phrase is enough to throw us back into the mystery:² *"The most incomprehensible thing about the Universe is that it is understandable"*.

But how do we see and understand how the Universe is made? By means of the Light.

The Light

What is the Light? We think we know it, but try to give a definition, to explain it to another person: it's difficult.³ In physics books one can find pages and pages about light, its many properties and characteristics; but when it comes to saying what light is, they just say that light is energy. At this point one thinks one has understood, but it is not so. Yes, okay, light is energy, but what is energy? Maybe we think we

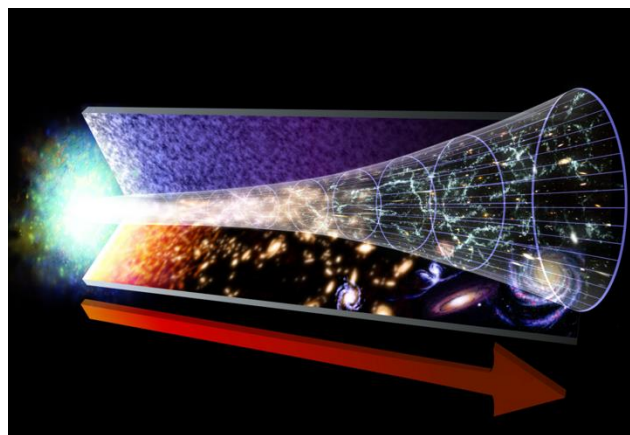


Figure 1. This image represents the evolution of the Universe, starting with the Big Bang. The red arrow marks the flow of time. Credit: NASA

know, but we will see later that we don't even know what energy is. Another mystery.

The first thing to say about light is that it's a strange "thing". In fact, light manifests itself in two different ways: as a wave, an *electromagnetic wave* (that is, a wave with electrical and magnetic properties), or as a set of granules, of energy particles called *photons*. A ray of light is a wave, but also a set of photons. The light is very strange indeed: it manifests itself with the wave aspect or the photonic aspect depending on how we study it, on what experiment we do! Light is emitted from a source (e.g., sunlight) and travels until it encounters something that absorbs it, that uses it: for example, in our eye light causes a chemical reaction that sends a signal to the brain: and this allows us, in fact, to see. In science, the word *light* has a very broad meaning: by light science means not only what our eyes can see, more precisely defined visible light, but also other types of light, different in their content in energy, which our eyes cannot see. Our eyes do not see photons that have very high energy, for example those of ultraviolet light or X-rays, nor do photons that have too low energy, such as those of infrared light or radio waves. Often in science instead of light the term *radiation* is used, which includes all types of light, both that which our eyes can see and that which our eyes cannot see.

Stars emit radiation that is in part visible light, what we see, but they also emit many other types of radiation, X-rays, gamma rays, radio waves, etc., which our eyes do not see. But scientists have invented special equipment with which they can "see", that is analyze, radiation that our eyes do not see. By analyzing radiation, visible or non-visible, emitted by celestial bodies we can learn many things about the Universe. The quality and quantity of light emitted by a source depend on the materials of which the source is made and the temperature at which it is located. Therefore, by analyzing the light emitted by a star we can understand what material there is on that certain star and also what temperature that star has.

The Light has another oddity, another exceptional property: it comes out of the source and propagates at an

unimaginable speed: 300,000 km per second. To get an idea of what 300,000 km per second means, consider that the circumference of the Earth is about 40,000 km. So a ray of light in a second travels around the Earth seven times. There is nothing faster than light. For comparison, remember that the sound propagation speed is only 350 meters/sec. (1000 km/h).

