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Comprehensive analysis of Icy Moons' oceans searching for traces of life

State of the art: When searching for life in the Universe we always look for water. The presence of water is one of the necessary conditions for life to emerge and persist[1]. This simple molecule is in fact important in so many ways. The main biochemical reactions need water to make up the building blocks of life; it is the "universal solvent" that permits cells transport and use substances like oxygen and nutrients; and it fills cells to support cellular structure once formed. That is why ocean worlds of the Solar System and beyond are extremely important for astrobiological purposes [2,3]. When we are talking about ocean worlds, we refer to planets or natural satellites that host oceans on or below the surface. Earth itself is an ocean world but not the only one. Our Solar System hosts several of them that are mainly moons of the gaseous giants Jupiter and Saturn, i.e., Europa [4], Ganymede, and Callisto, and Enceladus[5], Titan and Mimas but also Neptune's moon Triton and the dwarf planet Pluto. All of them are not in the well-known habitable zone, the zone of a planetary system where it is possible to have liquid water on the surface of a body. However, several, energetic and thus heat conditions permit these objects to possess potential subsurface oceans that could host necessary conditions for life to emerge and persist. Having such worlds directly accessible by space missions makes them even more intriguing because this let us owe remote sensing data of their surface that can give us direct constraints of their liquid reservoirs. In addition, in many cases, these worlds appear to be active with plumes activity that connects the ocean to the surface making remote sensing data even more interesting. This activity seems to show up also on their ocean floor making it possible to find hydrothermal systems that are thought to be home of primordial life. Thus, ocean worlds of the Solar System are nowadays a main topic in astrophysics and astrobiology.

Objectives: With this PhD project I purpose to investigate the ocean worlds of Europa and Enceladus with different tools to achieve a comprehensive description of their geophysical properties. In particular, the main topics of this purpose are the following:

- **Geophysics**: Several geophysical processes will be extended from Earth to other worlds. For example, determining possible subsurface ocean currents' paths [6] can help us find places of interest on the surface of ocean worlds like surface-subsurface connection regions; while plume eruptions models can help us find where ocean material falls back on the surface. During my PhD I would like to improve geophysical models of icy moons with an ocean below the surface, focusing their interior and plume eruptions. This can help determine astrobiological constraints for possible life forms survivability and their paths through the ocean and up towards the surface.
- **Remote sensing**: Geophysical investigation will help in selecting sites of interest for remote sensing analyses to verify what is predicted by models and search for astrobiological

signatures. In particular, data acquired by spacecrafts (like NASA's Galileo and NASA/ESA/ASI's Cassini) will be used to characterize the surface features and their properties. Visual images will be used to produce geological maps through software such as QGIS with the aim of identifying surface units of interest linked to the ocean underneath. Hyperspectral images will be used to produce spectral maps of moons' surfaces to identify the spectroscopic features related to molecular compounds and in particular to detect the presence of organics [7].

References:

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