# Enceladus: a new venue for life?

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The search for life beyond the Earth has been going on ever since the erstwhile Soviet Union launched *Sputnik 1* in 1957. In 1960, Joshua Lederberg coined the term exobiology for the 'active scientific search for extraterrestrial life', and along with J. B. S. Haldane, advocated its study to find such organisms and take necessary precautions to avoid the 'contamination' of Earth by alien forms of life[1]. Fifty years hence, we are still searching for life in the little known Universe outside the Earth, even as the study of exobiology has evolved to become a 'multidisciplinary endeavour that seeks to understand the interactions between a developing and evolving biological system and the physical environments within which these evolutionary processes take place[2]'.

*Chandrayaan I*'s recent discovery of water on the moon has instigated a wave of excitement among the scientists and the general public. The *Cassini–Huygens* mission, a cooperative project of NASA, the European Space Agency and the Italian Space Agency, recently discovered that Saturn's moon, Enceladus (Figure 1), too, shows the presence of water, and there is speculation about the presence of a subsurface liquid water reservoir. This has given fresh impetus to the search for extraterrestrial life.

Enceladus, one of Saturn's 61 moons, is present near the outermost E-ring of the planet. It emits a plume from certain fissures, known as the Tiger Stripes, present near its southern pole. This plume has, in fact, generated the E-ring of Saturn. The chemical nature of the plume was, for long, a mystery. The Cassini probe's Enceladus flyby on 14 July 2005 found, using ion and neutral mass spectrometry and ultraviolet imaging spectrography, that the intriguing plume is made primarily of water and carbon dioxide[3]. In 2008, the Cassini Saturn Orbiter's Ion and Neutral Mass Spectrometer (INMS) discovered that the plume also contains methane, ammonia and various other organic compounds, the possible presence of radioactive Argon and deuterium (Figure 2)[4]. In 2009, the probe discovered the presence of sodium salts in the plume, through measurements made by Cassini's Cosmic Dust Analyser[3]. These discoveries have prompted scientists to suggest the probable presence of a liquid water reservoir below the icy crust of Enceladus. This, in turn, has encouraged the view that there could be a likelihood of life on that moon. In a recent editorial, Balaram[5] quotes from Phillip Ball's book, *$H_2O$: A Biography of Water*: 'The issue then is not whether there is water elsewhere, but whether it is liquid – for only in the liquid state does water seem to be capable of providing the matrix of life'.

Stanley Miller's experiments in 1953, which proved that living organisms were probably formed on the Earth due to certain chemical reactions that might have been catalysed by the prevailing environmental conditions of primitive Earth, also meant that life or life precursors may be formed on other planets (or moons) which also have similar conditions. Thus, exobiologists explore other planets on the premise that conditions that might have given rise to life on the Earth, probably would produce life elsewhere too.

Willard Boyle, one of this year's Nobel laureates for Physics says, '. . . the most important part of our invention, which affected me personally, was when the Mars probe was on the surface of Mars and it used a camera like ours . . . and we saw for the first time the surface of Mars[6]'. The *Viking* vessels that landed on Mars in 1976 were the first to photograph the Martian surface. It was also by these vessels that the first exobiological 'search' was done on Mars. The *Viking* probes had, along with other instruments, a component to conduct biological experiments to check for the presence of life on the planet's surface[7].

Later missions explored other planets and moons that showed some features that may allow them to harbour life. One such mission was the *Galileo* spacecraft that explored Jupiter's moons in 2000, and found evidences that led scientists to suggest that Jupiter's moon Europa may have a liquid ocean under its icy crust[8] – a case that strongly resembles the present case of Enceladus.

The *Cassini* Equinox mission, launched by NASA on 15 October 1997, entered Saturn's orbit on 1 July 2004 and made its first close flybys of Enceladus in 2005. This and subsequent flybys of Enceladus have led to the discovery of the nature of Enceladus' plumes, the presence of cryo-volcanic activity on the moon, the intriguing presence of higher temperatures at the Tiger Stripe region of the moon (where the temperature is –93°C, 115°C warmer than other regions on the moon)[3] and the surprising possibility of the presence of liquid water in a region so far away from the sun, which could indicate the possibility of the presence of life.

**Figure 1.** A full disc view of Enceladus. The Tiger Stripes are visible. Source: NASA Planetary Photojournal PIA06254.