The distance between the Moon and Earth is 380,000 km: the light of the Moon takes 1.3 sec to reach Earth. The distance between the Sun and Earth is 146.6 million km: a jet plane would take 16 years to go from the Sun to Earth. The Light takes 8.5 minutes. This number, 8.5 minutes, tells us another very important thing: when we see it, the Sun is actually no longer there; it was there 8.5 minutes before. The distances in the Universe are so great that it is not convenient to measure them in km. Antares, one of the brightest stars, is away from us 10 million billion km: a 1 followed by 16 zeros, too large a number, too inconvenient to use. Thus it was decided to take as a unit of distance measurement in the Universe not the kilometer, but the *light year*, that is, the distance that light travels traveling for a year. The light year equals nearly 10 trillion km. Expressed in light years, the distance between the Earth and the Antares star is 1000 light years. This means that by looking at Antares, we actually see where Antares was 1000 years ago!

Since its inception, the Universe has expanded and continues to expand: it has not yet been understood what shape it has, and therefore what size. Someone has calculated that if you imagine the Universe as a sphere, but also on this point there are many discussions, it has a radius of one hundred thousand billion billion km, equal to 46 billion light years. How big the Universe is! And it is expanding! Certainly there are stars so far away that we have not yet seen because their light has not yet arrived! Always thanks to the Light, with simple trigonometric calculations we can measure the distances between us and the various stars and also understand the movements of the stars. Stars are celestial bodies at very high temperatures that emit light. Our sun is a star. Stars are often surrounded by other celestial bodies which we call planets, which in turn may be surrounded by satellites. The Earth is a planet of the Sun, which is much larger than Earth: it has a radius 109 times greater than that of the Earth. The Moon is a satellite of the Earth, it has a radius 4 times smaller than that of the Earth. Planets and satellites do not emit light: they are bright because they partly absorb, but partly reflect the light emitted by their star. Analyzing the reflected light we can get information on the chemical composition of the planet or of the satellite.

And dark matter, what would it be? Matter that does not emit any type of radiation and therefore we cannot see it in any way. But it can manifest itself through gravitational effects. And what about dark energy? It is light that cannot leave the star that emits it, light that is swallowed up, attracted by the great gravitational force of the star.

This happens in the so-called black holes that emit light that cannot reach us.

How many stars are there in the sky? Have you ever tried to count them? The visible ones, that is those that emit light that our eyes can see, are about six thousand, but there are many other stars that are not bright enough to be seen without a telescope or that do not emit visible light, but other types of radiation (X-rays, gamma rays, radio waves etc.) that scientists are able to analyze with their equipment. In total, it is estimated that there are about one hundred thousand billion billion stars in the sky (a 1 followed by 23 zeros), a number so large that it is difficult to understand. To try to appreciate it, suppose we can see them all and start counting them, one per second: to count them all, it would take 3 million billion years. An impossible task for a human! The Universe is not on a human scale. Reality is much bigger than we are. In the Bible there is a psalm, Psalm 147, which says: "*The Lord appoints the number of the stars; He calls to them all by names*". Then there is another psalm, Psalm 115, which says "*The heavens are the heavens of the Lord; but He has given the earth to the sons of men*". Here, we have to take care of the Earth, not the Universe. The Earth, says Pope Francis in the encyclical *Laudato si'*, is "*Our Common Home*".⁴

The Earth

The Earth was formed 4.5 billion years ago, then 9 billion years after the "birth" of the Universe, the Big Bang. The Earth was formed by the aggregation of materials that have become detached from the Sun. As a first approximation, the Earth has a spherical shape, with a radius of 6,400 km (Fig 2).

But to understand well what Earth is, our Common Home, we need to do other types of reasoning. In a famous photograph, taken by NASA astronaut William Anders on December 24, 1968 during the Apollo 8 mission, one can admire the extraordinary spectacle of the rising of the Earth seen from the Moon. Contemplating the scene he was photographing, Anders said,⁵ "*We came all this way to explore the Moon, and the most important thing is that we discovered the Earth.*" Looking at the Earth from far away, we indeed realize what our real condition is: we are passengers of a spaceship that travels in the infinity of the universe.



