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Potential signs of life on Europa

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Abstract. This paper discusses the possibility of life on Europa, the moon of Jupiter by analyzing the biological components, energy source, and ocean environment on Europa. The biological components, especially amino acids, have great possibilities of forming or have already existed on Europa since its compositive elements are present and the environment on Europa is very similar to the primitive Earth. Energy sources are expected to come from the hydrothermal vents at the ocean bottom, which are formed by tidal forces and tidal heating. The hydrothermal vents are rich in chemicals and elements and have the possibility of forming lives in the future. The ocean environment is thought to be rich in oxygen, which comes from the planet Jupiter, it is first reflected on the surface of Europa, but later on, transported to the ocean through the ice layer and a lake in between. Furthermore, the freezing point of the ocean might be affected by the fact that it contains salt, but not by the fact that it has very low air pressure. To conclude, there is a great possibility that lives exist on Europa, but it cannot be 100% positive since no specific experiments have been done throughout the research, and there are so many uncertainties in space that have not been discovered yet.

Keywords: Europa, amino acids, hydrothermal vents, hidden ocean.

1. Introduction

Europa, as shown in Figure 1, is known as the moon of Jupiter, which is considered one of the moons with the greatest possibilities of life's existence. It is composed of a cold surface ice layer, a salty ocean, a rocky mantle, and an iron core. Lives started forming on Earth many years ago, it was a complex process with the need for energy sources, water, and biogenic elements. For lives to exist on Europa, similar ingredients would highly possibly be needed. This essay will be evaluating and summarising the possibility of life on Europa through the analysis of its similarity with the environment of primitive Earth on the aspects of biological elements and compounds, energy sources, and ocean environment.

Ref. [1] shows that Europa has an ocean, which is mostly composed of water ice. This has been proved by the results of magnetic field detection. It is said the field was detected, and the ocean layer below the surface is the most probable conducting layer since water is polar. It also states that all living organisms require energy sources, water, and organic compounds. According to Ref. [2], the characteristic of Europa ocean is very similar to Earth's ocean. This characteristic is very supportive for the possibility that Europa might have aquatic life existing. This essay will further focus on Europa biological components, energy source, and ocean environment.

For the first point, Ref. [3] stated an original 'origin of life' experiment which proves that amino acid, the basic structure of a protein, was introduced in Ref. [4] could be produced by the interactions between

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inorganic elements, the presence of these elements is shown in Ref. [5, 6] through a method called near-infrared mapping spectrometer. This experiment was also mentioned in the paper to state the primitive hypothetical environment on Earth. The environment was later redressed with a different set of elements in Ref. [7, 8] which helped with further detailed explorations. For examining the actual circumstance on Europa, Ref. [9] mentioned a method called capillary electrophoresis, which can detect the presence of amino acids by collecting Europa ocean samples.

For the second point, Ref. [10, 11] states that sunlight is not the only energy source for organisms, hydrothermal vents may exist to support the existence of lives, because of the tidal force and tidal heating mentioned in Ref. [12-14]. It can provide both heat and nutrients.

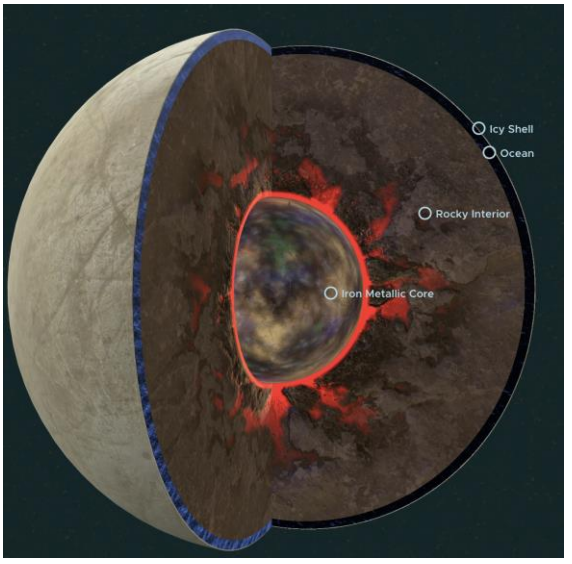

Figure 1. Structure of Europa [13].

For the third aspect, Ref. [15, 16] has mentioned that life can exist and produce offspring at a temperature range from -15 to 122 degrees Celsius. Europa has a temperature range from about -160 to -220 degrees Celsius, which is making the possibility of life doubtful on the surface of Europa. However, inside the hidden ocean, the water might exist in different temperature ranges due to the possible presence of the hydrothermal vents, as well as the state of water in different environments. There might be lives that can survive in such environments which will be mentioned in the passage according to Ref. [17-19]. Ref. [20] shows that there is oxygen on the surface of Europa, and is transported through a lake in between the ice surface and the hidden ocean. Also, it is mentioned in Ref. [21, 22], the higher the pressure, the lower the freezing point, and the air pressure on Europa is very low, so the freezing point of the ocean might not be affected by this, but it might be affected by the salt component in the ocean.

