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Exotic water worlds: how life-friendly is an ocean mightier than the ones on Earth?

Liquid water at the surface of a planet is a key ingredient for life. But recent results show that extrasolar planets covered globally by a mega-ocean may not be the most habitable: in a very deep ocean the formation of eternal ice may be more likely than the formation of life.

A group of German, Belgian and Austrian scientists, led by Lean Noack of the Royal Observatory of Belgium, has explored the possible habitability of deep oceans on exoplanets. They analysed numerical models of extrasolar planets with masses of up to 10 times the Earth's (called super-Earths) and with oceans that not only cover the whole surface of the planets, but are also up to 100 times deeper than the Earth's seas.

Noack and her colleagues have shown that the best candidates for habitable planets are planets with a rather shallow ocean (of up to few tens of kilometres mightiness), a small mass or a high surface temperature. Planets with deep oceans are highly likely to have an icy layer underwater, which could make them inhabitable.

The Mariana Trench south of Japan is the deepest spot on Earth, covered by a layer of water with a thickness of 11 km. At its floor, the pressure is more than 1000 times that of the atmosphere at Earth's surface, but life can still evolve and flourish in such deep, dark and cold environments (with temperatures below 5°C). At the ocean floor of a water-rich super-Earth exoplanet, the pressure could be much larger still. "*Imagine an ocean layer of 1000 km thickness ─ the density of the water at the floor of such an ocean would be like the density of concrete on Earth,*" says Dr. Noack. "*The conditions down there are not comparable to those of the Earth's oceans*."

As pressure increases with depth, water molecules begin to stick to each other and a high-pressure ice layer forms. "*At school we learned that ice always floats on top of an ocean*," states Noack. "*But at the large pressures we observe in oceans hundreds of kilometres deep, physics is different.*" Depending on the surface temperature and the pressure, the lower part of the ice layer can become warm enough to melt, making a second ocean above the ocean floor appear. Dr. Helmut Lammer of the Austrian Academy of Sciences Space Research Institute states: *"For ocean planets, a wide range of atmospheric temperatures are possible that lead to a liquid-water layer in at least the uppermost part of the ocean."*

However, life requires more than liquid water. Prebiotic building blocks are essential for the origin of life as we know it, and nutrients must be provided continuously. "*While it is certainly nice living IN water, so far no organism has ever been found that can live entirely OF water. Also, from all that we know, water alone is not alive and it will not spontaneously evolve into life. So clearly there is a need for more than just water, if you are looking for life.*", says Dr. Jan Hendrik Bredehöft of the University of Bremen.

At a depth of several kilometres, potential organisms don't have sufficient access to solar energy so they require other forms of energy, such as thermal or chemical, coming from the interior of a planet.

Dennis Höning of the Institute of Planetary Research at the German Aerospace Centre (DLR) adds: "*The interaction between crust and ocean can be important to create disequilibrium and to provide nutrients. Not by chance, we see a large biodiversity in the immediate vicinity of hydrothermal vents in the oceans here on Earth – a process which is closely related to plate tectonics*." An icy layer would prevent the access to energy and nutrients from the silicate mantle.

The scientists introduced a new classification for the habitability of water-rich exoplanets. Class H1 oceans are habitable: they are completely liquid and prebiotic material can be delivered from the surface all the way to the bottom of the ocean. Class H2 habitats have a liquid water layer above the seafloor, but surface and ocean floor are separated by an ice layer, hindering transport of material in the ocean. Planets where no liquid water touches the sea floor are in the third class H3. H2 planets are called conditionally habitable, whereas H3 planets are inhabitable.

The work will be presented at the General Assembly of the European Geoscience Union in Vienna, April 28 - May 2. An EGU press conference on the topic of "Fingerprints of life: from the early Earth to outer space", where the work of Noack and her colleagues will be presented as well, is scheduled Thursday, May 1 at 11 am.

Abstract: EGU2014-14725, Possible Habitability of Ocean Worlds, Lena Noack, Dennis Höning, Jan Hendrik Bredehöft, and Helmut Lammer

