The Universe in my pocket

# The search for extraterrestrial life

TUIMP
No 19
THE UNIVERSE IN MY POCKET

Danielle Briot
Paris Observatory

Landscape of Mars

The Atacama Desert in Chile

These two landscapes are very similar, but Mars will never offer a landscape like this one:

The Atacama Desert in bloom

In fact, no one today can give a satisfactory definition for 'life'.

Despite the lack of a clear definition, we do have some ideas about what life is, and so far, planet Earth is the only place known to harbour life. Life can be found practically everywhere on our planet, even in conditions that seem impossible to us. Such living beings are known as extremophiles.

The study of living beings is called biology, while the search for life on planets other than planet Earth is called astrobiology, bioastronomy or exobiology. This science involves scientists from a variety of disciplines: astrophysicists, biologists, biochemists, philosophers...

It is generally thought that life began on Earth, but it is not known how. Another theory suggests that it was imported from space by meteorites or comets.

# The Drake equation


N: probable number of civilisations in our galaxy

$R_*$ : number of stars that form each year in our galaxy

This parameter can now be estimated.

$f_p$ : proportion of stars with planets

This parameter can now be estimated.

$n_e$ : average number of planets likely to harbour life per star with planets

$f_l$ : fraction of these planets where life has actually appeared

$f_i$ : fraction of these planets with intelligent life (civilisation)

$f_c$ : fraction of planets with intelligent life able and willing to communicate

L: average duration of such a civilisation in years.

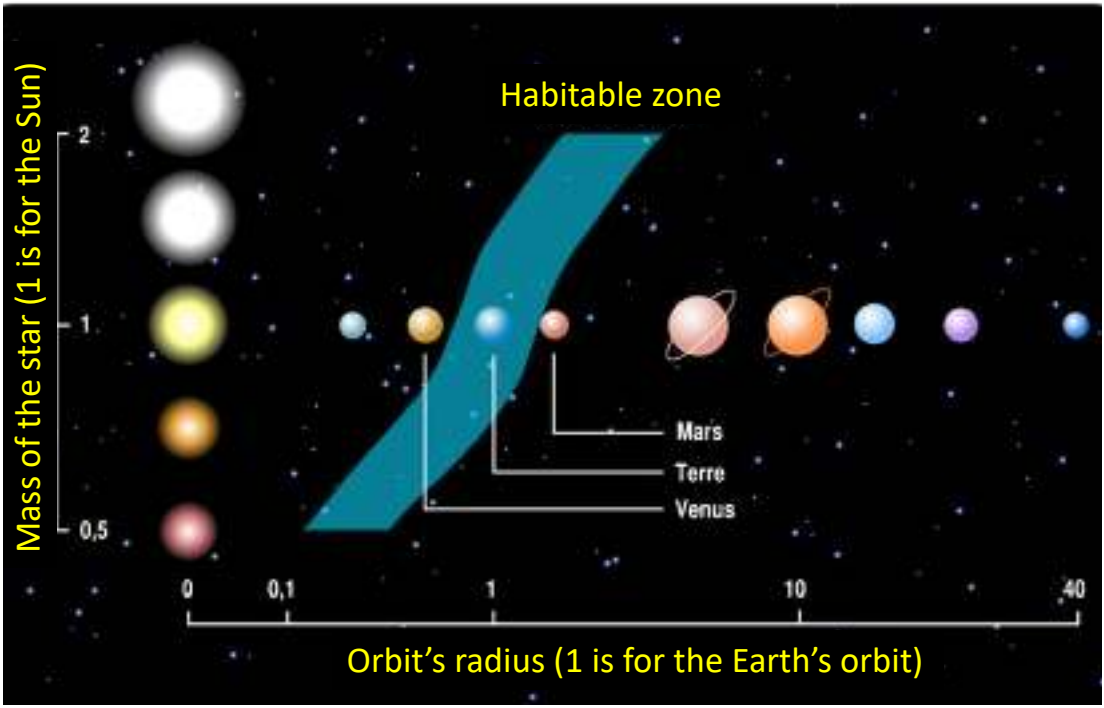
Credit sciencenotes.org

# Paradox and estimation

The question of the existence of other worlds, possibly inhabited, has been raised since ancient times. See TUIMP no. 8.

How might we find them?
In 1950, the physicist Enrico Fermi (1901-1954) asked the question: `Where are they?' In other words, if intelligent extraterrestrials exist, why haven't we already met them? This question, known as the Fermi paradox, has given rise to countless answers, and continues to be studied on the basis of various hypotheses.

In 1961, astrophysicist Frank Drake (1930-2022) established a probability formula for estimating the number of extraterrestrial civilisations with which we might come into contact. The possible answers range from 0 for the pessimists to several million for the optimists.




