Here are the 7 best places to search for life in the solar system

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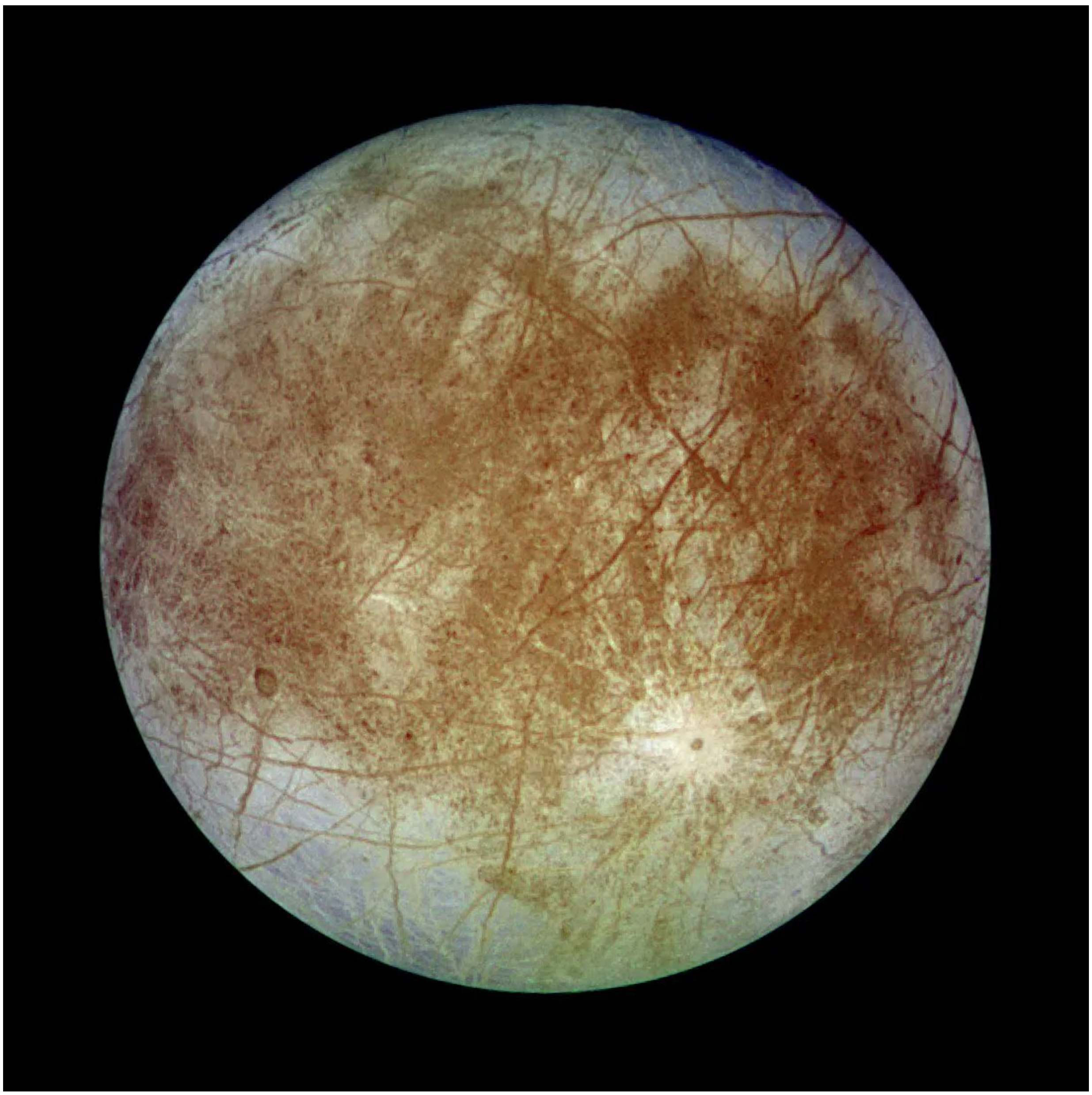

Europa. Credit: NASA / JPL

If humanity is ever going to find life on another planet in the solar system, it's probably best to know where to look. Plenty of scientists have spent many, many hours pondering precisely that question, and plenty have come up with justifications for backing a particular place in the solar system as the most likely to hold the potential for harboring life as we know it. Thanks to a team led by Dimitra Atri of NYU Abu Dhabi, we now have a methodology by which to rank them.

The methodology, published in a recent preprint paper on arXiv, is focused on a new variable—the Microbial Habitability Index (MHI). MHI is intended to measure how habitable a specific environment is for the various types of extremophiles found in extreme places here on Earth.

As with many great engineering challenges, the authors broke down the process of developing an effective MHI into a series of steps. First, they defined a series of six environmental variables that can affect the habitability of a particular environment for life. They then defined six types of environments that are generally thought to exist on many potentially habitable worlds. They then picked seven of those habitable worlds and collected all the data they could on the environmental factors for each type of environment on each potentially habitable world.

