Lunar outpost for meeting aliens

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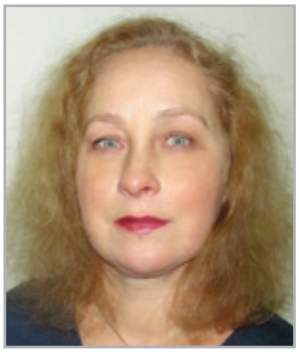

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The paper considers certain astronomical, historical, biological and energy aspects of the issue of the search for extraterrestrial life connected with lunar research. We mention the Moon and its ifluence to the beginning and development of life on the Earth. We discuss how the Moon became a starting point for scientists in their speculations on the search for space brothers, the object that symbolizes the entry into space. The pathway of scientific research from the Moon to exoplanets and SETI is associated with the name of Otto Struve who was born in Kharkiv and became a promoter and supporter the "Ozma" project. Also we discuss the problem of bringing terrestrial life to the Moon and of the energy supply for lunar bridgeheads of mankind.

Keywords: The Moon, life origin, spaceflight, Earthshine, exoplanets, SETI

Introduction

What is the Earth's Moon – the cunabula of the human race, its giant leap to outer space, a cosmic gate or the outpost of civilization?

In the present paper, we would like to consider certain astronomical, historical, biological and energy aspects of the issue concerning the search for extraterrestrial life connected with lunar research. Astronomy in Kharkiv has been developing for more than 200 years since the University was founded. Thus we would also like to mention famous scientists and their studies performed in Kharkiv and connected with the issue of extraterrestrial life.

Why are we specifically talking about the Moon? Because it is the most studied extraterrestrial object to date. Because we have got the biggest quantity of extraterrestrial matter from this satellite. Because humans have been there for many times. Therefore the step to the Moon, as American astronaut Neil Armstrong proclaimed, "*is one giant leap for mankind*".

Aspect 1. Why we exist?

Before discussing possible contacts with aliens, one needs to find out why humans exist. In this respect, it is necessary to mention the Moon and its influence on the Earth, its existence and orbital motion, and the beginning and development of life on the Earth. In fact, we are dealing with a dual Earth-Moon system with an approximate mass ratio of 81 to 1. The axis of rotation of the Earth and the inclination of the rotational axis to the plane of the Earth's orbit (mean value of 23.3 deg) are quite stable over hundreds of million years. If there were no Moon, what would happen? Back in the 1990s French astronomers integrated the equations of the Earth precession and found a large chaotic zone which extends from 60 deg to 90 deg in obliquity (Laskar, Joutel, Robutel, 1993). That is, over the past billions of years, the angle of the Earth would have changed very much, at 85 degrees, as it happens to

Uranus. Large variations in obliquity resulting from its chaotic behavior might have driven dramatic changes in climate. The Moon, which stabilizes this slope, stabilizes the climate. This may be contributing to the emergence of life on our planet because nature loves stability. These obliquity variations would mean extreme temperatures on the surface of the planet, the winds would be much stronger and the day on Earth much shorter. That is, our civilization owes its existence to the Moon.

A particular part of the story concerns ebb and flow. Tides in the Earth's oceans made up such a part of the Earth's biosphere as a band of tides along the shores of the oceans. When life is thought to have arisen, the Moon was still much closer to us than it is now. This fact, together with Earth's much more rapid rotation, led to tidal cycles every two to six hours. Moreover, tides were able to pass through land over hundreds of kilometers. According to some theories, coastal areas were subject to dramatic cyclical changes in salinity, which led to repeated association and dissociation of double-stranded molecules similar to DNA (Lathe, 2004). The following development of life could be potentially supported by the very high concentration of nutrients in ebb and flow zone.

But, how does all this relate to search for extraterrestrial life, especially with other planets? Here is an example: scientists are studying the extraterrestrial planets orbiting around other stars – the so-called exoplanets. In particular, for the TRAPPIST-1 system at 40 light years from Earth, recent observations reveal that at least seven planets with sizes and masses similar to those of Earth revolve around a star (Gillon, Triaud, Demory, 2017). It was found that planets have low enough equilibrium temperatures to make possible the presence of liquid water on their surfaces. There is a habitable zone potentially favorable for life, as astrobiologists call it. Nevertheless, there are no moons. The reason is that the star's gravity is too powerful, thus no satellites and no stable orbits for them. This means that on these planets the climate would be very chaotic just like on Earth if there were no Moon.