Figure 2. One of the most famous photographs of Earth, taken on December 7, 1972 by the Apollo 17 crew from ~ 45,000 km away. Credit: NASA

On this spaceship, we are many, almost eight billion and so different: white, black, yellow, rich and poor, good and bad. In another famous NASA photograph (Figure 3), taken by the Cassini Orbiter spacecraft when it was near the rings of Saturn, at a distance of 1.5 billion kilometers, the Earth appears as a pale blue dot in the cosmic darkness. It looks like an insignificant fragment of matter that travels aimlessly in the infinity of the universe. There is no evidence that the Earth is in a privileged position in the Universe, there are no signs that suggest our particular importance, nothing that leads us to believe that we can receive help from others, no indication of places where possibly be able to emigrate. It is very interesting and also instructive to look at these two photos: they should be shown and commented in elementary, middle and high schools and, even more, in university courses that open up to political careers. If you meditate on these photos, you understand that the Earth is indeed a spaceship,^{6,7} but it is a very special spaceship, very different from those we see in the movies: from the spaceship Earth no one can leave, if not dying, and nobody can come from outside: to live on the spaceship Earth you have to be born on it. Not only that: it is a spaceship that can never "land" anywhere, can never dock at any port to refuel or unload waste. The resources we can count on are the materials that make up the ship and the sunlight. And if something doesn't work, if something "breaks" we have to get by on our own, without even going down.

This is what we have been trying to do in recent months, since the Covid-19 pandemic has developed on the spaceship Earth (Figure 4). The virus has killed tens of thousands of people in several countries and forced billions to shut themselves up in their houses. Waiting for a vaccine, we hope to have taken control of the pandemic at least for the next few months.

What is the origin of the Covid-19? President Trump claims that it has been released from a Chinese research laboratory, by purpose or mistake, but scientists believe that the Covid-19 pandemic, as well as previous ones, are caused

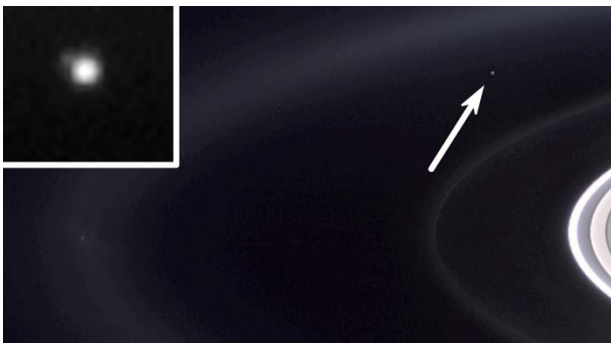


Figure 3. Photograph taken by the Cassini Orbiter spacecraft on September 15, 2006, at a distance of ~ 1.5 billion kilometers from Earth. The dot to the upper left of Saturn's rings, indicated by the arrow, is the Earth. Saturn was used to block the direct light from the Sun, otherwise the Earth could not have been imaged. Inset: expanded image of the Earth which shows a dim extension (the Moon). Credit: NASA.



Figure 4. The Covid-19 pandemic

by our mistakes in the relationship with nature:⁸⁻¹⁰ exaggerated use of resources, pollution, climate change, excessive occupation of the soil, growing loss of biodiversity, increase in the consumption of animal products, including wild food. Originally, viruses only infected animals, particularly wild animals, but then make the jump from animal to humans, a well-known phenomenon called *spillover*. In a way, viruses are "refugees" from environmental destruction caused by the progressive occupation of human in all natural environments. A great scientist, Edward Wilson, has provocatively proposes to leave half the Earth to Nature if we want to live well on this planet.¹¹

The most serious problems are caused by fossil fuels, coal, oil and natural gas, used to obtain energy. On Earth, every second we burn 250 tons of coal, 1000 barrels of oil and 105,000 cubic meters of gas.¹² Every second! The use of fossil fuels causes the release into the atmosphere of huge quantities of carbon dioxide (1200 tons per second) and many polluting substances. The huge amount of carbon dioxide (CO₂), a colorless, invisible gas, wraps the planet like a blanket that allows the sun's rays to reach the ground, but prevents, in part, the heat generated from escaping towards the outer space. It is the so-called greenhouse effect: the planet heats up. This global warming,^{6,7} causes complex climate changes such as melting ice, rising sea levels, changes in the precipitation regime, extension of desert areas.

