Habitability potential of icy moons around giant planets and the JUICE mission

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1. Introduction

When looking for habitable conditions in the solar system, recent studies focus on the natural satellites of gas giants, rather than the terrestrial planets only. Indeed, the habitable zone may be larger than defined by the traditional concept where liquid water exists on the surface of a planet or a natural satellite. The strong gravitational pull caused by the giant planets may produce enough energy to sufficiently heat the interiors of orbiting icy moons. And several satellites show evidence for harboring organic chemistry in their atmospheres or exospheres. The outer solar system satellites then provide a conceptual basis within which new theories for understanding habitability can be constructed. Measurements from the ground but also by the Voyager, Galileo and the Cassini spacecraft revealed the potential of these satellites in this context, and our understanding of habitability in the solar system and beyond can be greatly enhanced by investigating several of these bodies together [1].

2. Habitats in the jovian system

Indeed, several of the moons show promising conditions for habitability and the development and/or maintenance of life. Europa, Callisto and Ganymede may be hiding, under their icy crust, putative undersurface liquid water oceans [2] which, in the case of Europa [3], may be in direct contact with a silicate mantle floor and kept warm by tidally generated heat [4].

Such potential habitats can only be investigated with appropriate designed space missions, like ESA's L1 JUICE (JUpiter ICy moon Explorer) for Ganymede and Europa [5] and NASA's Europa Clipper mission.

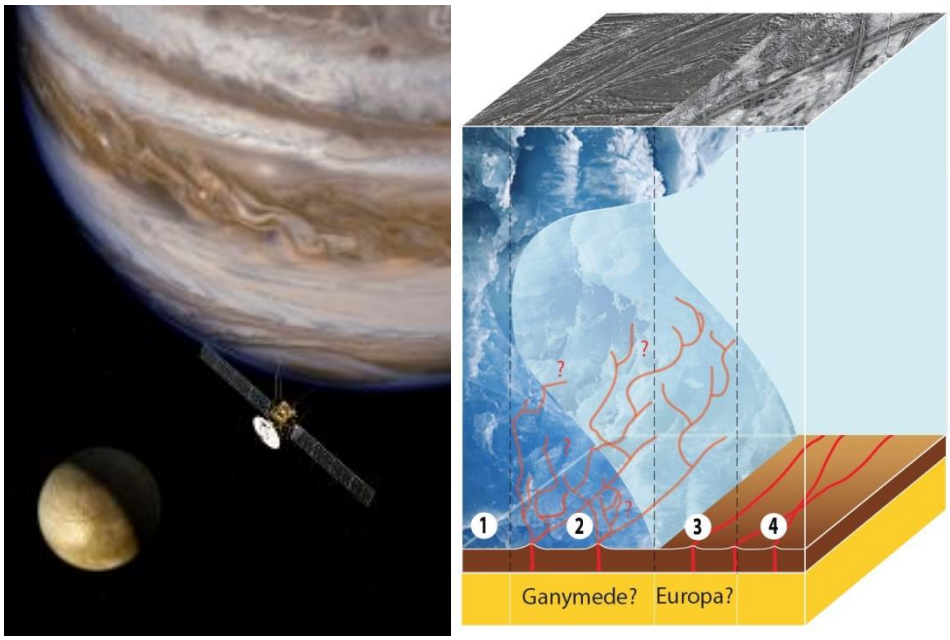

Figure 1: The JUICE mission is the first large mission within ESA's Cosmic Vision Programme. It will launch in 2022 aiming to study the emergence of habitable moons around Jupiter, with emphasis on Ganymede, but also Europa and Callisto, and the Jovian system [5].

3. Habitats in the kronian system

Titan and Enceladus, Saturn's satellites, were found by the Cassini-Huygens mission to possess active organic chemistries with seasonal variations [6], unique geological features and possibly internal liquid water oceans. Titan's rigid crust and the probable existence of a subsurface ocean create an analogy with terrestrial-type plate tectonics, at least surficial [7], while Enceladus' plumes find an analogue in geysers. As revealed by Cassini the liquid hydrocarbon lakes [8] distributed mainly at polar latitudes on Titan are ideal isolated environments to look for biomarkers.

Titan has been suggested to be a possible cryovolcanic world due to the presence of local complex volcanic-like geomorphology and the indications of surface albedo changes with time [9,10]. Such dynamic activity that would most probably include tidal heating, possible internal convection, and ice tectonics, is believed to be a pre-requisite of a habitable planetary body as it allows the recycling of minerals and potential nutrients and provides localized energy sources. In a recent study by [4], we have shown that tidal forces are a constant and significant source of internal deformation on Titan and the interior liquid water ocean can be relatively warm for reasonable amounts of ammonia concentrations, thus completing the set of parameters needed for a truly habitable planetary body.

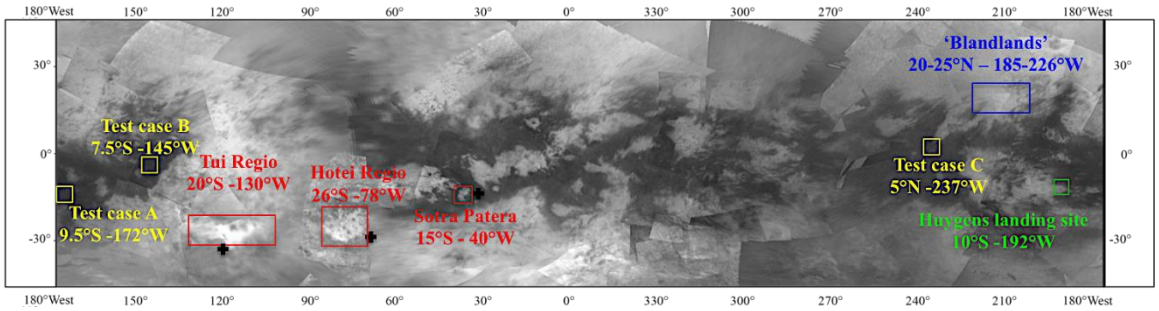

Figure 2: Map of Titan's surface showing possible active regions [10].

4. Conclusions

If the silicate mantles of Europa and Ganymede and the liquid sources of Titan and Enceladus are geologically active as on Earth, giving rise to the equivalent of hydrothermal systems, the simultaneous presence of water, geodynamic interactions, chemical energy sources and a diversity of key chemical elements may fulfil the basic conditions for habitability.

5. References

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Short Summary

Several of the icy moons in the outer solar solar present conditions which may be favorable for habitability, like the presence of liquid water underneath the surfaces, organic chemistry and energy sources. Future space missions will investigate that potential.