Current Understanding of Europa and Potential in Upcoming Exploration

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SUMMARY

Europa, one of Jupiter's moons, has been an object of interest to many scientists, including astrobiologists, for some time. In particular, Europa has drawn interest due to evidence suggesting the presence of a subsurface liquid water ocean, which could potentially support life. Only recently, however, has concrete planning begun for exploration of this celestial body. These missions are described, followed by an overview of selected areas of research on Europa relevant to astrobiologists, along with discussion of planned investigations for upcoming missions to explore Europa. Finally, based on these potential benefits to scientific knowledge, it is argued that exploration of icy moons such as Europa should remain a priority as they provide opportunities for the study of astrobiology that cannot be offered by the current focus of most study, Mars.

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Europa (Figure 1) is Jupiter's sixth-closest moon and was first discovered by Galileo Galilei in 1610. Visually, Europa is characterized as a smooth-looking satellite devoid of large-scale features such as craters and mountains, but covered with many reddish streaks known as lineae (Alexander, et al., 2009).

By the late 1900s, mounting evidence suggested that various surface features of Europa were the result of activity of its water-ice crust, similar to plate tectonic activity on Earth.

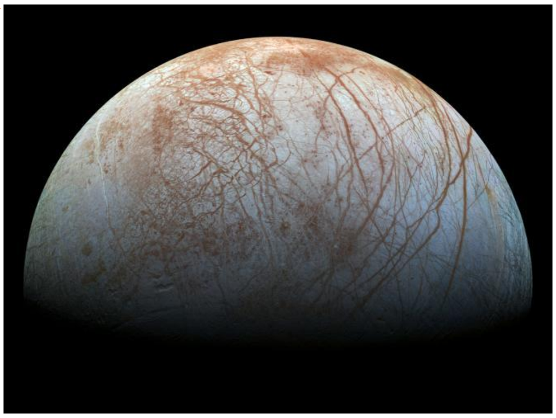

Figure 1: Europa, a moon of Jupiter, is known for its icy surface with reddish streaks known as lineae; this enhanced colour image was taken by NASA's Galileo mission (NASA, JPL-Caltech, SETI Institute, 2014).

Furthermore, this ice crust activity pointed to the presence of a layer of liquid water beneath the surface (Alexander, et al., 2009), drawing interest since liquid water is required for Earth-like life. With these advances occurring concurrently with the growth of astrobiology as a scientific discipline (see for example the overview in Lai, 2015), the potential for life in such an environment quickly caught the attention of astrobiologists.

Despite various proposed missions throughout the years, no concrete plans for a mission to Europa have been produced until recently. In light of these upcoming missions, an overview of currently planned missions will be given, followed by a summary of several topics of relevance to the astrobiological study of Europa, along with potential for scientific advancement with the upcoming missions. Finally, based on these benefits, it is argued that icy moon exploration should continue alongside exploration of Mars, since each environment provides very different scientific opportunities.

UPCOMING MISSIONS

One proposed missions to Europa is the European Space Agency's Jupiter Icy Moons Explorer. This mission would arrive in the Jovian system around 2030 and perform two flybys of Europa en route to studying Jupiter's moon Ganymede in greater depth (Grasset, et al., 2013).

The National Aeronautics and Space Administration (NASA) also has a planned mission to Europa: the Europa Multiple-Flyby Mission. This mission would arrive in the 2020s and conduct 45 flybys of Europa (NASA, 2016).

CURRENT UNDERSTANDING OF EUROPA

ICE CRUST THICKNESS

The thickness of Europa's ice crust remains a subject of debate. Estimates have ranged from a few hundred meters to several tens of kilometers (Hoolst, et al., 2008). Attempts to estimate the thickness of the ice crust have approached the problem by attempting to model various Europan phenomena, including tidal dissipation and surface features such as cycloid cracks and craters.

Tidal dissipation methods take into account the heat lost by Europa's crust and the heat generated by tidal forces on Europa due to Jupiter. Hussmann, Spohn, and Wieczerkowski (2002) used to method to calculate an ice crust layer that is a few tens of kilometers in thickness. More recently, Quick and Marsh (2015) used this method to estimate a thickness of 28 km.