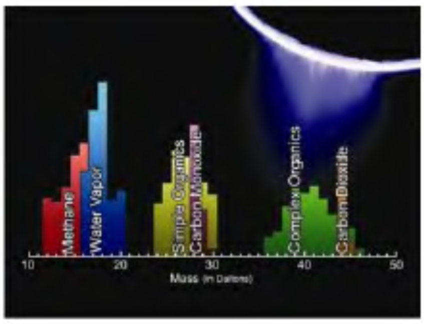


**Figure 2.** A mass spectrum that shows some of the chemical constituents of Enceladus' plume sampled by Cassini's INMS on 12 March 2008. The plume emanating from Enceladus can also be seen. Source: http://photojournal.jpl.nasa.gov/catalog/PIA10356

Frank Postberg, a Cassini scientist at Max Planck Institute, Heidelberg, Germany, says, 'Before the discovery of Enceladus' plumes, most people would have considered the likelihood of (cryo-volcanic) activity at such a small object as very low (the diameter of Enceladus is about 500 km). This has changed now. Scientists think that Enceladus might not be the only active icy moon in the solar system. There are speculations that Jupiter's moon Europa shows similar activity which has been overlooked by the *Galileo* spacecraft. Since the flyby of *Voyager 2* it is known that Triton at Neptune also shows cryo-volcanic activity, although no water is involved there but liquid nitrogen'[9].

There have been many evidences to explain the anomalous high temperatures of Tiger Stripe region of the moon and to suggest that the water beneath the surface of Enceladus may be liquid. A study by some Cassini scientists says that the fault lines at the moon's Tiger Stripes may rub back and forth due to the gravitational force exerted by Saturn as the moon goes around it, and this frictional force might be generating the heat required to sublimate the water that forms the plume[10]. Another study says that two moons that orbit near Enceladus, Tethys and Dione gravitationally 'pull' Enceladus, and such 'flexing' over millions of years might have caused the moon to heat up[11]. Such heating might contribute to the liquidation of water present on Enceladus, leading to the formation of the plume.

Later studies have suggested that the source of the water in the plume might be a subsurface liquid water reservoir. The detection of ammonia (with a mixing ratio of 0.8%) and various other organic compounds including methane by a flyby on 9 October 2008, and the detection of sodium and potassium salts crystals in the plume has led Waite *et al.*[4] to suggest that the moon might contain liquid water within the surface. They suggest that 'Ammonia's presence in the plume, along with the detection of Na and K salts in E-ring ice particles, implies that the interior of Enceladus may contain some amount of liquid water. Ammonia (together with methanol and salts) acts as an antifreeze that permits the existence of liquid water down to temperatures as low as 176 K'.

The possible presence of liquid water logically leads one to consider the possible presence of life. As Frank Postberg says, 'Astrobiologists say that it needs at least three prerequisites for the formation of life or life precursors: water, heat and certain chemical ingredients. All three things seem to be available at Enceladus, but it is by no means clear how life develops from these basic ingredients and on which timescale. Maybe the chance is 1 : 1,000,000 maybe its 50% . . . nobody knows'[9]. McKay *et al.*[12] have discussed the possibility of origin and sustenance of life on Enceladus. They have discussed the applicability of various theories, such as origin of life in an organic-rich mixture, origin in the redox gradient of a submarine vent, and panspermia that seek to explain the origin of life on Earth, to conditions prevalent on Enceladus. They have also quoted the various instances of organisms on Earth living in apparently unfavourable conditions, such as methanogens and sulphur reducing bacteria that live in extreme conditions like deep within volcanic rocks, and have suggested that similar forms of life may be present on moons like Enceladus. They have also said that methane that has been detected in Enceladus' plume might be of biological origin.

More flybys of Enceladus have been planned over the next few years. The next flyby is in November this year. According to Postberg, the November flyby will again bring *Cassini* close to the plume, and the ***in situ*** instruments will get better data of the plume composition. Other flybys will be used to get a better estimate of the temperatures at the Tiger Stripe region. Later, manoeuvres dedicated to precise measurement of the magnetic and gravitational moments will be carried out. These will help to investigate the size of a subsurface liquid water reservoir[9].

The *Cassini* discoveries have left many facts to be verified and many questions to be answered. 'For the foreseeable future the best device to explore Enceladus is the *Cassini* spacecraft. There will be no other space mission arriving at Saturn before 2030. There currently is a plan to extend the mission until 2017 including another 8 Enceladus flybys', says Postberg. According to him the future role of Cassini's Enceladus flybys will be to: (1) Confirm the finding of a subsurface salt-water reservoir, (2) Determine the subsurface structure of Enceladus, and to estimate the size of the water reservoir ('ocean or lake'), (3) Find out other chemical components that may be present, (4) Find out how 'hot' Enceladus is, and how the heat is produced, (5) Find out how the surface exchange processes work and to determine if larger convection processes are involved, which go down to Enceladus' rock core, and (6) Narrow down the likelihood of formation of life or life precursors[9]. Jonathan Lunine, another Cassini scientist from the University of Arizona, Tucson, says, 'After *Cassini* completes its mission in 2017, one would hope that an advanced mission to further determine where the liquid water is and what kind of chemistry is occurring there might then be under development'[13].


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