The "breakdowns" caused by the climate change are already very evident and scientists warn that if measures are not rapidly implemented to reduce the consumption of fossil fuels to zero, the situation will get worse and faster and will have catastrophic results for the next generations. To avoid pollution and climate change we will have to use sunlight and the force of wind and rain as energy sources. All these problems, pollution, climate change, loss of biodiversity, the corona virus and many others, we have only us who are on this strange, small planet of the solar system, the Earth. It should be noted that they are not intrinsic problems of the planet, they are our problems: problems that we have created, we who are the result of the strangest and most mysterious

thing of all those we have already seen, probably unique in the whole Universe: the fact that on Earth, about 3.5 billion years ago, life developed and then the evolution of life led to us! Thinking about it, you have to be breathless: the Earth, this insignificant fragment of a Universe that includes one hundred thousand billion billion stars, the Earth, this small fragment of matter seems to be the only place in which life has developed!

The Life

What is life?^{13,14} We know it well, but if we were to explain what is life to someone, we would be in trouble. On the other hand, even scientists do not agree in saying what life is, nor are they able to "build" it in the laboratory.

Life is a "concept", an "entity", a "something" too complex, important and sublime to be "forced" into a definition. This also happens for other fundamental concepts. Of the concept of time, Saint Augustine said: "*If nobody asks me, I know; if I want to explain it to those who ask me, I don't know anymore*".¹⁵ Also of the concept of energy, Richard Feynman said:¹⁶ "*We must realize that in Physics we don't know what energy is*". A scientist who has recently tried to define energy in a dictionary took 10 lines and then concluded as follows:¹⁷ "*Energy is something of a universal nature that appears in material and immaterial forms and that cannot be "reduced" to anything more elementary*". Yes, energy also appears in an immaterial form: human is not only made of matter, but also of something that we call spirit, an entity which is also difficult to define, but easy to clarify with an example. When my wife sees me fatigued and says "I am going to prepare you a tea", she performs material actions (she warms up water, she pours it in a cup etc.), but she is guided by her loving me. She makes me a tea because she loves me. Loving is a spiritual energy.

So, what is life? What do we know? How does it work? We know that the Earth and also all living beings that populate it are made up of atoms (C, O, N, Fe, etc.) that join together to give rise to aggregates that we call molecules.¹⁸ The molecule that everyone knows, that of water, H₂O, is made up of two hydrogen atoms linked to an oxygen atom. There are millions and millions of types of molecules. There are also very large ones such as hemoglobin which is composed of 9072 atoms: C₂₉₅₄H₄₅₁₆N₇₈₀O₈₀₆S₁₂Fe₄. Atoms and molecules are very small. The unit of measurement that we use in everyday life is the meter, but we have seen that in the Universe we cannot measure distances in meters and not even in kilometers: it is better to use as a unit of measurement the light year, which is worth ten thousand billions of km. Similarly, for very small things, we cannot use the meter as a unit of measurement. We must use the thousandth of a meter (millimeter) or the millionth of a meter (micron), or even the billionth of a meter, the nanometer (10⁻⁹ m). The dimensions of atoms and molecules are measured in nanometers. The water molecule, H₂O, has a diameter of about 0.2 nm, two tenths of billionths of a meter. The molecules, therefore, are incredibly small. Hard to believe,

but it's true! Scientists, just as they invented equipment to study the infinitely large Universe, have invented other equipment to study very small things like atoms and molecules.