2. Methods

2.1. Biological elements and compounds – amino acids

All living organisms are composed of organic compounds and require different types of organic elements to survive and perform life functions. Certain elements contributed to the existence of primitive lives on Earth. If these elements exist on Europa as well, living organisms might exist or be formed.

Amino acids are organic compounds that are required by all organisms [23]. Amino acids can be built up into longer chains into proteins, their sequences can determine the functions that the proteins perform. If amino acids are discovered on Europa, they can be a part of the evidence of the existence of life. A possible method is a capillary electrophoresis. This method can easily detect liquid samples like the ocean which do exist on Europa. The process includes combining the ocean sample with a reagent, then using the laser-induced fluorescence detection method to observe molecules with different moving

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speeds. Different molecules would separate away at different speeds. This method can detect many amino acids at the same time, with very low concentrations. This method is very suitable for finding amino acids on Europa, since Europa has a great portion of seawater. When samples are taken from Europa, the result will be easier to find [9].

Since there are no specific results of the experiment mentioned above, a simple analysis can be made. Amino acids have a great possibility to be found on Europa. NASA's Galileo spacecraft used a piece of equipment named a near-infrared mapping spectrometer and discovered molecules that are composed of elements like oxygen, carbon, sulfur, hydrogen, and nitrogen [5]. Oxygen, carbon, hydrogen, and nitrogen happen to be the basic elements of all amino acids [24], and these are as well the elements that existed on primitive Earth, this creates the possibility for these elements to form into amino acids. (A near-infrared mapping spectrometer is an equipment that can be used to detect the environment, chemical and biological components, structure of planets and satellites by measuring the near-infrared light [6].)

Although these basic elements are proven to be existing on Europa, it does not show their possibility of interacting with each other. Fortunately, during the original 'origin of life' experiment performed in the 1950s by Stanley L. Miller and Harold C. Urey, amino acids were produced. The environment they simulated contains methane, ammonia, hydrogen, and water vapor, to make the experiment more precise, the scientists used electricity to simulate lightning. When these elements interact together, amino acids were yielded [3]. Then it was later found that the atmosphere of primitive Earth mainly consist of carbon dioxide and nitrogen, and with a more precise mixture of 'atmosphere', chemists found out that very few amino acids were yielded [7], but both of these two experiments showed that organic compounds, like amino acids, can be composed of inorganic elements through interactions.

2.2. Energy source – hydrothermal vents

Energy sources are needed by organisms to perform life functions and activities [23], such as photosynthesis by the energy source of sunlight. Sunlight is known as the energy source of most living organisms. However, right above the ocean of Europa, there is a thick layer of ice shell, which the sunlight is not able to pass through. Fortunately, it was thought that hydrothermal vents have a high possibility of existing under the ocean in the dark [1]. Hydrothermal vents are formed when the temperature of the subsurface of the ocean increases under the effect of magma in the ground, then rises back to the seafloor and spread to the surroundings. The water vented through have great amounts of chemical, which the chemosynthesis microorganisms can use to convert into energy. This is the fundamental resource that can support the whole ecosystem around it. This was first discovered on Earth, which can support the fact that lives can live without sunlight, creating more possibilities for the existence of lives on Europa [10]. It is also thought to be where life on Earth first started since it is rich in organic elements and compounds.

Hydrothermal vents are thought to be existing because of the way it rotates around Jupiter and the changing gravitational energy. Europa's orbit is elliptical (eccentricity = 0.01), which means its tidal force keeps changing. According to the gravitational force formula:

$$F = \frac{GMm}{r^2} \tag{1}$$

which is a formula about the attraction forces between objects in the universe [25] (F – gravitational force, G - gravitational constant, M – mass of Jupiter, m – the mass of Europa, r – the distance between Jupiter and Europa) the further the distance between Jupiter and Europa, the smaller the gravitation force. When Europa rotates closer to Jupiter on the elliptical orbit, it experiences greater forces. This is called a tidal force, as shown in Figure 2, representing the changing gravitational force. Also, when Europa rotates, the side closer to the planet experiences greater attraction than the side further away from it.

$$F = \frac{GMm}{(r+d)^2} \tag{2}$$

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(F – gravitational force, G - gravitational constant 6.67*10^-11, M – the mass of Jupiter, m – the mass of Europa, r – the distance between Jupiter and Europa, d - the diameter of Europa), the whole equation represents the gravitational force of the further side of the moon by adding the extra diameter of the moon. When Europa experiences different gravitational forces on its different sides at different positions constantly, the continuous stretches and releases cause tidal heating due to its internal friction, which can induce hydrothermal or volcanic vents [12-14].

Figure 2. Tidal force and tidal heating [26].

It is believed by many biologists that hydrothermal vents are possibly existing in the ocean of Europa. Since hydrothermal vents have many organic chemical molecules, they can build up together to form more complex compounds and longer chains which can lead to the basic structures of life like proteins or DNA, that can further develop into more complex organisms and eventually form a complete ecosystem.

