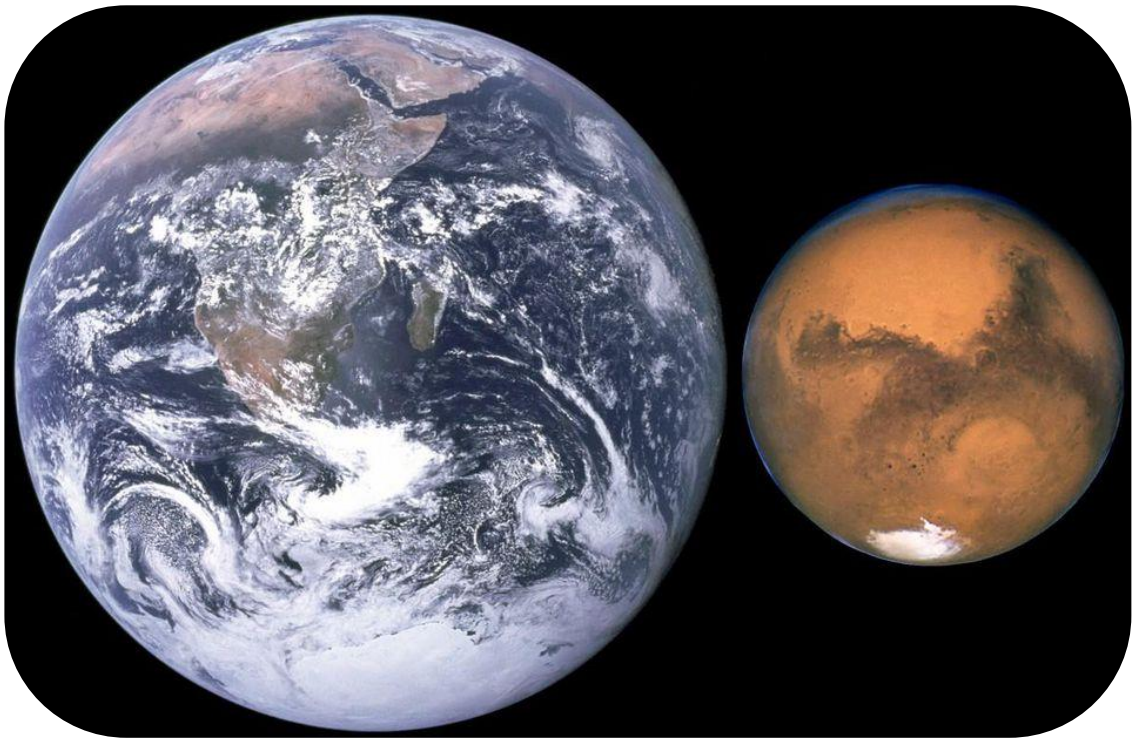
CESAR Science Case

Seasons on Mars

Following the Martian seasons with Mars Express

Teacher Guide



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Fast Facts

FAST FACTS

Age range: 12-16 years old

Type: Guided investigation

Complexity: Easy

Teacher preparation time: 30 minutes

Lesson time required: 1 hour

Location: Indoors

Includes use of: Computers, internet

Curriculum relevance

General

- Working scientifically.
- Use of ICT.

Physics

- Rotation of the planets.

Space/Astronomy

- Research and exploration of the Solar System.
- The seasons.

You will also need…

- CESAR VMC web tool:
  http://cesar.esa.int/tools/18.martian_year/

To know more…

- CESAR Booklets:
  - "Mars"
  - "The Solar System"

Outline

In these activities, students learn about Mars and its movement around the Sun.

Using real images taken with the VMC camera on board the ESA Mars Express mission, the different Mars seasons can be observed.

By looking at the size of the Mars polar ice caps students will identify the season. With this information students will be able to estimate the duration of a Martian year.

Students should already know…

1. The basics of how seasons work on Earth.
2. How to identify features in images (i.e. polar ice caps).
3. The connection between size of polar ice caps and seasons.
4. The basic orbital parameters of Earth and Mars.
5. Elementary maths.

Students will learn…

1. The basic properties of Mars compared with Earth.
2. How to handle astronomical images.
3. How information, extracted from astronomical images, allows scientific studies to be performed.
4. The duration of a Martian year.

Students will improve…

- Their understanding of scientific thinking.
- Their strategies of working scientifically.
- Their teamwork and communication skills.
- Their evaluation skills.
- Their ability to apply theoretical knowledge to real-life situations.
- Their skills in the use of ICT.

Summary of activities

Title	Activity	Outcomes	Requirements	Time
1. Compare Mars and Earth	Students investigate the differences and similarities between Earth and Mars.	Students improve: • Their understanding of scientific thinking. • Their strategies of working scientifically. • Their teamwork and communication skills. • Knowledge of Mars.	None.	15 min
2. The Seasons	Students need to identify the seasons on Earth and Mars.	Students improve: • Their knowledge of the seasons. • Their communication skills. • Their scientific thinking.	None.	15 min
3. How long is a Martian year?	Students will estimate the duration of a year on Mars.	Students learn: • How scientists extrapolate information. • The duration of a Martian year. Students improve: • Their understanding of scientific thinking. • Their strategies of working scientifically. • Their teamwork and communication skills. • Their evaluation skills. • Their ability to apply theoretical knowledge to real-life situations. • Their skills in the use of ICT.	• Completion of Activity 1 and 2.	30 min

Introduction

Mars is one of the planets of our Solar System that is visible to the naked eye and therefore it has been known since humans first started to watch the sky. The first observations of Mars using a telescope were made by Galileo Galilei in 1610. Within a century, astronomers made various discoveries about the planet, such as dark and light patches on its surface and the presence of polar ice caps.

In the 19th century some astronomers suggested that it might be home to intelligent life. This idea was popularly accepted until the 1970s when the first space missions travelled to Mars and returned high resolution images from its surface showing no evidence of life as it was known on Earth.

Whilst Mars and the Earth are seemingly very different places today, they share a common history: they were born from the same swirling cloud of gas and dust, with the new-born Sun at the centre. Mars is an interesting world and exploring it can help us to further understand rocky planets in general, including the important processes of our planet, the Earth.

One of the many spacecraft currently orbiting the Red Planet (as of 2019) is the European Space Agency's Mars Express mission. On-board this spacecraft there are different instruments capable of measuring the composition of the planet and its thin atmosphere. These instruments include the Visual Monitoring Camera (VMC) that has taken thousands of images of Mars and is able to image the entire disk of the planet (in visible light). Although the VMC was initially an engineering camera, it has become a key scientific instrument for the monitoring of regional and global processes on Mars, such as the evolution of clouds, dust storms and the polar caps.