The presence of cycloid cracks, which form pairs of ridges, has also been used as a method for estimating the thickness of Europa's crust. It has been suggested that in order for these features to form, Europa's crust thickness must be sufficiently thin that the cracks can reach a layer of liquid water. Based on calculations by made by Hoppa, et al. (1999), this means that the ice thickness must not exceed a few kilometers at most.

Crater depth methods make use of measurements of crater features on Europa's surface and attempt to model these to determine what crustal thickness would be consistent with the observed craters. Studies using this method have produced mixed results, but generally agree that the crustal thickness exceeds 4 km. In the work of Bray, et al. (2014), which uses this technique along with a hydrocode simulation, Europa's crustal thickness is estimated to be 7 km.

Given the variation in calculated ice thickness using different methods, it is evident that an upcoming mission could provide valuable direct measurements of the ice thickness. Both planned missions incorporate ice-penetrating radar as part of their instrument packages. Heggy, et al., (2017) predict that it should be possible to examine shallow subsurface features such as cracks with radar specifications like those proposed for these missions. Furthermore, with a possible penetration depth ranging from 1 to 18 km, it may be possible to characterize the deep ocean, and thus, the ice thickness.

PRESENCE OF SUBSURFACE OCEAN

Beneath the icy crust, it is proposed that Europa's subsurface contains a body of liquid water, which could potentially harbour life. The heat required to keep water in a liquid state in such conditions is proposed to be produced by tidal forces acting on Europa from Jupiter, along with other sources such as radioactive decay occurring at the putative seafloor (Melosh, et al., 2004). The composition of such an ocean is a topic of interest to researchers, with implications for both physical features observed on the surface, and for the conditions within which any potential organisms on Europa would exist (Marion, et al., 2004; Thomas, et al., 2017). With the upcoming missions, the characteristics of this ocean could be further elucidated. Such study can be done with instruments such as magnetometers, which could allow characterization of the ocean's salinity and depth (Raymond, et al., 2015; Lunine, 2017).

PLUMES AND POTENTIAL SAMPLING

While the presence of plumes that might vent the contents of the subsurface had been previously proposed, it was not until 2014 that evidence of their existence was found, in the form of UV emission detected by the Hubble Space Telescope (Roth, et al., 2014).

Sampling these plumes could allow direct study of a putative subsurface ocean; even more intriguingly, such a sample could contain biomolecules, or even lifeforms. However, the potential for finding lifeforms is quite low. Lorenz (2016) created a simple model of such a situation, assuming sampling from a 2 km altitude, a supposed lower limit of feasibility. Based on this model, it would only be possible to detect a few hundred cells if Europa's waters were analogous to Earth's most life-rich waters; on the other hand, if Europa's waters were more like those of Lake Vostok, which is proposed to be a better analogue of Europan conditions, fewer than one cell would be statistically likely to be detected.

Upcoming missions have within their scope of interest the study of these plumes. These missions will characterize plumes with ultraviolet spectrometry; furthermore, any plume material that may be encountered could be examined using mass spectrometry (Lunine, 2017).

DISCUSSION AND CONCLUSION

Europa provides many exciting opportunities to further the understanding of life in the Universe. In particular, Europa's potential subsurface liquid water ocean could be a habitat for life, or provide clues as to conditions required for life to arise. Such an environment is not present on the target of greatest current astrobiological study: Mars. While evidence now suggests that Mars possessed liquid water oceans in the past (De Blasio, 2014, and references within), and may currently have some subsurface water ice that may melt (Stillman, Michaels, and Grimm, 2017), these conditions are very different from the water-rich environment that present-day Europa is theorized to possess.

In addition to providing an environment that might be more likely to currently harbour life than Mars, Europa, along with other icy moons such as Ganymede and Enceladus, also provides unique opportunities to study processes that are not present on Mars, but could affect the development of life, both here and elsewhere in the universe. Understanding of tidally-heated oceans and water ice crust dynamics could prove useful when applied to extrasolar systems, and the development of technologies required to detect biomolecules and signs of life could also further astrobiological research. Ultimately, exploration of icy moons like Europa should continue alongside the exploration of current targets like Mars, in order to broaden the perspectives available to astrobiologists in understanding the origins and distribution of life in the Universe.

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