2.3. ocean environment

Water takes a large portion of the Earth, mostly seawater, it is also considered to be where life possibly started, which is stated in the previous part of the paper, the hydrothermal vents. Water is a symbolic characteristic and existence on Europa, this has been proved by the results of magnetic field detection. It is said the field was detected, and the ocean layer is the most probable conducting layer [1] since water is polar.

Temperature: temperature is another key determinant of life's existence. When the environmental temperatures are too extreme, organisms would not be able to perform regular life functions. Ref. [15] mentions that most lives can exist and perform further reproduction processes at a temperature from -15 to 122 degrees Celsius. However, Europa's surface has a temperature range from about -160 to -220 degree Celsius, which is an extreme temperature range and is making the possibility of life very doubtful.

However, the temperature range is only restricted to the surface of Europa. Since there are salty oceans under its surface, the temperature would not be too extreme since it is in the form of liquid. On Earth, even though it is extremely cold sometimes on the surface and the ocean or lakes freeze into ice, the bottom layer of the ocean or lake under ice does not freeze, this is because water has the greatest density at a temperature of 4 degree Celsius, so it does not raise to the surface to freeze, instead, it stays around 4 degree Celsius for aquatic lives to survive. The logic might be the same for Europa since there is a thick layer of ice above the hidden ocean. Also, hydrothermal vents rise the temperature of the water around them as tidal forces are formed. On Earth, it can heat up to around 400 degrees Celsius, so the temperature might be suitable at the bottom of the ocean of Europa for life to survive.

The hidden ocean of Europa might be below 0 degrees Celsius since it is saltwater, and saltwater usually has a lower freezing point around -1.8 degrees Celsius [27]. Also, seawater has different states due to different environmental factors such as pressures, water components, and density of water. The freezing point decreases as the air pressure increases. The air pressure on the surface of Europa is a lot

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less than on Earth, which is around 0.1 micro pascals. Therefore the freezing point might not be very low [21, 22].

There are certain factors that this paper is not considering, if so, the ocean environment might be very extreme. Fortunately, life exceptions do exist. Some organisms can adapt to very extreme environments, for example, Tardigrades. They can survive in an extremely wide range of temperatures, down to 272.15 degree Celsius and up to 150 degrees Celsius [17].They can survive and develop in varieties of environments like forests, sand, and ocean. This proves that they have very strong adaptability and that they have the possibility of developing life in Europa's ocean in extreme environments [18].

Oxygen in the ocean of Europa is also thought to be able to support lives. The oxygen on the surface of Europa comes from Jupiter with sunlight and different particles. However, there is a thick layer of ice above the ocean, so how does the oxygen penetrate through the ice? The ocean is thought to be 15-25km under the ice layer, but there is a lake existing 3km beneath the ice. The lake act as a transportation tool that can help the oxygen to be transported from the surface of the moon to the deep ocean. The lake which is rich in oxygen is transported to the ocean through porosity waves. This is the process of widening the pores of ice, which allows the lake to pass through, and then close up the pores. This is a long process that happens continuously so that oxygen can be transported into the ocean constantly. It is been studied that 86% of the oxygen from Jutitar which is reflected on Europa is transported to the deep sea [20].

3. Results

For amino acidsamino acid, all elements required for the formation of amino acids are present. Also, due to the previous research scientists have done on the formation of life on the previous Earth, it is shown that lives can be formed with inorganic compounds and elements. There are also methods designed nowadays to detect the presence of amino acids on Europa. For the energy sourcenergy source, hydrothermal vents can be formed inside the ocean of Europa due to tidal forces and tidal heating, shown by the formula:

$$F = \frac{GMm}{r^2} \tag{3}$$

which can provide heat and energy under the ocean. For the ocean of Europa, it is rich in oxygen and have a relatively suitable temperature for life to exist, it might be below 0 degree Celsius due to the presence of the salty ocean, but the air pressure is low which does not straightly cause the decrease of the freezing point of water. If there are factors not being considered, species such as Tardigrades have great adaptability to an extreme environment.

4. Discussion

With all the research and evidence shown and analyzed above, lives are highly possible to have existed or will exist on Europa, especially inside its hidden ocean. However, this is not 100% positive. No specific decisive experiments have been done and there is not yet a specific conclusion. Other possibilities might exist as well. For example, energy and organic compounds are not the basic needs of lives outside of Earth, they have different requirements. There is an endless number of things that might be out of expectations, there are different dimensions and only a very small fragment of it have been explored.

5. Conclusion

After analyzing the results, there is a great possibility that lives have already existed, or will form on Europa since amino acids are highly possible to be exiting on Europa, there are energies provided by the hydrothermal vents and the temperature of the ocean might be suitable for lives. The essential purpose of the research is to provide a clearer vision of the potential of lives and spread overall knowledge. It will be a huge breakthrough if there are complex lives discovered, and it creates the possibility for

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migrations of the human society, also increases the chances for us to communicate with the outer civilizations. Last but not least, further research and experiments will certainly be needed, such as the actual discovery of amino acids of Europa, the movement of the hydrothermal vents, temperature of the hidden ocean, or sending lives there to take the first step of an extraordinary breakthrough.

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