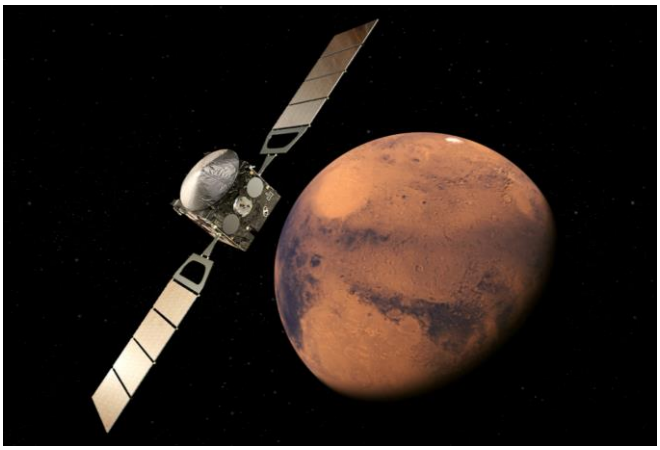


Figure 1: *Artist's impression of Mars Express at Mars. Credit: ESA/ATG medialab.*

Through a series of activities the students will explore the similarities and differences between Mars and the Earth with a focus on the seasons of both planets. The students will then analyse images acquired by the VMC to determine in which season the data was captured before they calculate the length of a Martian year.

Background

Seasons

Life on Earth would be very different if there were no seasons. Not only is biodiversity and global migration affected by the seasons, but also the shape of the terrain of our Earth (mountains, rivers, coasts, and more) is affected. For thousands of years humans had to take the seasons into account to survive and later they also became very important for agriculture.

Similar to Earth, the rotation axis of Mars is inclined with respect to its orbit. Therefore Mars also has seasons. In the winter season, sunlight does not reach the poles, but in summer they are continuously illuminated. As a consequence, **the ice covering the poles of the Red Planet changes with the seasons.**

The Red Planet

Celestial neighbours Mars and Earth have many similarities, for example, they both have seasons, and a day on Mars is just slightly longer that an Earth day. They also have many differences, such as the length of their years; a Mars year takes approximately two Earth years. Some comparisons between Mars and the Earth are outlined in Figure 4 (for more comparisons check the Mars Booklet).

Since the beginning of the space age, dozens of spacecraft from different space agencies around the world have explored Mars. They have provided scientists with a wealth of data, furthering our knowledge of the Red Planet, but also opening up many new questions for future Mars explorers to investigate. Has life ever existed on Mars? Was Mars once partially covered by a sea that slowly disappeared with time?

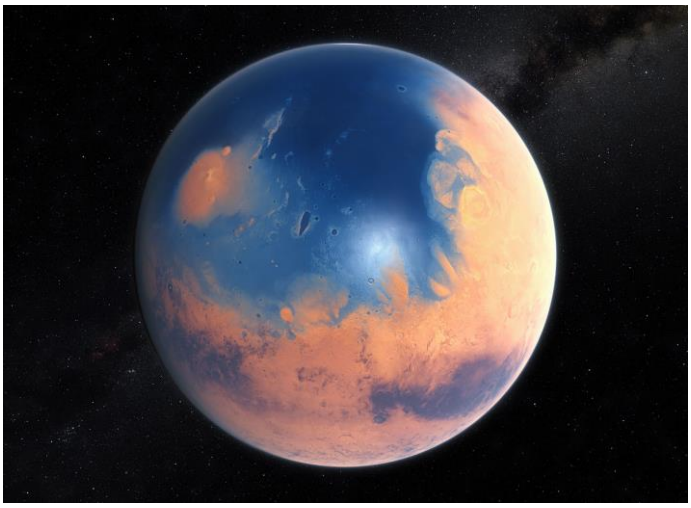


Figure 2: *Artist's impression of how Mars may have looked four billion years ago. Credit: ESO/M. Kornmesser/N. Risinger (skysurvey.org).*

In the coming decades, ESA plans to explore Mars further with more robotic missions, and perhaps one day humans will set foot on Mars. For that reason we need to know more about what they will find there.

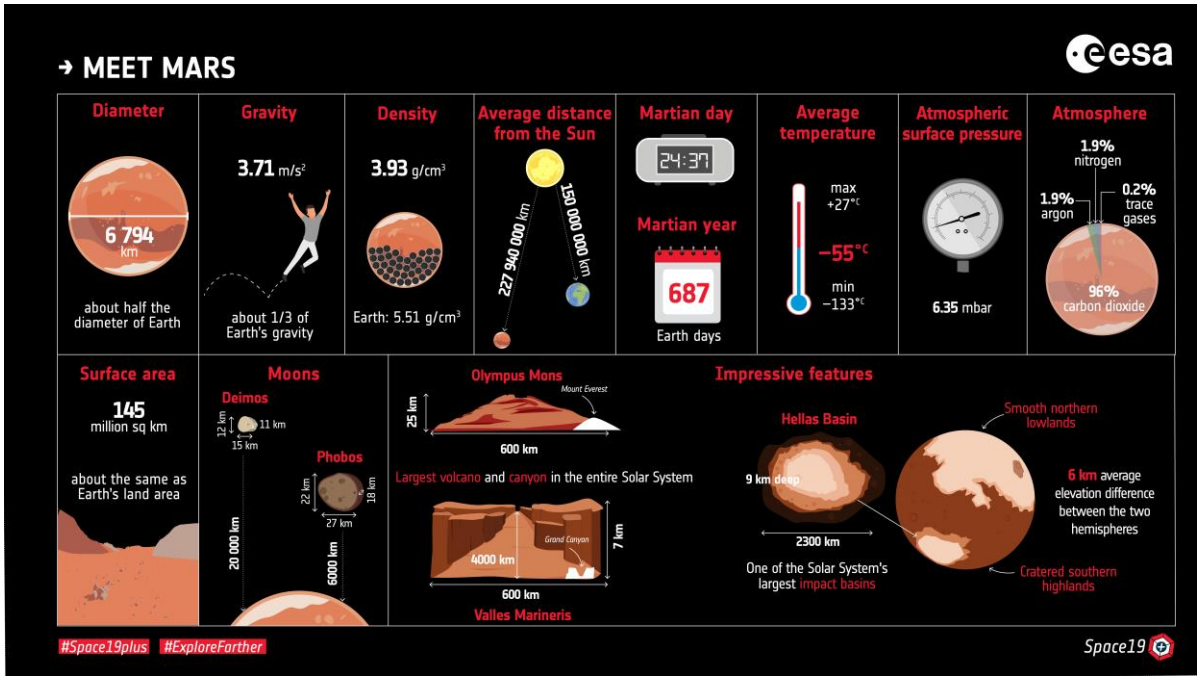


Figure 3: *Mars fast facts that are interesting for comparing it with Earth. Credit: ESA*

Investigating Mars

Activity 1: Compare Mars and Earth

Provide the students with the Mars fact cards (see Annex) and ask them to complete Table 1. The students could do further research about Mars if they have access to other sources of information, such as the CESAR Mars Booklet or the internet (see links section).

