Beyond JUICE: Searching for habitability of ocean moons and dwarf planets

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Possible tests of biogenicity are feasible with the instrumentation that has been approved by the forthcoming mission to the Jovian system, the European Space Agency JUpiter ICy Moons Explorer (JUICE) mission. Its Jupiter Ganymede Orbiter (JGO) will include orbits around Europa and Ganymede. For example, the sulphates known to be present in the low albedo regions should by micrometeorite bombardment produce a quantity of sulphur atoms in the thin Europa atmosphere. The sulphur-contaminated thin exosphere of Europa remains within the range of what can be measured with current developments in miniaturised instrumentation [1, 2]. But there is a need to go beyond JUICE: We have enquired about the habitability of the Jovian moon Europa, having realized from the Galileo early data that conditions of a likely ocean are compelling for habitability by extremophiles [3]. We are envisaging going beyond to Uranus and Neptune [4] and to some of the dwarf planets. Consequently, it is necessary to begin questioning whether the Europa-like conditions are repeatable. In other words, whether conditions in likely oceans are compelling for habitability by extremophiles. These observations suggest raising the question: *Where are possible ecosystems in the Solar System?* Calculations of Hussmann and coworkers [5] with available data do not exclude that even Uranus moons may be candidates for bearing subsurface oceans. These possibilities invite a challenge that we gladly welcome, of preliminary discussions of habitability of extremophiles in so far novel environments. Nevertheless, such exploration is currently believed to be feasible with the new generations of missions suggested for the time window of 2030 - 2040, or even earlier. At present three new missions are in the process of being formulated, including the selection of payloads that will be necessary for the exploration of the various so far unexplored moons.

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