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HABITABLE ENVIRONMENTS IN THE SOLAR SYSTEM AND THEIR FUTURE EXPLORATION

Abstract

Mars, has been and is still currently under extensive exploration (with Mars Express, ExoMars, Al-Hamal and various rover missions on the surface like Mars2020/Perseverance and Tianwen-1 since 2021), because the planet is very close to the habitable zone, where Earth is positioned in the center and suspected to have harbored liquid water in the past on its surface [1]. However, habitable conditions are now found in the outer solar system in the natural satellites of the giant planets whose strong gravitational pull may produce enough energy to sufficiently heat the interiors of orbiting icy moons. The outer solar system satellites then provide a conceptual basis within which new theories for understanding habitability can be constructed. Measurements from the ground and by Voyager, Galileo and Cassini 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 [2,3]. 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 which, for Europa [3], may be in direct contact with a silicate mantle floor and kept warm by tidally generated heat [4,5]. Titan, Enceladus and Mimas, Saturn's satellites, were found by the Cassini-Huygens mission to possess active organic chemistries with seasonal variations [5], unique geological features and possibly internal liquid water oceans [3,6]. 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 fulfill the basic conditions for habitability. In the solar system's neighborhood, 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 [4], NASA's Europa Clipper mission [5] and Dragonfly [6]. Such investigations take place under COSPAR's planetary protection requirements.

References:
Olsson-Francis et al. (2023), LSSR 36, 27. [2] Coustenis Encrenaz (2013), in "Life Beyond Earth", Cambridge Univ. Press. [3] Hand et al. (2020), SSR 216, 95. [4] Coustenis et al. (2021) The Bridge 51, 41. [5] Pappalardo et al. (1999), JGR 104, 24015. [6] Barnes et al. (2021), PSJ 2, 130.