	Earth	Mars
Radius	6378 km	3396 km
Colour	Mainly blue	Brown
Tilt in axis	23.5 degrees	25 degrees
Atmosphere	Yes, very dense	Yes, very thin
Polar ice caps	Yes	Yes
Average temperature	14ºC	-63ºC

***Table 1**: Comparison of some properties of Mars and Earth.*

Activity 2: The seasons

Activity 2.1:

The first thing the students need to understand is how seasons work. Emphasise to the students the importance of the seasons for our existence. If they already know about the seasons, they can jump to their first task which is to complete the missing information in a diagram.

The students have to label the seasons for Earth's Northern Hemisphere and the inclination of the Earth's rotational axis. Ask your students: What causes the seasons?

It is commonly thought that the seasons are caused by the Earth being closer to, or further from the Sun as it orbits, but this is not the case. **The difference between the seasons is the angle at which the Sun's rays hit the surface of the Earth**. **This angle of incidence is due to the inclination of the Earth's rotational axis.**

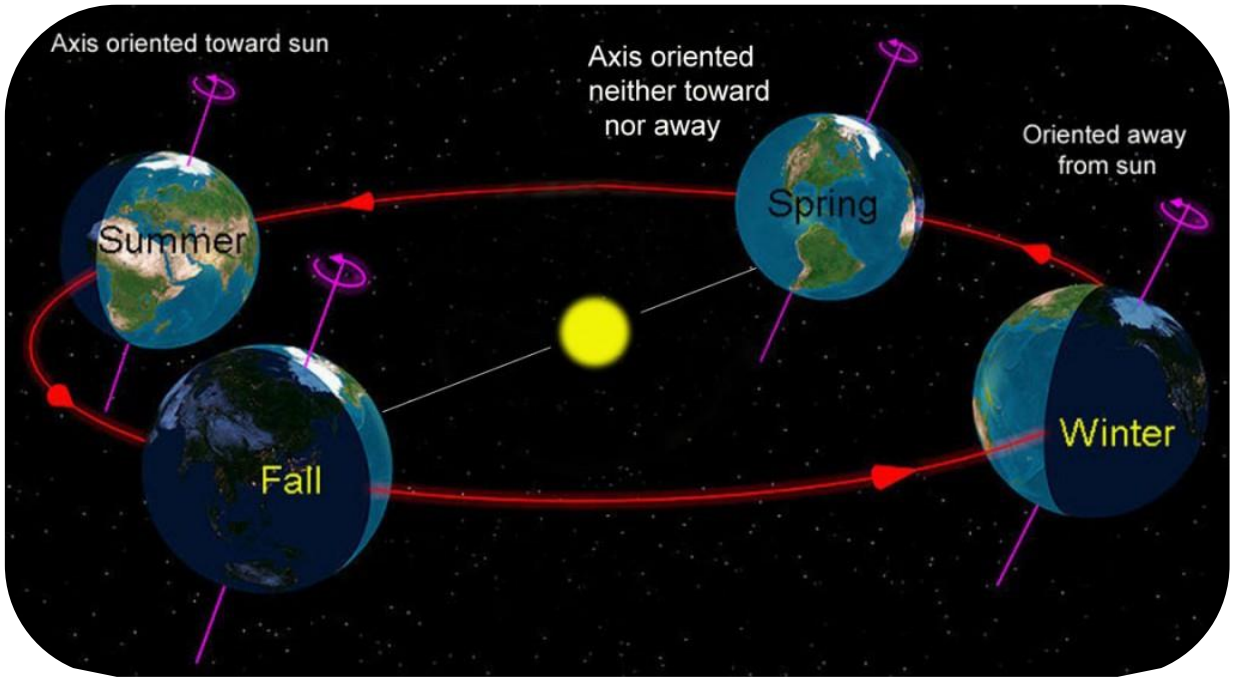


Figure 4: *Illustration of Earth's seasons (for the Northern Hemisphere) and its rotational axis. (Credit: Tao-olunga)*

The **ecliptic plane** is the plane where all the planets are located when orbiting around the Sun. The Earth's rotational axis is tilted about 23 degrees with respect to this ecliptic plane. Because the angle of the axis is fixed, we see the Sun at different altitudes at different times of the year.

Figure 4 shows that when it is summer in either of the hemispheres, the Sun is high up in the sky and its light hits the Earth at a higher angle than in winter, when the Sun is closer to the horizon. The higher the angle, the more the Earth is heated, because it receives the radiation with more efficiency and for a longer period of time.

The students need to know that, as for the Earth, the rotation axis of Mars is tilted, and that this is the main reason why there are seasons on both planets. Another reason for the existence of seasons is that the orbit of both planets is not perfectly circular. There is a small eccentricity which also plays an important role in the climate.

The students are then asked to think about differences between the seasons on Earth and Mars:

- *Do you think that Mars has seasons?*
- *What do you think the main similarities are between the seasons on Earth and Mars?*
- *What do you think the main differences are between the seasons on Earth and Mars?*

It is interesting to assess the students' knowledge of Mars. To do this, you could search for an image of the Solar System, similar to Figure 5. Show the students where Mars is and open a discussion about the planet.

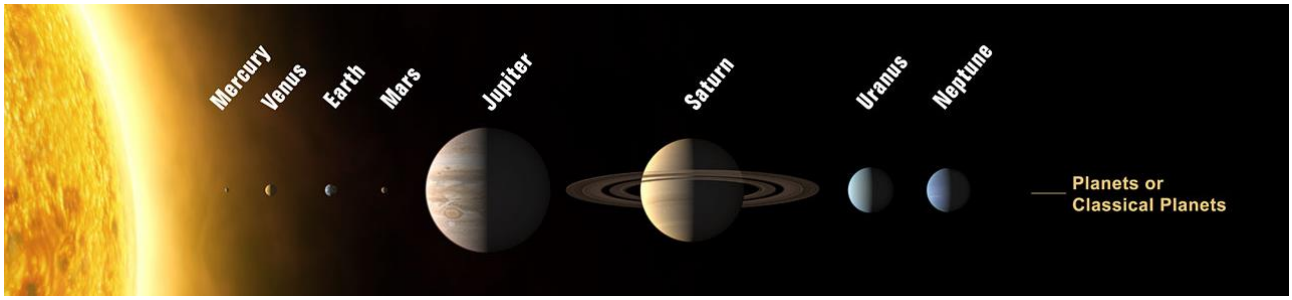


Figure 5: *Illustration of the Solar System (distances not to scale). Credit: The International Astronomical Union/Martin Kornmesser.*

Mars has seasons, but they last for longer because its orbital period is longer than Earth's. On Mars, the main feature that changes with the seasons is the temperature, which can vary by more than 40 degrees Celsius in both hemispheres of the planet. This temperature difference produces dust storms of various scales.