The habitable zone for planets in the Solar System and for exoplanets.

The Earth is in the habitable zone, and Venus and Mars are very close.

Stars are represented from the hottest (very luminous, massive and blue, quite rare) to the coolest (not very luminous, small and red, very abundant). The habitable zone is closer to the star when the star is less massive.
Planets in the habitable zone of red stars are thought to be close enough to their star to present always the same part facing the star.

# One of the probable conditions necessary for life

Of course, life outside planet Earth may be very different from what we know. It is generally thought that liquid water is one of the conditions necessary for life. Biochemical reactions require a fluid, and water remains in a liquid state over a wide temperature range. Water is also a very good solvent. Finally, water is one of the most abundant molecules in the Universe.

For Earth-like pressures, water is liquid when the temperature is between 0°C and 100°C. Based on this temperature range, a 'habitable zone' has been defined for planets in the Solar System and for extra-solar planets, i.e. planets orbiting other stars.

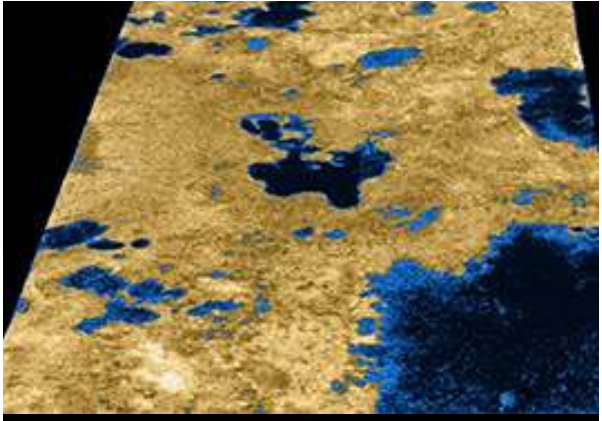
With this defiition, the habitable zone depends on the temperature of the star and the distance to the planet. But this concept is valid only as a first approximation.

The Martian surface as seen by Viking 1, the first spacecraft to land on Mars, on 21 July 1976. There are no canals.

NASA has confirmed the existence of a large reservoir of liquid water beneath the surface of Mars

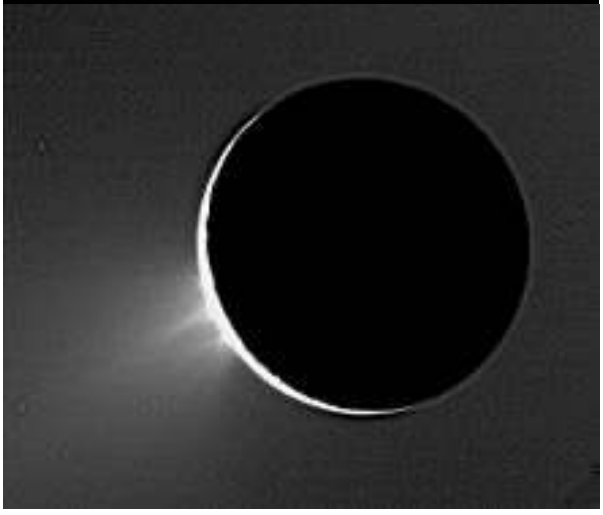
Among the planets in the Solar System in (or close to) the habitable zone, Venus has excessive physical conditions, with an average surface temperature of 464°C and a pressure 90 times greater than on Earth. But perhaps extremophiles could live there?

The planet Mars appears to be a more favourable candidate for the search for life. The false detection of the canals on Mars by certain scientists was a collective illusion. The Viking spacecraft did not find any canals. Today, the extraordinary achievements of space astronomy have made it possible to send both fixed and mobile devices to Mars to search for signs of life. The study of Martian terrain shows that liquid water once existed on Mars, and possibly an underground ocean still remains.



Lakes of hydrocarbons, methane and ethane on Saturn's satellite Titan.

Photo of Europa, a satellite of Jupiter, in true colour and showing numerous cracks.



Jets of matter above the south pole of Enceladus, a satellite of Saturn.

