The giant planets from our Solar System and their satellites: are they too cold to have ecosystems?

[1,2,3]I. Valentin Petrescu-Mag, [1]Claudiu Gavriloaie

[1] SC Bioflux SRL, Cluj-Napoca, Romania; [2] Department of Environment and Plant Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania; [3] University of Oradea, Oradea, Romania. Corresponding author: I. V. Petrescu-Mag, zoobiomag2004@yahoo.com

Abstract. This article is a referenced discussion. Astrobiologists investigate our solar system with various purposes, among which to find new environments similar to those we know on Earth, plenty of water. They consider that water is at the origin of the formation of life on Earth and very likely on other planets the situation would be similar. Although not totally wrong, some of them omit a very important aspect: life can most probably rise in water only in warm environments such in the case of Earth. Water is liquid only at temperatures higher than 273.15 K. While there are organisms on Earth capable to survive below this temperature, an accident such as the birth of organic matter from inorganic matter is unlikely without large surfaces of liquid water. Telluric planets Mercury, Venus and Mars have poor to no chances to own life forms. The remaining ones, the giant planets and natural satellites of our solar system are too distant from the sun and thus too cold to have liquid water on their surface. Although too cold to have life forms similar to those we know on Earth, the giant planets of our solar system have some special features which make them intriguing for astrobiology: firstly, due to their size, they generate heat and, secondly, one of the most important constituents of their gaseous atmosphere and liquid surface is methane. We can consider both methane planets and gaseous giant planets candidates for life-bearing planets due to the abundance in their atmosphere of constituents such as: methane, water, hydrogen, ammonia, hydrocarbons and oxygen. Such an environment is much more prone to generate organic molecules and tiny organisms than water. The melting/freezing point of methane is 455.65 K and the boiling point is 434.64 K. That means methane is liquid between 455.65 and 434.64 K while water is frozen at such temperatures. Having in view the cold environment on such planets, if life forms exist at those temperatures, the main biogeochemical cycle on these planets is presumed to be the methane cycle.

Key Words: methane planets, giant planets, Jupiter, Titan, extraterrestrial life.

Introduction. Astrobiologists investigate our solar system with various purposes, among which to find new environments similar to those we know on Earth, plenty of water (Carr 1996; Mckay 1997; Tosca et al 2008; Waite et al 2009). For this reason, Mars, Europa and Enceladus are the main targets for finding extraterrestrial life. They consider that water is at the origin of the formation of life on Earth and very likely on other planets the situation would be similar. Although not totally wrong, some of them omit a very important aspect: life can most probably rise in water only in warm environments such in the case of Earth (149.600.000 km distance from the Sun). Water is liquid only at temperatures higher than 273.15 K. While there are organisms on Earth capable to survive below this temperature (Petrescu-Mag et al 2007), an accident such as the birth of organic matter (as we have on Earth) from inorganic matter is unlikely without large surfaces of liquid water.

The twin sister of planet Earth, Venus, is most likely lifeless (Launius 2012), while Mars, in the most optimistic case, can accommodate scarce life forms (Petrescu-Mag 2009; Launius 2012; Fries 2017). Mercury is incandescent on one side while it is frozen on the other side (Strom & Sprague 2003). The other planets and natural satellites of our solar system are too distant from the sun and thus too cold to have liquid water on their surface, the only exception being Enceladus (Waite et al 2009).

Gaseous Giants and Methane Planets. Although too cold to have life forms similar to those we know on Earth, the giant planets of our solar system have some special features which make them intriguing for astrobiology: firstly, due to their size, they generate heat and, secondly, one of the most important constituents of their gaseous atmosphere and liquid surface is methane (CH_4). Methane can be both a premise for the birth of life forms and a result of the functioning or decomposition of organisms.

To avoid confusion, we should mention that, even they have an atmosphere plenty of methane, the giant planets of our solar system are not considered methane planets. Based on the classification of the planets, methane planets are a class of planets with surface covered by lakes or oceans of methane (Figure 1), having methane clouds in the atmosphere like it is on Titan, the largest natural satellite of Saturn (Petrescu-Mag et al 2011; Guzmán-Marmolejo & Segura 2015).