Not all planets in the Solar System have seasons, and between those that do, there are some exotic differences to Earth. However, **Mars's climatic behaviour is relatively similar to Earth's.**

The students are then asked to label Mars's seasons and rotational axis on the diagram in their Student Guides, see Figure 6.

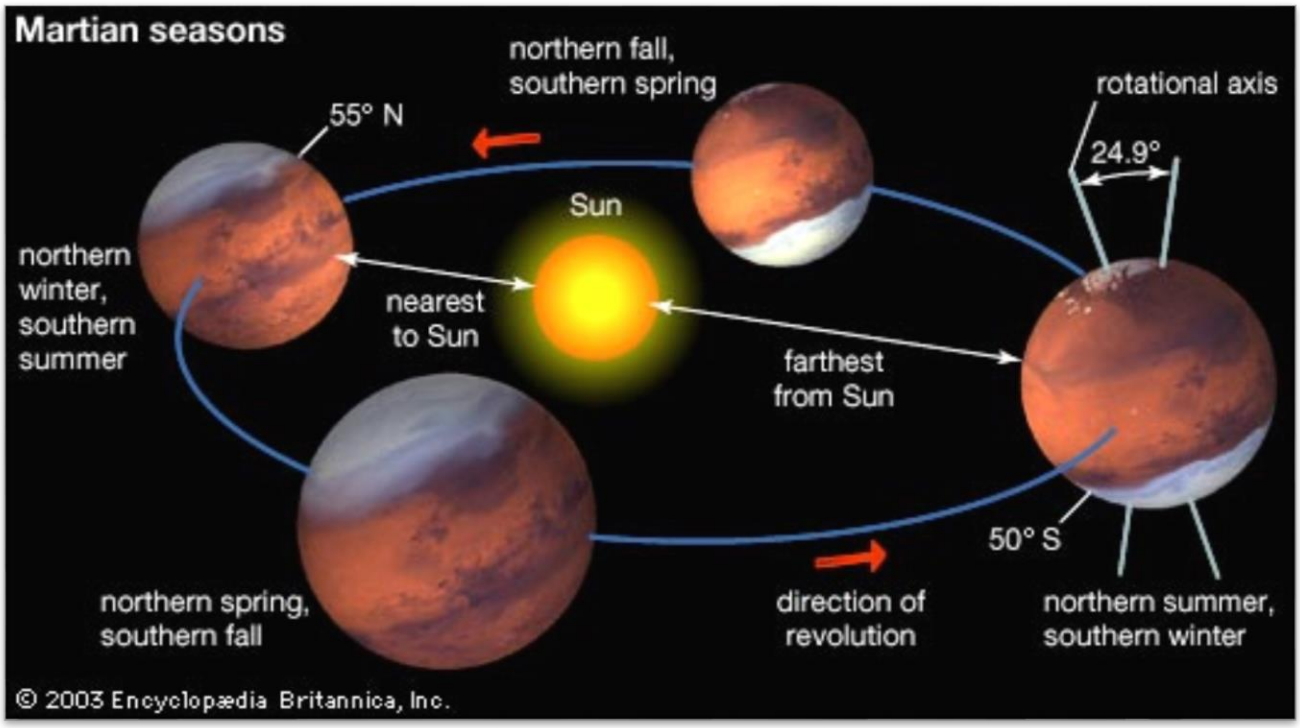


Figure 6: *Illustration of the Martian seasons. (Credit: Encyclopaedia Britannica)*

Activity 2.2:

Now it is time for the students to use the Seasons on Mars webtool:

http://cesar.esa.int/tools/18.martian_year/

In this activity, the students will learn about the seasons on Mars. They will understand the relationship between the illumination on both hemispheres of the planet and how the polar caps change in size, like they do on Earth.

The students choose to either look at images of the north pole or the south pole, and workout which season belongs to each image. For this activity the students can look at the size of the polar caps. When they are bigger the season is spring/autumn (when it is winter, the poles are in darkness so we cannot photograph them) and when they are smaller it is summer.

Figures 7 and 8 show the solutions:

