What is a habitable planet?

Numerous planets orbiting stars other than our Sun have now been detected in our galaxy, the Milky Way. These are known as exoplanets.

These exoplanets include gas giants similar to Jupiter, Saturn, Neptune and Uranus in our Solar System, as well as much smaller rocky planets (known as telluric planets) like Earth, Mercury, Venus and Mars in our Solar System. This raises the question of whether these small planets, some of which being more or less similar to Earth, can harbour life. What makes a planet habitable?

This question is the subject of much debate within the scientific community, since the only example we know of is the planet Earth... Nevertheless, we can legitimately assume that for life – as we know it – to develop, water in its liquid form is an important element. But what are the necessary conditions for liquid water to be present on the surface of a planet?

Level: primary school

Objectives

- Learn about the different states of water.
- Learn that the surface temperature of a star determines its colour.
- Position a planet at the right distance from its star so that liquid water can exist on its surface.

Materials required: activity to be carried out in groups (ideally in pairs)

For each group of pupils:

- 1 glue stick
- 1 A3 sheet
- 1 ruler
- 1 slate, with felt-tip pen and eraser

As well as, for each pupil:

- 1 pair of scissors
- 1 pencil or mechanical pencil
- 1 pencil sharpener
- 1 eraser

Duration: about 1 hour

Author: Caroline BARBAN, UFE, Observatoire de Paris

Activity plan

1- Conditions necessary for the appearance of life on a planet

The teacher asks the pupils what conditions they think are necessary for life to appear on a planet. Several answers are possible: presence of an atmosphere, a moderate temperature, oxygen, vegetation, food, etc. and water in liquid form.

Emphasis will be placed on the fact the one and only case we know of is… planet Earth.

2- The three states of water

The teacher asks the pupils what states of water they know of. The answers should be: liquid (e.g. the water from the oceans, the drinking water, etc.), solid (ice), and gaseous (water vapour – often mistaken for the matter of clouds; cloud matter is in fact droplets of liquid water, but that distinction is not necessary here).

The teacher then asks why water is not always in the same state, and how we can force such changes. Expected answer: the different states of water depend on the temperature. (Actually it also depends on the atmospheric pressure as well.)

If the pupils do not give more details, the teacher asks the temperature thresholds between states. Collectively, the pupils will recollect the following values: at sea level (since atmospheric pressure is important) water between 0 and 100°C will be liquid; at a temperature warmer than 100°C water will become vapour (a gas), and below 0°C it will freeze down, switching to solid (ice) state.

3- Positioning a habitable planet with liquid water at the right distance from its star

The teacher distributes Annexes 1 (the 3 stars and their characteristics) and 2 (the 4 planets labels) and asks the pupils to cut out all the labels.

Then the teacher asks several questions to make sure the documents are understood:

- Which one is the hottest star? (Regulus)
- The coldest one? (61 Cygni A)
- What colour is it? (orange)
- And so on.

The pupils are now asked to paste the Sun label in the top-left corner of the landscape-oriented A3 sheet. Where should the Earth and Jupiter labels be pasted? The pupils will answer that Jupiter should be pasted five times further from the Sun than Earth. To be more specific, the teacher imposes a common scale: 3 cm will represent 1 Astronomical Unit (or 150,000,000 km).

The groups will now do the same for the two other stars. They will also paste the “telluric exoplanet” label at the distance from the star where water can be liquid. (The teacher can mention that gas giant exoplanets do exist too, but as they do not have a solid surface, they cannot host large bodies of liquid water, and are thus not of peculiar interest for this specific exercise – their solid icy satellites could be, though.)

Eventually, the teacher asks the pupils to place the liquid water (drop) label in the right place for each star. Where in the stellar system will the temperature be too hot for liquid water? Expected answer: anywhere closer to the star than the “liquid” label. What will happen at distances further away from the star? Answer: the temperature being too cold, water will only exist in solid state. Pupils are to paste the solid (icicle) and vapour (cloud) labels at the right place for each of the three stellar systems.

Displaying the result on the board, the teacher guides the discussion: the hotter the surface of a star, the greater the distance between the star and the zone where a planet with liquid water on its surface can be found.

4- “Astronomical” riddle

The teacher asks the students to take out their slates. They will try and recognize a celestial body through a series of hints. Each pupil should write their answer on their slate; they can change their answer at any time until the last hint.

Hint 1: I was born in a cloud of gas, dust, and ice. What am I?
Several possible answers: anything that makes up a planetary system (like our solar system): star, planet, dwarf planet, comet, asteroid, artificial satellite

Hint 2: I shine in the sky but I don't produce my own light. What am I?
So it can't be a star. All other bodies are possible.

Hint 3: You can walk on my surface. What am I?
So it can't be a gas giant planet.

Hint 4: I am spherical. What am I?
It could be a telluric planet or a dwarf planet.

Hint 5: I am much bigger than the Moon. What am I?
This can only be a terrestrial planet.

Now, the teacher will ask questions on that specific telluric planet.

Question 6: I'm 1 AU away from my star. Could life forms (as we know it) have developed here?
We can’t tell because we don't know whether the star is similar to or different from the Sun.

Question 7: I am 1 AU away from my star, which is hotter than the Sun. Could life forms have developed there?
No, because at this distance from a star hotter than the Sun, water is only present in gaseous form. It's too hot on this planet!

5- Extension of the session in visual arts

The pupils draw a planetary system other than the solar system, giving names to the host star (or stars) and to the various planets.

References

This activity was largely inspired by the ‘Habitability’ workshop, proposed during the visit itinerary of the Meudon site of Paris Observatory.