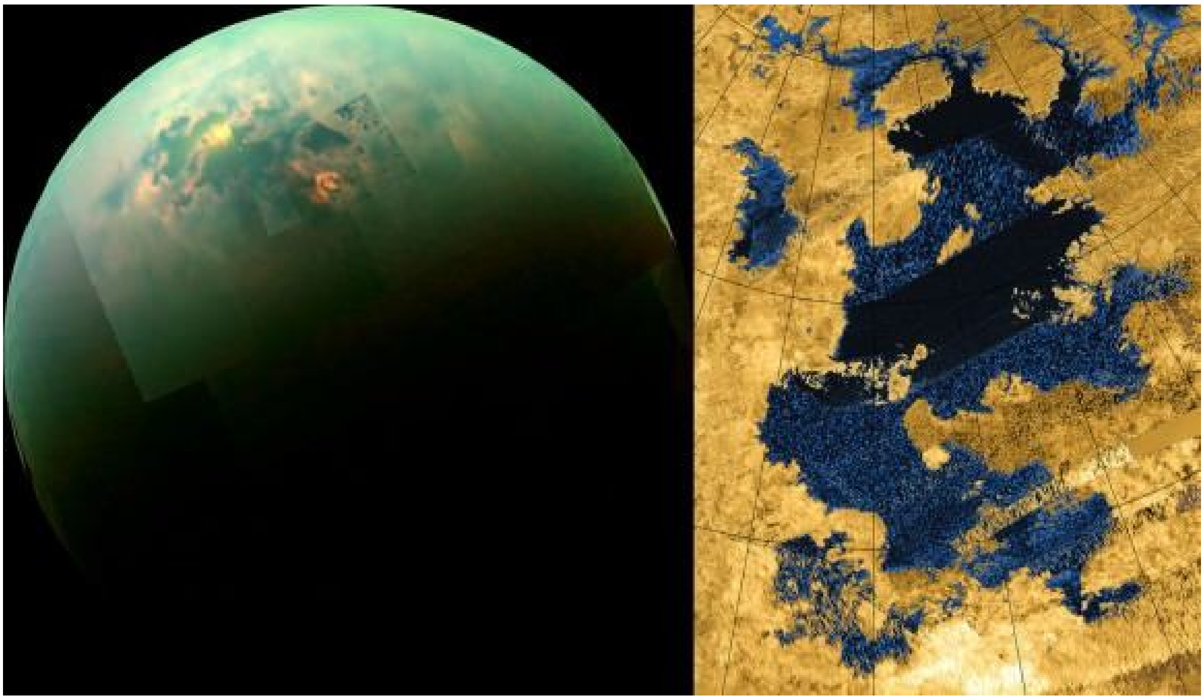

Figure 1. Mosaic of images taken in near infrared light showing Titan's polar seas (left) and a radar image of Kraken Mare (right), both taken by the Cassini spacecraft. Credit: NASA/JPL.

Observed with the telescope outside the atmosphere, methane planets appear blue to aqua green because methane absorbs red light and reflects blue and green light. Some methane clouds appear whitish due to the fact they contain phosphorus while others are orange because they contain something astronomers call "tholin" (planetstar.wikia.com). Tholin is an informal term used by scientists to name a complex mixture of organic compounds formed by solar ultraviolet irradiation or cosmic rays from simple carbon-containing compounds such as carbon dioxide (CO_2), methane (CH_4) or ethane (C_2H_6), frequently in combination with nitrogen (N_2). This informal name, tholin, is used mostly in astronomy due to the fact that, given the distance of the object, precise analyses of the compounds are difficult.

Methane planets are assumed to have similar climates to Earth's but from far much colder (94.15 K). Another difference compared to Earth-like planets is the fact they use methane as a "variable gas" instead of water vapor as it is on Earth. For instance, there are methane rain or methane snow instead of water rain or water snow. In the case of a methane planet, its atmosphere consists mainly of nitrogen (N_2) and oxygen (O_2) with different amounts of methane (CH_4) and trace amounts of nitric oxide (NO) and other gases (planetstar.wikia.com).