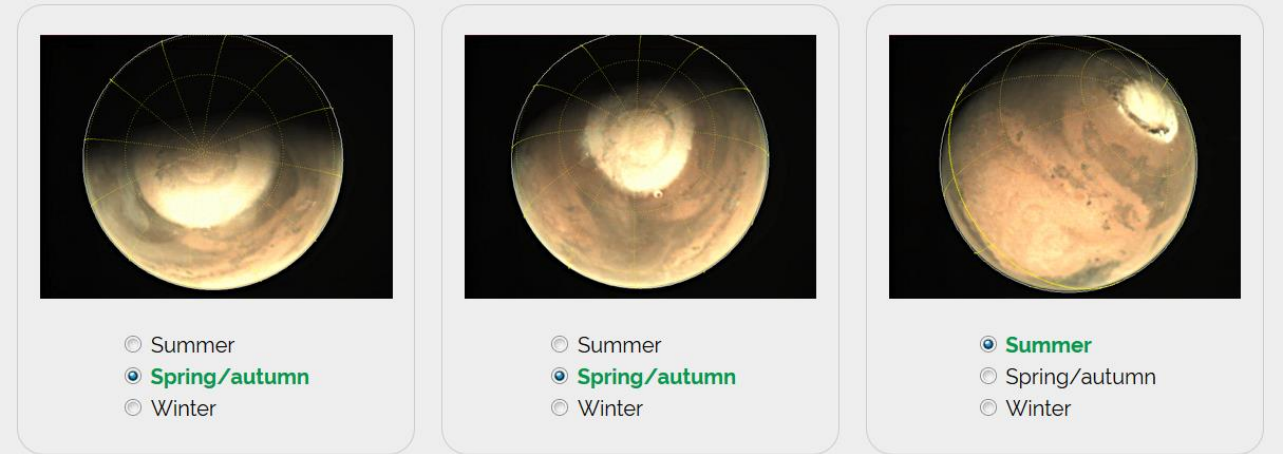


Figure 7: *Northern hemisphere. Credit: ESA/Mars Express/VMC – CC BY-SA IGO 3.0*

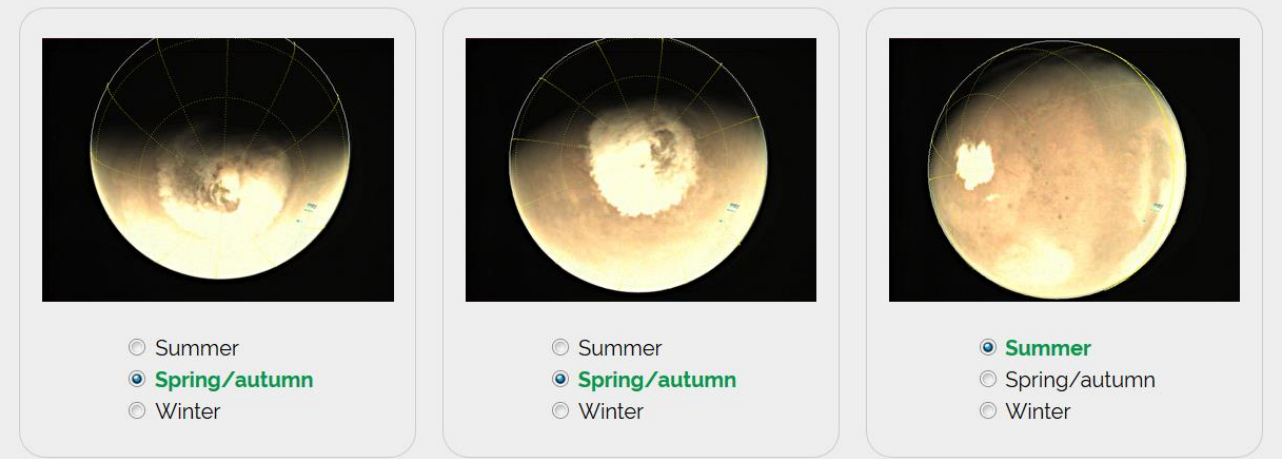


Figure 8: *Southern hemisphere. Credit: ESA/Mars Express/VMC – CC BY-SA IGO 3.0*

On Mars, just like on Earth, the north or south pole doesn't receive any light during winter. In the cold of the winter, the carbon dioxide (CO_2) freezes and forms the polar caps. In summer the opposite takes place. When winter ends and light from the Sun starts to heat the poles, the CO_2 from the caps passes from solid to gas state (it starts to sublimate). As time passes and temperatures increase, the polar caps melt and the CO_2 returns to the atmosphere. The polar cap then significantly reduces in size.

Activity 3: How long is a Martian year?

In this activity, the students estimate the duration of the Martian year using the VMC images and the information of the date and time associated with them. After completing Activity 2.2, where they learn how to identify the Mars seasons in one of the hemispheres, students need to choose a selection of images that cover one Mars year, based on their understanding of how the icy polar caps of Mars evolve over the course of a year.

Steps 3-5 in the Seasons on Mars webtool:

http://cesar.esa.int/tools/18.martian_year/

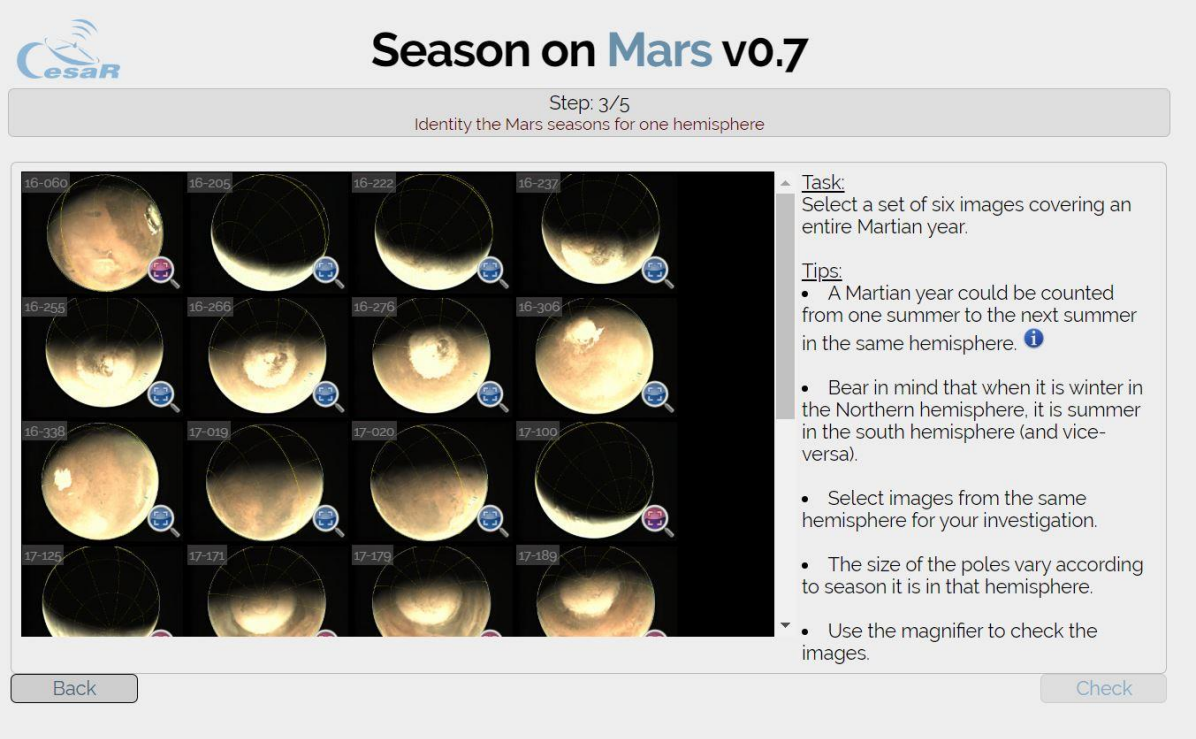


Figure 9: *Step 3 of the webtool - image gallery. Credit: ESA/Mars Express/VMC – CC BY-SA IGO 3.0*

Step 3 of the webtool provides a gallery of images showing the northern and southern hemispheres of Mars. The students must select images from the same hemisphere. The hemisphere can be identified by the colour of the magnifying glass icon in each image: pink indicates images of the northern hemisphere and blue the southern hemisphere (see Figure 9).

Students should take into consideration that: (1) As on Earth, when a pole is more illuminated, it is likely to be summer, while when it is dark, it is likely to be autmn/ early spring or winter.

Note: Some of the images that look almost dark correspond to winter, but it is more difficult to use those images because the surface of the planet is overexposed and the poles are not visible. However, what the students need to realise is that in those images the polar ice caps are in shadow.