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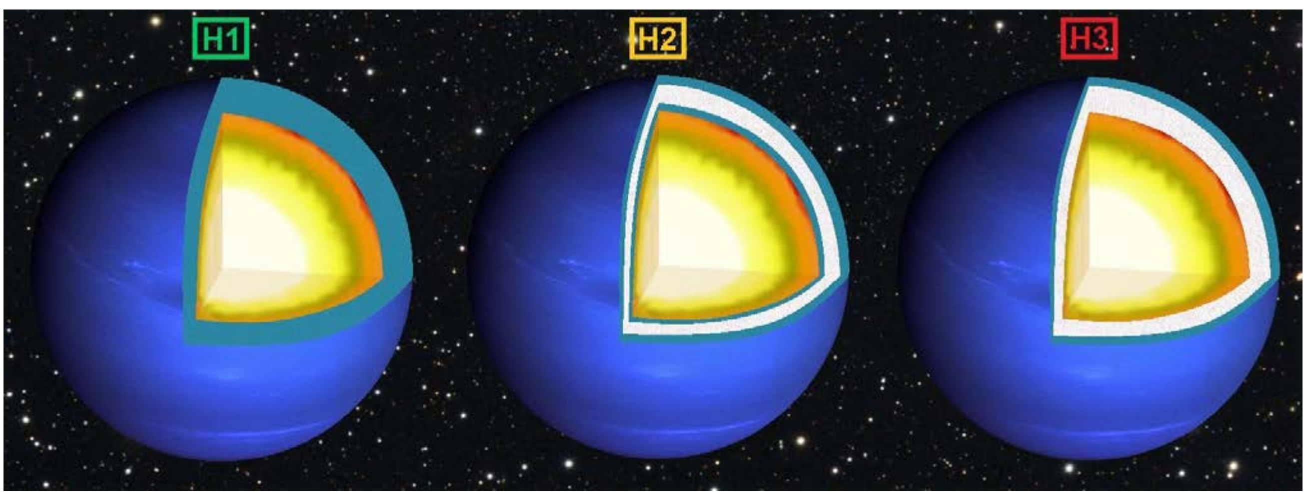
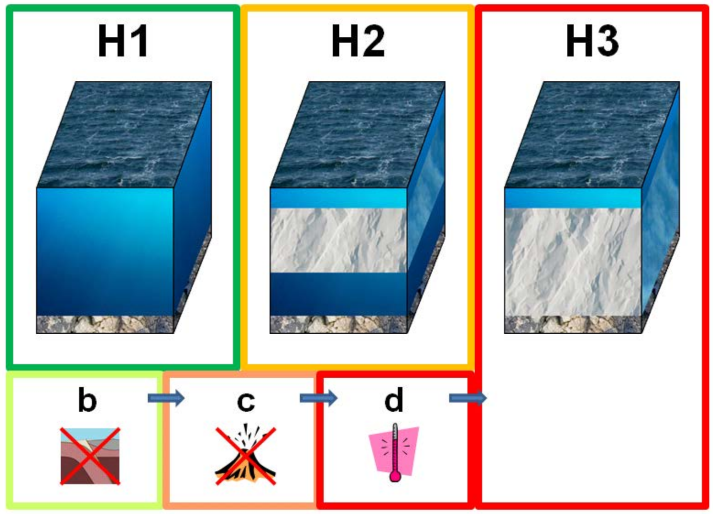
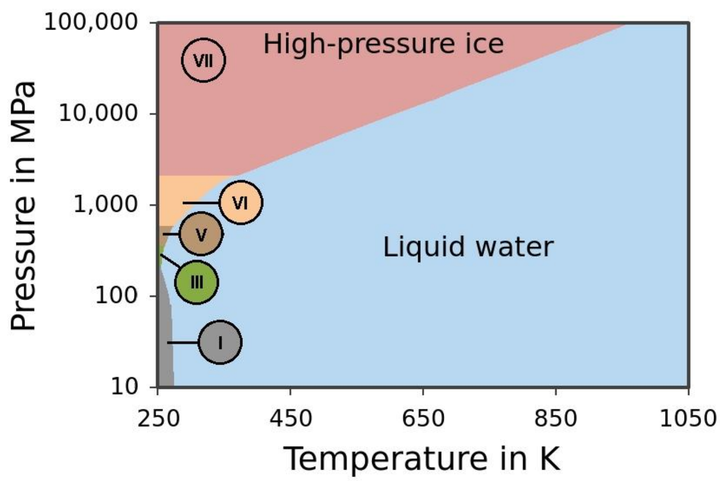


Possible interior structures of an ocean world. The ocean can be entirely liquid (H1, habitable), have an water-ice-water structure (H2, conditionally habitable) or can be frozen in the lower part and thus access to nutrients and energy coming from the silicate mantle is inhibited (H3, not habitable). Ice is represented in white.



The new proposed habitability classification with three subclasses: H1b (liquid ocean but no plate tectonics), H1c (liquid ocean but high pressure/temperature) and H2b (liquid water above ocean floor but no volcanism/replenishing of nutrients).



H_2O–phases depending on pressure and temperature. The blue shaded area shows the liquid phase, and the coloured areas show ice phases ranging from surface ice (ice I) to high-pressure solid ice phases of H_2O.