Aspect 2. Historical dimension

Let us turn to the historical dimension of the issue of whether we are alone in the Universe. Here the Moon becomes a kind of starting point for scientists in reflection on the search for space brothers and on the flight to other worlds.

In general, the first detailed map of the Moon was made by the astronomer Francesco Grimaldi (1618-1663), Italian physicist and astronomer, together with

Jesuit intellectual Giovanni Riccioli (1598-1671). This map was published in the book "*Almagestum novum*" (1651) and contained the following statement: "*Nee Homines Lunam incolunt, Nee Animae in Lunam migrant*" [*Neither do humans inhabit the Moon, nor do spirits migrate there*] (Fig. 1.). This rerflects Riccioli's feeling that Holy Scripture did not support any dwellers on the Moon, whether of flesh or spirit (Montgomery, 1999).

FIGURE 1. First detailed Grimaldi/ Riccioli Moon map, in Riccioli's "*Almagestum novum*" (1651). From Linda Hall Library, https://www.lindahall.org/

Two centuries later a French novelist, poet, and playwright, Jules Verne, wrote the novel "*From the Earth to the Moon*" (1865) where he gave many naive but scientifically founded technical details of the flight to the Moon. In general, there is an opinion that this novel is a precursor of science fiction and Verne is often regarded, together with Herbert G. Wells, as one of the creators of the genre, "*fathers of science fiction*" (Grove, 2020).

Let us remind some historical records of how scientists of USSR paved the way to the Moon. Since it is a very long story, we would like to give one interesting example, the one of Yuri Kondratyuk (pseudonym of Alexander Shargei). He was a pioneer of domestic rocket engineering and made a significant contribution to the development of cosmonautics and rocket technologies (Maksimov, 2007). He became interested in interplanetary flights during his years in the classical school in Ukraine. Among his most known studies are the manuscript entitled "*To Those Who will Read in Order to Construct*" (written in 1918−1919 in Kiev) and the book "*Conquering of Interplanetary Space*" (1929) where several new approaches to spaceflight to the Moon and planets are proposed. First, as for ballistic coast: it is better to use atmospheric resistance to brake the rocket during descent in order to save fuel. Second, when flying to other planets, it is more appropriate to launch the ship into the orbit of an artificial satellite, and use a small takeoff and landing

module to land on them and return to the ship. Third, use the gravitational field of oncoming celestial bodies to accelerate or decelerate when flying in the Solar System (gravitational or perturbation maneuver).

In particular, the lunar route scheme with the orbiter and the ascending and descending ship called by this principle as LOR (Lunar-Orbit Rendezvous) was implemented 30 years later by the American agency NASA for a manned flight to the Moon. This flight route is now called the Mitchell-Hubolt scheme (Hansen, 1995), after American engineers who reanalyzed and improved it, working on the program "Apollo" (1969−1972).

Aspect 3. Moon as a kind of cosmic gate

To truly reach other worlds, to look beyond the horizon, one must somehow prove this achievement. It is necessary to reveal something that cannot be seen from Earth. The farside of the Moon has been the object reaching which symbolizes a breakthrough into outer space.

On the famous engraving from the book of the prominent French astronomer Camille Flammarion (1842 – 1925) there is such a picture with a traveler or a monk in it. This person is trying to look beyond the horizon, that is, he reached the place where the Earth meets the sky. Flammarion illustrates the attempt to study the structure of the Universe through this engraving.