With that data, they compared the values found in those environments to the values that extremophiles can live in. The results aren't particularly surprising to anyone interested in solar system astrobiology, but quantifiable data back them up. It seems Europa, Mars, and Enceladus are the most likely candidates to find bacterial life.

To get to this conclusion required a lot of data collection and quantification, though. First, the team had to define what environmental factors were the most important for the potential habitability of life. They settled on six: temperature, pressure, UV radiation, Ionizing radiation, pH, and salinity. Life can only survive in a narrow band of these values, and they serve as a reasonable basis for starting to think about what environmental features are necessary to support life.

Luckily, scientists have also collected data on life forms that thrive in the extremes of each of those six factors. From Serpentinomonas sp. B1 that can survive in pHs as high as 12.5 to Thermococcus piezophilus CDGS that can withstand pressures of up to 125 MPa, Earth's extremophiles give a good indication of what life might be able to contend with on other planets. Utilizing the highs and lows of the factors they selected, the scientists were able to determine the bounds an environment would have to conform to support life as we know it.

Those environments were the next things the scientists turned their attention to. They came up with a list of six potentially biologically interesting environments that were found to harbor life on Earth and then defined the ranges of the six environmental factors in each of those environments on Earth. Included in the list were: Icy Poles, Surface Continent, Subsurface Continent, Subsurface Ices, Ambient Ocean, Deep Ocean Floor, and Hydrothermal Vents. Each of those environments on Earth harbors life in some form, so the authors posit they could do so on some other world as well.

To find the most habitable places in the solar system, the researchers went down the list of worlds in the solar system. They eliminated most based on an outlier in one or more of the environmental factors they had defined as essential to biological life. At the end of their eliminations, though, they were left with seven potentially habitable worlds: Mars, Europa, Enceladus, Titan, Ganymede, Callisto, and (somewhat surprisingly) Pluto.

After getting all the selections out of the way, the authors got to the data collection phase. They collected data as much data as they could find about every time of environment that had been found on each of the worlds. Not every world is blessed with each of those environments, though. For example, Mars has no hydrothermal vents that we know of. However, that doesn't mean that other environments on the Red Planet wouldn't make a good candidate for astrobiology.

After collecting what data they could, they compared that data to the range defined by whether a microbe could withstand the ranges of environmental factors they would be subjected to at a given environment and, in so doing, came up with the MHI. The best way to summarize the outcome of their calculations is through a table showing the number of environmental factors that fall within the habitable range of extremophiles for each of the six environments selected as part of the study. The table is reproduced below.

Environment	Mars	Enceladus	Europa	Titan	Callisto	Ganymede	Pluto
Icy Poles	4/6	2/6	2/5	2/3	-	0/2	0/2
Surface	3/6	3/6	1/5	0/3	2/4	1/3	0/4
Subsurface Continental	1/6	-	-	-	1/3	1/4	-
Subsurface Ice	2/6	3/6	2/6	1/4	1/3	1/4	-
Ocean	-	3/6	2/5	-	1/3	1/5	-
Ocean Floor	-	3/6	2/5	0/2	1/3	1/3	-
Hydrotherm al Vents	-	5/5	4/5	-	-	1/2	-

Table from the paper showing the habitability of the six different environments on the six different worlds the authors picked as the most habitable. Credit: Arti et al.

The denominator in each of the entries signifies how many of the environmental factors the researchers could find data on. If the number is less than six, the researchers could not find data on one or more of the factors. The numerator in each fraction is the number of those environmental factors that lie within the bounds of environmental habitability for each. So, for example, the 1/4 value in the Subsurface Ice row of the Titan column means that there were data points available for four of the six environmental factors and that one of those environmental factors laid within the bounds set by the minimum and maximum of the livable conditions of extremophiles.

The chart clearly indicates that the most likely place that life could exist in the solar system is Enceladeus' hydrothermal vent system, which scores a five out of five on potential environmental factors—it is missing data on ionizing radioactivity. But the icy moon isn't alone at the top of the potentially habitable list. Mars and Europa both harbor environments that could be habitable to life, though the other candidates on the list seem less hospitable.

Ultimately there are a series of missions that will be focused on finding any microbial life that might exist at many of these locations, including Europa Clipper and the Mars Sample Return mission. This paper provides yet another reason why Enceladus should have its own mission in the works. But for now, having the framework that lets researchers and engineers focus their efforts on the most likely places to find one of the most sought-after discoveries in human history will help focus their efforts. Maybe something will come of it in the long run.

More information: Dimitra Atri et al, Assessment of Microbial Habitability Across Solar System Targets. arXiv:2203.03171v2 [astro-ph.EP], doi.org/10.48550/arXiv.2203.03171

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