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Habitability potential of icy moons: a comparative study

Anezina Solomonidou (1,2), Athena Coustenis (1), Thérèse Encrenaz (1), Frank Sohl (3), Hauke Hussmann (3), Georgios Bampasidis (1,4), Frank Wagner (3), François Raulin (5), Dirk Schulze-Makuch (6), and Rosaly Lopes (7)

(1) LESIA - Observatoire de Paris, CNRS, UPMC Univ. Paris 06, Univ. Paris-Diderot – Meudon, 92195 Meudon Cedex, France, (2) University of Athens, Department of Geology and Geoenvironment, Athens, Greece, (3) Institute of Planetary Research, DLR, Rutherfordstrasse 2, D-12489 Berlin, Germany, (4) University of Athens, Department of Physics, Athens, Greece, (5) LISA-IPSL, CNRS/UPEC & Univ. Paris Diderot, Créteil, France, (6) Washington State University, School of Earth and Environmental Sciences, Washington, USA, (7) Jet Propulsion Laboratory, Pasadena, California, USA

Looking for habitable conditions in the outer solar system our research focuses on the natural satellites rather than the planets themselves. Indeed, the habitable zone as traditionally defined may be larger than originally con-ceived. The strong gravitational pull caused by the giant planets 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 but also by the Voyager, Galileo and the Cassini spacecrafts 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]. Their environments seem to satisfy many of the “classical” criteria for habitability (liquid water, energy sources to sustain metabolism and chemical compounds that can be used as nutrients over a period of time long enough to allow the development of life). Indeed, several of the moons show promising conditions for habitability and the de-velopment and/or maintenance of life. Europa, Callisto and Ganymede may be hiding, under their icy crust, putative undersurface liquid water oceans [3] which, in the case of Europa [2], may be in direct contact with a silicate mantle floor and kept warm by tidally generated heat [4]. Titan and Enceladus, Saturn’s satellites, were found by the Cassini-Huygens mission to possess active organic chemistries with seasonal variations, 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 [5], while Enceladus’ plumes find an analogue in gey-sers. As revealed by Cassini the liquid hydrocarbon lakes [6] distributed mainly at polar latitudes on Titan are ideal isolated environments to look for biomarkers. Currently, for Titan and Enceladus, geophysical models try to explain the possible existence of an oceanic layer that decouples the mantle from the icy crust. If the silicate mantles of Eu-ropa 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 en-ergy sources and a diversity of key chemical elements may fulfill the basic conditions for habitability. Titan has been suggested to be a possible cryovolcanic world due to the presence of local complex volcanic-like geomorphol-ogy and the indications of surface albedo changes with time [7,8]. 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 Sohl et al. [2013], we have shown that tidal forces are a constant and significant source of inter-nal deformation on Titan and the interior liquid water ocean can be relatively warm for reasonable amounts of am-monia concentrations, thus completing the set of parameters needed for a truly habitable planetary body. Such habi-tability indications from bodies at distances of 10 AU, are essential discoveries brought to us by space exploration and which have recently revolutionized our perception of habitability in the solar system. In the solar system’s neighborhood, such potential habitats can only be investigated with appropriate designed space missions, like JUICE-Laplace (JUpiter ICy moon Explorer) for Ganymede and Europa [9]. JUICE is an ESA mission to Jupiter and its icy moons, recently selected to launch in 2022.

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