To understand how small molecules are, an example will suffice: in a drop of water there are 10²¹ water molecules, that is, one thousand billion billion molecules. Here is another incredible number! If we could and wanted to count, at the rate of one per second, the molecules that are in a drop of water would take 30,000 billion years. Another example, even more incredible, is the following: in the body of a human there is a number of atoms ten thousand times greater than the one hundred thousand billion billion stars of the Universe! And, which causes an even greater wonder, these billions of billions of atoms that make up a man's body are not piled up in bulk, but are extremely well ordered and connected to form molecules, which in turn are grouped together to form more and more complex systems. As complexity and organization increase, new properties emerge that make it possible to perform increasingly valuable functions: this leads to the simplest form of life, the cell of a bacterium, which is made up of thousands of billions of molecules and has dimensions of 200 nm (two hundred billionths of a meter). A further increase in complexity leads to the formation of larger and more complex cells that come together to give tissues, which in turn form organs that are capable of performing increasingly complex functions, up to that supreme organ which is the brain of the human.¹⁸

The mystery of Life

From the view point of science, the mystery of life does not lie, as once thought, in a not better defined "life force", but in a huge number of extremely complex chemical processes, incredibly organized and capable of such a rich diversified functionality to arouse our amazement and escape our reasoning. The more we know about life, the more wonder increases. Edoardo Boncinelli wrote:¹⁹ "*Every day, in every moment of our life, a real miracle occurs within us: the ability to learn, to remember, to make choices*". George Wald, a famous American scientist, spoke of the thread that connects the atom to human in these terms:²⁰ "*It is a very important part of our dignity that we can know and that through us matter can know itself. Organized as they are within us, hydrogen, carbon, oxygen, nitrogen, water, having become "us", can begin to understand what they are and how they came to be*". So we are shrouded in mystery. Science speaks to us only of concrete, material things, not of spiritual ones. Science gives us news on how the world works, but leaves open all the questions of meaning. Why is there the Universe? Why is there Light? Why is there Life in this insignificant fragment of the Universe called Earth? Why did the evolution of Life lead to man? What is the meaning of the presence on Earth of man, the only thinking creature, subject in a world of objects, formed by a number of atoms ten thousand times larger than the hundred thousand billion billion stars of the Universe? What's the meaning of my life? Why can a virus, a

non-living 100 nanometer entity, attack and kill a human, a living entity made up of ten billion billion times more atoms? We are not the masters of the world. Reality is much, much greater than we are. It is beyond our ability to understand it.

Science is useful for understanding how the world works and can help us solve problems, even if sometimes it is science itself that creates problems. In any case, science cannot make us omnipotent. The answers to the questions of meaning are not found in matter and science. We must look for them in the categories of the spirit, in philosophy and in religion. Even Pope Francis, in the encyclical *Laudato si'*, asks questions of meaning:³ *"What is the purpose of our life in this world? Why are we here? What is the goal of our work and all our efforts? What need does the earth have of us?"* The answer, says Pope Francis, lies in the dignity of man: *"We need to see that what is at stake is our own dignity. Leaving an inhabitable planet to future generations is, first and foremost, up to us. The issue is one which dramatically affects us, for it has to do with the ultimate meaning of our earthly sojourn"*. Therefore, we must *"... protect our common home and bring the whole human family together to seek a sustainable and integral development, for we know that things can change"*.

Human is free to choose between good and evil but *"Human beings, while capable of the worst, are also capable of rising above themselves, choosing again what is good, and making a new start. No system can completely suppress our openness to what is good, true and beautiful. ... Education in environmental responsibility can encourage ways of acting which directly and significantly affect the world around us; ... such actions can restore our sense of self-esteem; they can enable us to live more fully and to feel that life on earth is worthwhile"*.³

Here then: perhaps the Covid-19 pandemic is a providential reminder. We are asked to better protect the common home and all its inhabitants, to abandon wars, consumerism and inequalities and to take the path of peace and ecological and social sustainability. We are asked to learn how to make better use of all the talents that have been given to us and, in particular, our precious sources of spiritual energy: wisdom, creativity, responsibility, collaboration, friendship, sobriety and solidarity. We are asked to understand that on this spaceship Earth which, as the psalm says, God *"gave to the sons of men"* and on which we are all born and we must all live to death, we are all brothers because we are loved children of that God much greater than us who, as the psalm says, *"appoints the number of the stars and calls to them all by names"*.

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