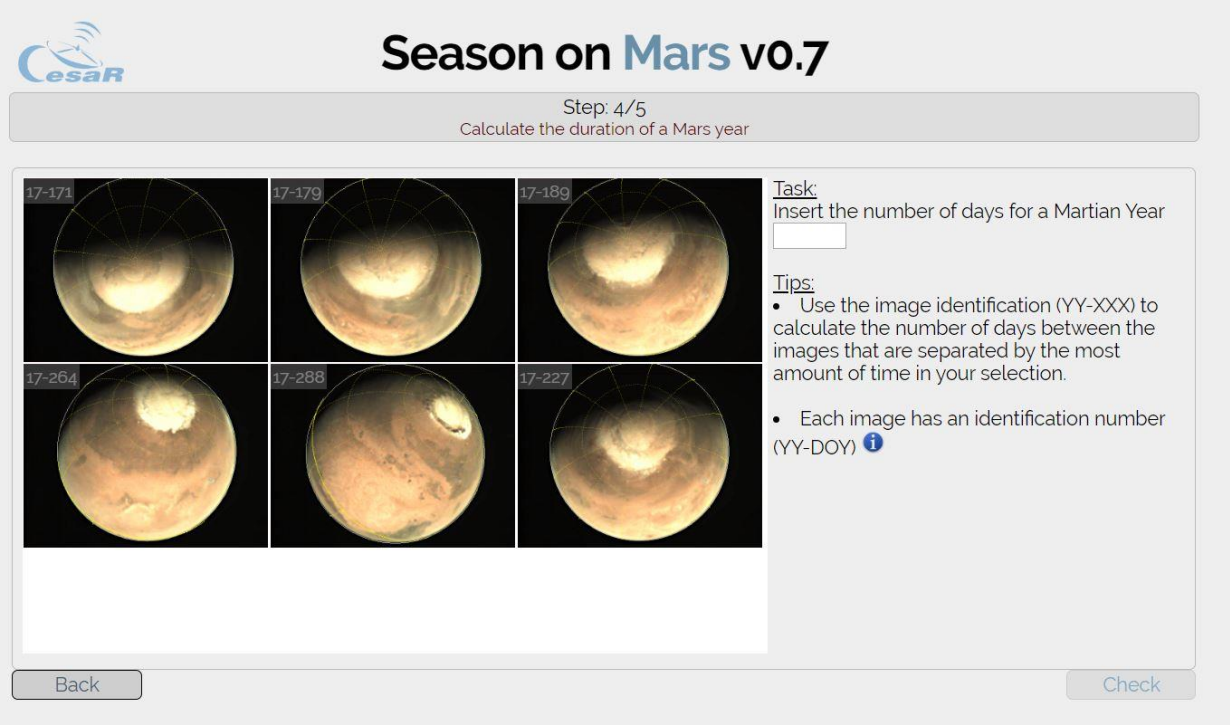


Figure 10: *Step 3 of the webtool - image gallery. Credit: ESA/Mars Express/VMC – CC BY-SA IGO 3.0*

Using the images they selected the students need to identify the duration of a Mars year. Every image has an identification number which is actually the date it was taken: YY corresponds to the last two numbers of the year when the image was collected, i.e. 16 refers to the year 2016. DOY corresponds to the day of the year which has values from 1 to 365 (or 366 in a leap year), i.e. 32 corresponds to the 2 February. For reference the dates of the images shown in Figure 10 are summarised in Table 2. These dates are then used for an example calculation.

Year	Day
2016	60
2017	171
2017	189
2017	227
2017	259
2017	288

Table 2*: Example image dates for calculating a Mars year.*

The duration of a Mars year can then be calculated as follows, using the earliest and latest dates from the images selected:

$$288 \text{ days [from 2017]} + (365\text{-}60) \text{ days [of 2016]} = 288 + 305 \text{ days} = 593 \text{ days} = \text{N}$$

Once the students have entered their value for the duration of a Mars year into the webtool, the accuray of their result will be displayed, see Figure 11.

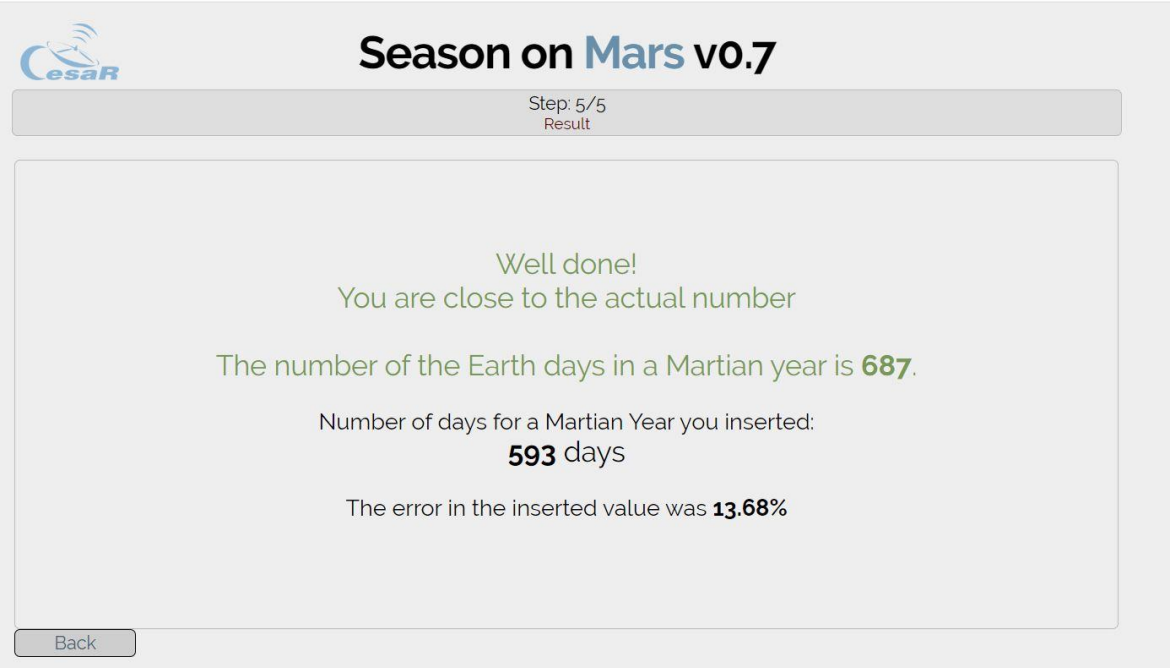


Figure 11: *Step 5 of the webtool, showing a good value for the length of a Mars year.*

The result that students will obtain for the length of the Mars year will depend on the dates in the images they select. If the difference between the dates of the earliest and latest images is too low, the value for the length of the Mars year will also be low, resulting in a greater error. This is also indicated by the webtool in Step 5 (See Table 3 and Figure 12).