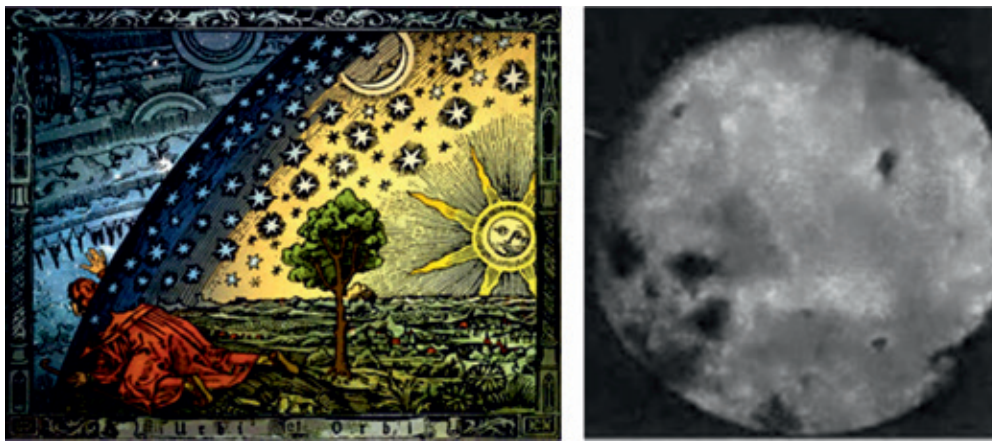

FIGURE 2. Left: The Flammarion engraving (from the book "*L'atmosphère : météorologie populaire*", 1888) Right: First image of the lunar farside (Soviet mission "Luna-3")

It was Flammarion who met a young Russian student, Nikolai Barabashov, and after a long conversation he gave him his book with the following dedication "*To my new colleague N. Barabashov from a fellow citizen of heaven. C. Flammarion*". Motivated by splendid wishes of the great astronomer, Barabashov became then a professional astronomer, just that man who was able to look beyond the horizon. Namely, he analyzed first images of the Moon acquired by "Luna" missions (Fig. 2) and in 1960 he became a co-author of the first Atlas of the far side of the Moon. Barabashov worked as a director of Kharkiv Astronomical Observatory for many years until his death in 1971.

Moreover, 100 years ago, in 1918, when Nikolai Barabashov was still a student, his scientific advisor Vasily Grigorovich Fesenkov, a well-known Soviet astrophysicist, asked him to study the reflectivity of the Earth as a planet. The only way to solve this problem (Earth albedo) was to study the so-called Earthshine on the Moon. To do this, it was necessary to know the reflective properties of the lunar surface. After studying for many years the reflectivity of the lunar surface, Barabashov proved that human landing on the Moon could be safe. In 1965, in the movie "The Moon" of the Soviet film director Pavel Klushantsev, Nikolai Barabashov argued in the interview:

– Apparently, the lunar surface is covered with something like small rubble from fragmented volcanic rocks. The astronaut will not stumble.

– Can he fall in case this rubble is too fragile?

– I suppose not. Images made by Americans using the Ranger-7 confirm my opinion.

Actually, Barabashov said these words in the Soviet movie 4 years before human landing on the Moon.

Aspect 4. From the Moon to exoplanets and SETI

Where has this interest in the Earthshine on the Moon taken modern astrophysics? The Earth became a reference point for the study of Earth-like planets now. The Moon is used in such a scheme as a kind of "mirror" of the Earth. The Earth - the planet Earth - is observed as if it were an exoplanet. The so-called biosignatures have been found on Earth by the method of such a space mirror. That is, in the atmosphere these are oxygen, ozone, methane and carbon dioxide – the evidences of life.

FIGURE 3. The 85-foot (26 m) Howard E. Tatel Radio Telescope at NRAO used in the project Ozma [https://upload.wikimedia.org/wikipedia/commons/a/ad/Howard_E._Tatel_Radio_Telescope_-_side.jpg]

This algorithm is sensitive to visible areas of vegetation and could be considered as a bench-mark for the diagnostics of the atmospheric composition, mean cloud height and surfaces of exoplanets (Sterzik, Bagnulo, Palle, 2012).

Let us pay our attention to extraterrestrial intelligence (SETI problem). It is worth recollecting one quotation: "*We believe that science has reached that point where it is necessary to take into account the action of intelligent beings, in addition to the action of the classical laws of physics*" (Struve, 1960). This was written by Otto Struve in 1960. This man, who was born in Kharkiv, graduated from Kharkiv University in 1919. During the Civil War in Russia, he emigrated to the United States and became one of the greatest astrophysicists of the 20th century. He is a representative of one of the most famous astronomical dynasties in the world. By the way, Otto Ludwigovich Struve is the son of Ludwig Ottowich Struve - Director of the Kharkiv Astronomical Observatory, Professor of Kharkiv University, Dean of the Faculty of Physics and Mathematics of the University.