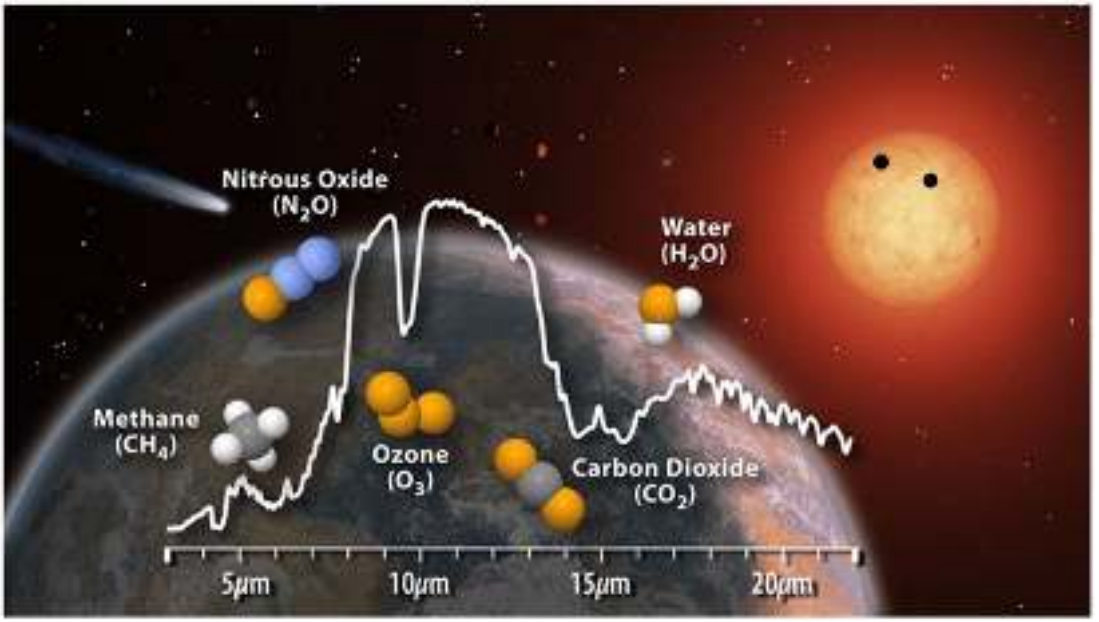
Might various satellites harbour some form of life?

# The Solar System's fascinating satellites

The planets beyond the habitable zone are giant, gaseous planets on which it is difficult to imagine life. But these planets have many very interesting satellites. Titan, a satellite of Saturn, has an atmosphere and methane lakes that have been detected by spacecraft. Europa, a satellite of Jupiter, has an ocean of liquid water under a layer of ice; there are plans to send probes to pierce the ice and search for life in this ocean.

Underground oceans of liquid water have also been discovered on Saturn's satellite Enceladus, on Jupiter's satellite Ganymede, and recently on Saturn's satellite Mimas. Other underground oceans are suspected.

So there are many possibilities for life!




Some examples of molecules detected in the atmosphere of an exoplanet that could be biosignatures, i.e. that indicate the presence of life (Credit: Meixner, et al. 2021, JATIS).

The Amazon rainforest is the largest vegetated area on Earth. Could such vegetation be detected on an exoplanet?

# Extrasolar planets

In 1995, the discovery of extrasolar planets, of which several thousand are now known, extraordinarily revitalized the search for extraterrestrial life. See TUIMP No. 8. Of the hundreds of billions of planets that probably exist in our galaxy, we are particularly interested in rocky planets, i.e. non-gaseous planets located in the habitable zone of their star.

How can we detect life on these planets, when few of them are visible from Earth? Certain gases indicating life might be present in the exoplanet atmospheres and could be detectable from Earth. It may even be possible to observe large areas covered by plants whose chlorophyll might be detectable.

We have more questions than answers, but the future looks very promising and exciting.

# Quiz

Which of the following statements are true and which are false? Please note that there may be several true sentences per subject.

## 1/ Origin of life

a) Life formed on planet Earth.
b) Life comes from space.
c) We don't know yet...

## 2/ Presence of water in the solar system

a) The Earth is the only place in the solar system where water is found.
b) There are several underground oceans on planets and satellites.

## 3/ Life has been found on a planet around a star other than our Sun.

a) True
b) No, but research is active on this subject.

# Answers

True sentences are in red and false sentences are in blue.

1/ Origin of life

a) Life formed on planet Earth.

b) Life comes from space.

c) We don't know yet...

2/ The presence of water in the Solar System

a) The Earth is the only place in the Solar System where water is found.

b) There are several underground oceans in planets and satellites.

3/ Life has been found on a planet orbiting a star other than our Sun.

a) True

b) No, but research is very active in this area.

# The Universe in my pocket N° 19

This booklet was written in 2025 by Danielle Briot, from the Paris Observatory, and revised by Jean Schneider, also from the Paris Observatory.

Cover image: Metal box containing the Golden Disc carried on board the Voyager 1 and Voyager 2 probes and intended for possible extraterrestrial intelligent life. On the lid is a diagram showing how to read the disc. The disc contains images and sounds about humans and life on Earth.

To find out more about this collection and the topics presented in this booklet, visit http://www.tuimp.org.

Translation: Stan Kurtz