Year	Day
2016	60
2017	100
2017	125
2017	171
2017	179
2017	189

Table 3*: Example image dates for calculating a Mars year.*

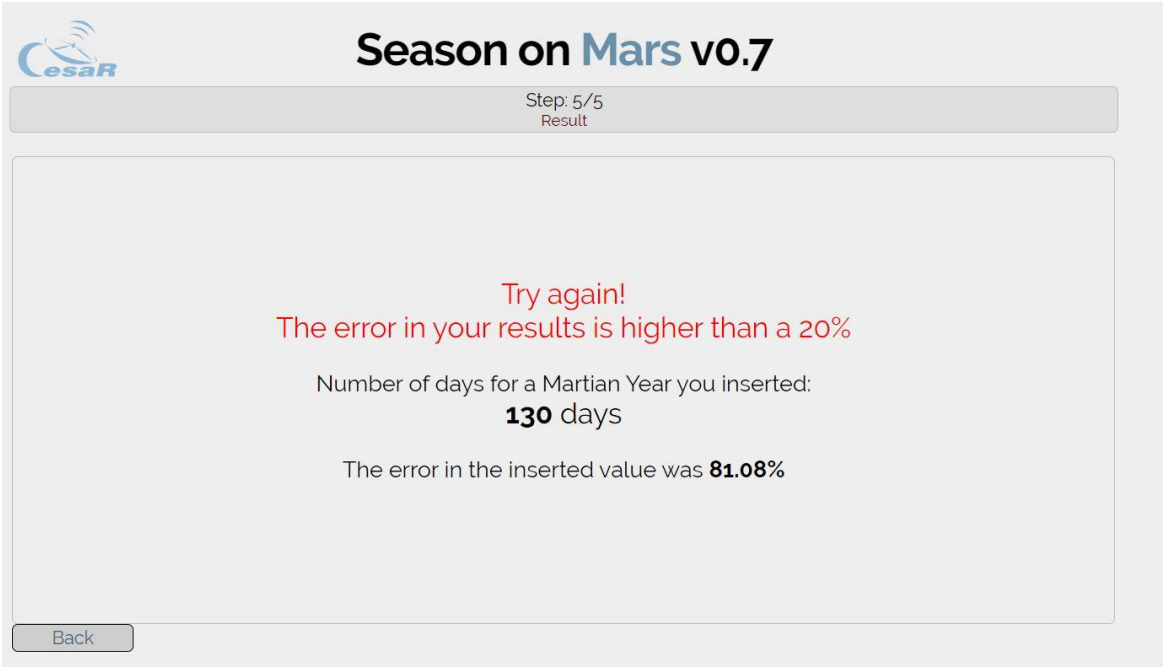


Figure 11: *Step 5 of the webtool, showing a low value for the length of a Mars year.*

Compare and discuss the results of your students with a focus on the importance of observations and conclusions, rather than the exact value.

Links … to know more

ESA Mars Express mission

- ESA: Mars Express overview: http://www.esa.int/Our_Activities/Space_Science/Mars_Express
- ESA: Mars Express in depth: http://sci.esa.int/mars-express/
- Achievements: http://blogs.esa.int/mex/files/2013/06/Mars-Express-10-year-highlights.png

Mars

- ESA: The Red Planet: http://exploration.esa.int/mars/44997-the-red-planet/
- CESAR Booklet: Mars: http://cesar.esa.int/upload/202004/bookletmars_v6_spanish.pdf
- ESA: Life on Mars: http://exploration.esa.int/mars/43608-life-on-mars/
- ESA: Mars infographics: http://www.esa.int/Our_Activities/Human_and_Robotic_Exploration/Exploration/ExoMars/Highlights/Ten_things_about_Mars

Seasons

- Simulation: Seasons and ecliptic simulator: http://astro.unl.edu/classaction/animations/coordsmotion/eclipticsimulator.html
- Simulation: Time-Lapse Seasons Demonstrator: http://astro.unl.edu/classaction/animations/coordsmotion/transitmovie.html

ESA Education Teach with Space classroom resources

- Could like survive in alien environments?: https://www.esa.int/Education/Teachers_Corner/Could_life_survive_in_alien_environments_-_Defining_environments_suitable_for_life_Teach_with_space_B09

- Astrofarmer: www.esa.int/Education/Teachers_Corner/Astrofarmer_-_Learning_about_conditions_for_plant_growth_Teach_with_space_PR42

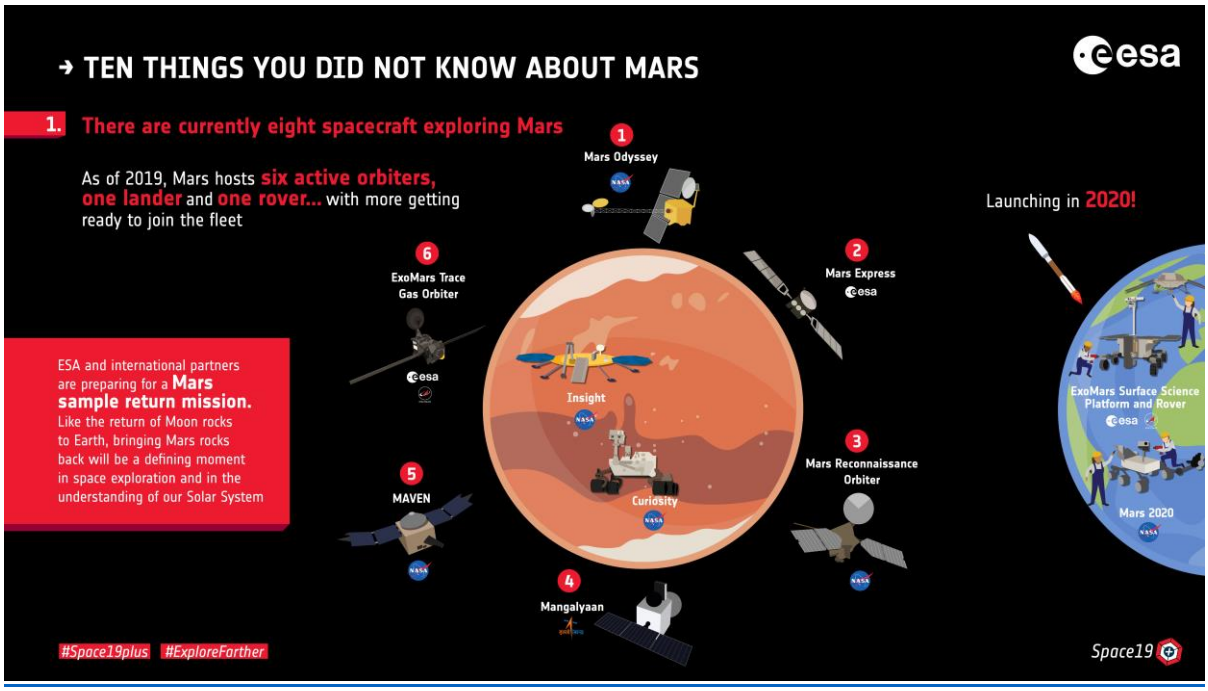
- Astrofood: https://www.esa.int/Education/Teachers_Corner/Astrofood_-_Learning_about_edible_plants_in_Space_Teach_with_space_PR41