Otto Struve made a huge constructive contribution to the practical creation of a powerful American astronomical instrumentation and developed the idea of using

spacecraft for astronomical observations. Being the first to use the achievements of radio electronics in astronomy, Struve had a huge impact on the development and formation of radio astronomy. Probably, the most important thing was that by the end of his days he was deeply convinced of the need to search for extraterrestrial intelligent life forms and in the existence of life in other stellar systems. Thus unexpectedly for many, in the 1960s he strongly supported the most ambitious project of the 20th century in connection with extraterrestrial civilizations, the so-called "Ozma" project by Frank Drake. With Struve's support, Drake built a 26-meter radio telescope based on the NRAO, the first measuring instrument in human history designed specifically to detect extraterrestrial life by looking for signals from other civilizations (Fig. 3). Drake's ideas about the possibility of extraterrestrial life were reinforced by a lecture from Otto Struve in 1951; hence Drake had a lifelong interest in extraterrestrial life and civilization (https://en.wikipedia.org/wiki/Frank_Drake). Thus, former Kharkiv citizen and student Otto Struve made a huge contribution in the problem of finding extraterrestrial civilizations.

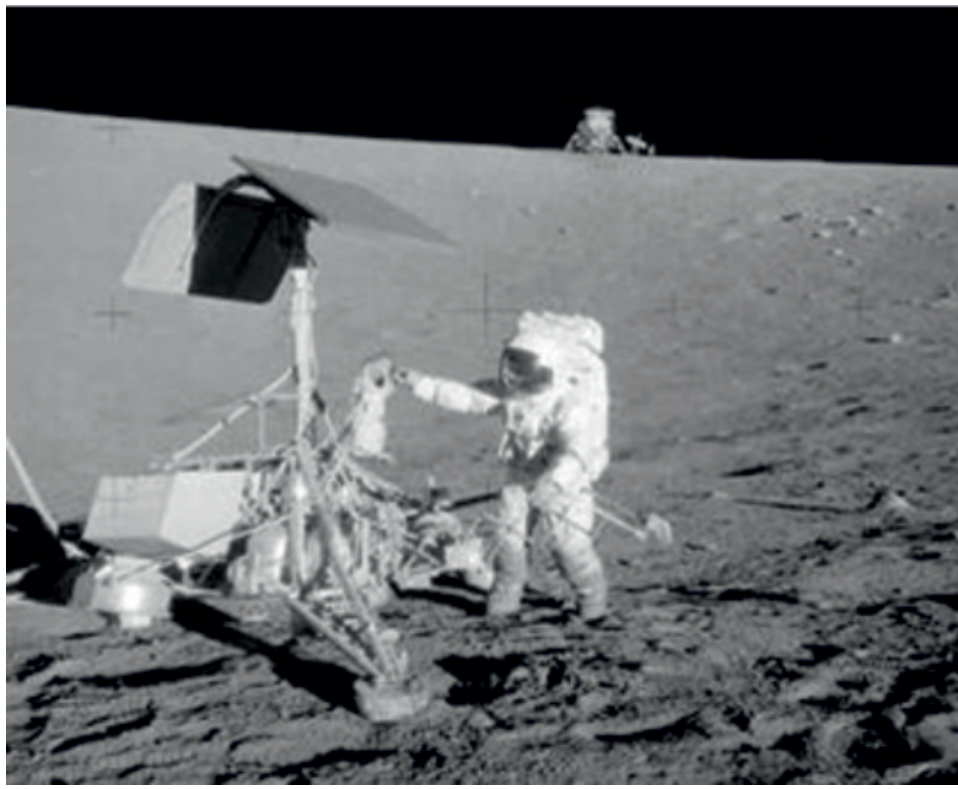

FIGURE 4. Astronaut Alan Bean inspects Surveyor 3

Aspect 5. Survival on the Moon

Recalling Francesco Grimaldi's words said in 1650 "*Neither humans inhabit the Moon, no spirits migrate there*", we should note at least two cases of bringing terrestrial life to the surface of the Moon.

First, this is the so-called "case of Apollo 12" in 1969. Astronauts from Apollo-12 spacecraft visited and inspected the landing site of Surveyor-3 lander (Fig. 4). An earth bacterium was found on a spaceship Surveyor-3 that spent two and a half years on the surface of the Moon. *Streptococcus mitis* was able to survive in conditions of huge temperature variations and space vacuum, which should not leave a chance for the survival of microorganisms. Such bacteria, about a micron in diameter, are often found in the human respiratory tract. It is striking that the bacteria managed to survive on the Moon for 31 months, being inside a leaky television camera. Similar microorganisms were found on the astronaut suits, in which they visited the lunar surface. The lunar soil itself is very inert in its effect on living organisms – it is neither a stimulant nor an inhibitor.