Astrobiologists use Titan as a model for understanding the methane planets. Such planets are in general cloudy, dark and hazy, because stellar radiation breaks methane molecules apart and forms different types hydrocarbons, such as: ethane (C_2H_6), diacetylene (C_4H_2), methylacetylene (C_3H_4), acetylene (C_2H_2) and propane (C_3H_8). This breakdown can also produce non-hydrocarbon compounds like: carbon monoxide (CO), carbon dioxide (CO_2), hydrogen cyanide (HCN), cyanoacetylene (C_3HN), and cyanogen ($(CN)_2$) (planetstar.wikia.com).

The assumption that methane planets are candidates for life-bearing planets is fair (Petrescu-Mag et al 2011; Guzmán-Marmolejo & Segura 2015). Life on methane planets is strange that the life forms can adapt to extreme cold environment and use methane as a solvent, whereas life on Earth uses water as a solvent. Is believed that under a hazy atmosphere, like Titan atmosphere, the plant life relies on chemosynthesis as there are not enough light for photosynthesis because methane planets orbit far from the light of their parent stars (planetstar.wikia.com). It is also believed that on such planets plant-like organisms use methane (CH_4) and nitric oxide (NO) to produce methanol (CH_3OH), nitrogen (N_2), and oxygen (O_2), as it is presented below:

$$2\ CH_4 + 4\ NO + energy \rightarrow 2\ CH_3OH + 2\ N_2 + O_2$$

The source cited above predicted that animals take in oxygen and release nitric oxide instead of carbon dioxide. Such animals eat foods rich in methanol and drink liquid methane. The main biogeochemical cycle on methane planet is presumed to be the methane cycle, while the main biogeochemical cycle on Earth is the carbon cycle (planetstar.wikia.com). Though only hypothetically outlined, this idea is perfectly plausible.

A carbon-based living organism is however vulnerable to extremely low temperatures. Therefore, is believed that life on some methane planets may not be carbon-based but silicon-based as the organisms have better survivability to extreme cold than carbon-based life (planetstar.wikia.com).

Returning to our gaseous giant planets (Jupiter, Saturn, Uranus, Neptune), although they are known to have no tellurian surface, they have a lot of methane in their atmosphere and oceans similar to methane planets (Lutz et al 1976; Baines et al 1995; Karkoschka 1998). On the surface of these planets there is no clear delimitation between the atmosphere and the ocean of liquefied gas. The blend of gases consists mainly of hydrogen (H_2), helium (He), methane (CH_4), water (H_2O), ammonia (NH_3) hydrogen sulfide (H_2S), phosphine (PH_3), hydrocarbons, oxygen (O_2), carbon monoxide (CO), carbon dioxide (CO_2) (Atreya et al 2003). Such an environment is much more prone to generate organic molecules and tiny organisms than water. The melting/freezing point of methane is 455.65 K and the boiling point is 434.64 K. That means methane is liquid between 455.65 and 434.64 K while water is frozen at such temperatures. Having in view the cold environment on such planets, if life forms exist at those temperatures, the main biogeochemical cycle on these planets is presumed to be the methane cycle.

Another peculiar issue with these planets is that they produce a lot of internal heat because of their mass. Their temperature depends more on height above the surface. This is because heat is driven not by the sun but by the interior of the planet. For instance, Jupiter has an average temperature of 128.15 K (Taylor Redd 2012), but the temperature varies drastically with depth. Close to the core of the planet, temperature is as high as 35773.15 K (www.universetoday.com).

It is both difficult and intriguing to imagine a huge Jovian ecosystem like a nebula.

Conclusions. We can consider both methane planets and gaseous giant planets candidates for life-bearing planets due to the abundance in their atmosphere of constituents such as: methane, water, hydrogen, ammonia, hydrocarbons and oxygen. Such an environment is much more prone to generate organic molecules and tiny organisms than water.

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Authors:
I. Valentin Petrescu-Mag, SC Bioflux SRL Cluj-Napoca, 54 Ceahlau Street, 400488 Cluj-Napoca, Romania; Department of Environment and Plant Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania; University of Oradea, 1 Universitatii Street, 410087 Oradea, Romania, e-mail: zoobiomag2004@yahoo.com
Claudiu Gavriloaie, SC Bioflux SRL Cluj-Napoca, 54 Ceahlau Street, 400488 Cluj-Napoca, Romania, e-mail: claudiugavriloaie@gmail.com

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