The second recent example is the Israeli mission Bereshit-1 (2019). Beresheet crashed into the Moon during a failed landing attempt. It carried human DNA samples, many terrestrial organisms, so-called Tardigrades or water bears (Fig. 5), locked in

FIGURE 5: Tardigrade (water bear), about 0.5 mm long when fully grown

a kind of environment, and 30 million very small digitized pages of information about human society and culture. It is unknown if the water bears survived the explosive impact when Beresheet crashed, but it is known that they received the title of the most enduring animals on Earth. At the International space station tardigradum survived during a 10-day stay without protection in outer space. Water bears are able to withstand prolonged drying (several years): dried ones can withstand temperatures from -271 ° C to +150 ° C for a short time. They tolerate radiation a thousand times higher than humans (570,000 Röntgen). Also they can stay in a state of anabiosis quite a long time – 120 years. Thus, we cannot rule out the surviving of Tardigrades on the Moon. In general, this problem leads to the issue of bacteriological contamination of extraterrestrial worlds and reverse pollution of the Earth.

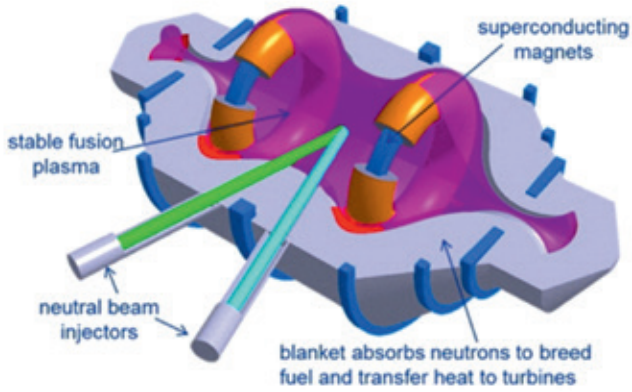

FIGURE 6. Skunk Works fusion reactor (by Lockheed Martin). A diagram showing the basic reactor configuration (https://www.lockheedmartin.com/en-us/products/compact-fusion.html)

Aspect 6. Energy supply of mankind

When thinking about future exploration of space and living in space, we need to solve the problem of energy supply for extraterrestrial bridgeheads of mankind.

Do we have the resources in the future to create lunar bases? This question should be addressed to thermonuclear power engineering which should use the helium isotope, the so-called Helium-3. A reactor small enough to fit on a truck could provide enough power for a small city of up to 100,000 people (Fig. 6). This will give almost infinite amount of energy in the future; but there is a very small amount of this isotope on Earth. On the Earth, helium is basically abundant in the form of ^{4}He. In contrast, the lunar soil has an essential content of the ^{3}He isotope in addition

to ^{4}He (Taylor, 1994). The source of ^{3}He is the solar wind irradiating the Moon's surface for billions of years. Solar-wind helium is implanted into the near-surface layers (few hundreds angstroms thick) of regolith particles and partially stored there. The highest concentration of 3He and its highest amount per 1 m^2 of the regolith layer (~150 mg/m^2) are predicted for some lunar maria. A store of ^{3}He in a 3-m-thick regolith layer of an area of 1.5 km^2 can keep a 500-MW power station working for a year (Taylor, 1994). This will power the lunar bases for many years.

Conclusion. Why does humanity need the Moon?

In conclusion, we will just list a few points, trying to answer to the question: Why does humanity need the Moon now?

1. First of all, the surface of the Moon carries information about events that took place hundreds of millions and even billions of years ago. This is the so-called archive of the Solar System.
2. Scientific and industrial bases must be built on the Moon because we have almost a vacuum ambient, low gravity, and the presence of natural minerals there.
3. Certain energy problems can be solved, as we noted, such as solar energy and thermonuclear fuel, helium isotope.
4. Unfortunately, we must not forget about military use because there are several centers of power on Earth that are trying to take over the space now.
5. Finally yet importantly, the Moon must be an outpost for further development of the Solar system and the search for our space brothers.

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