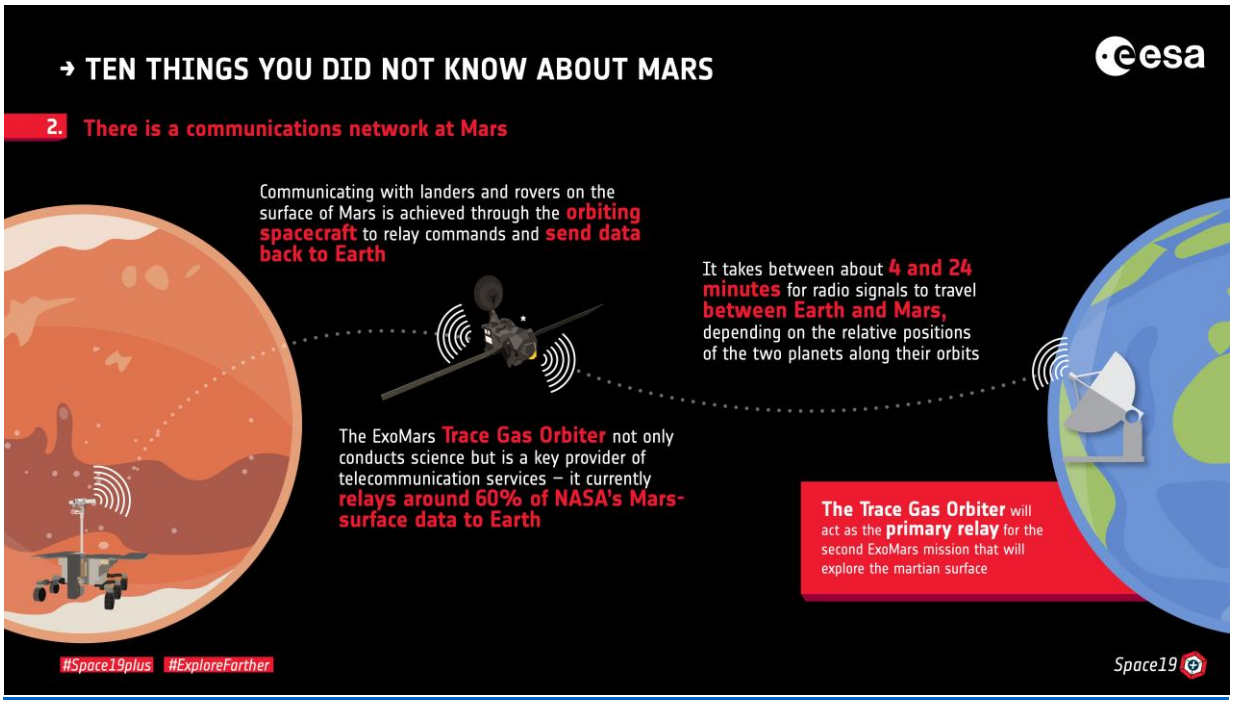
- Plants on Mars: https://www.esa.int/Education/Teachers_Corner/Plants_on_Mars_-_Build_an_automatic_plant_watering_system_Teach_with_space_T09

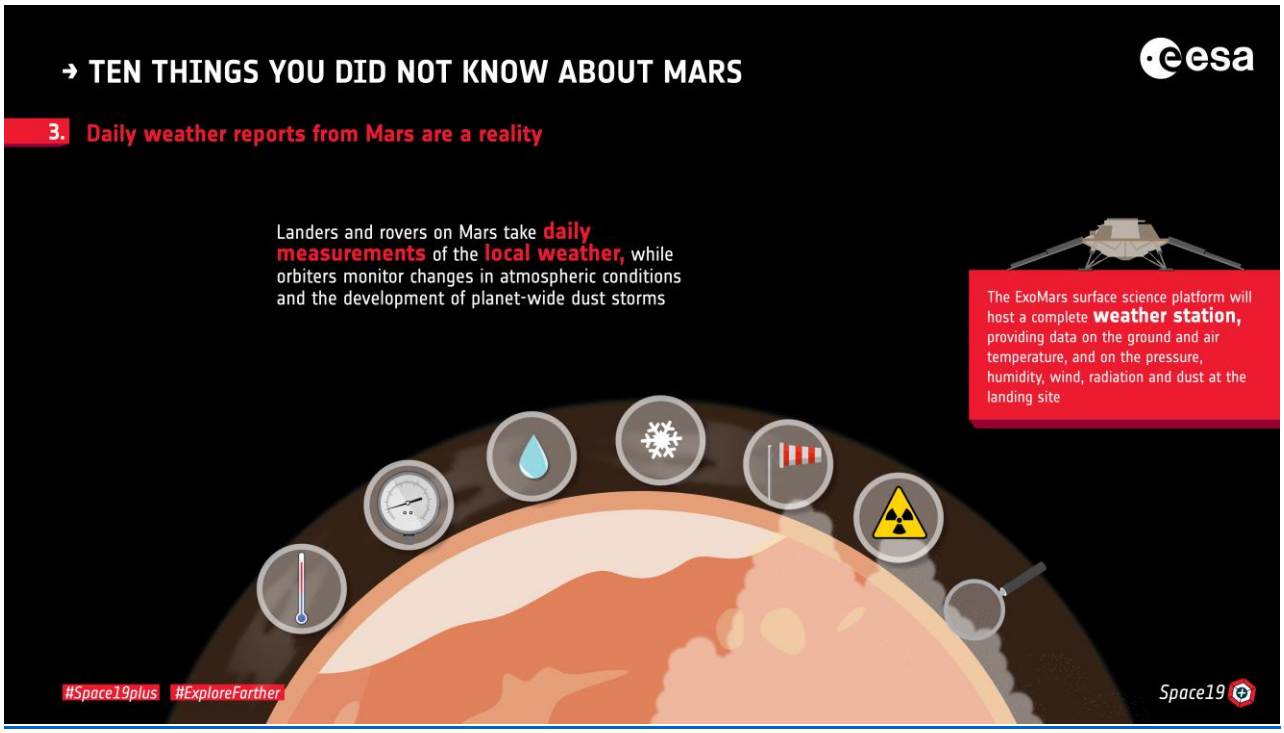
Annex: Mars fact cards

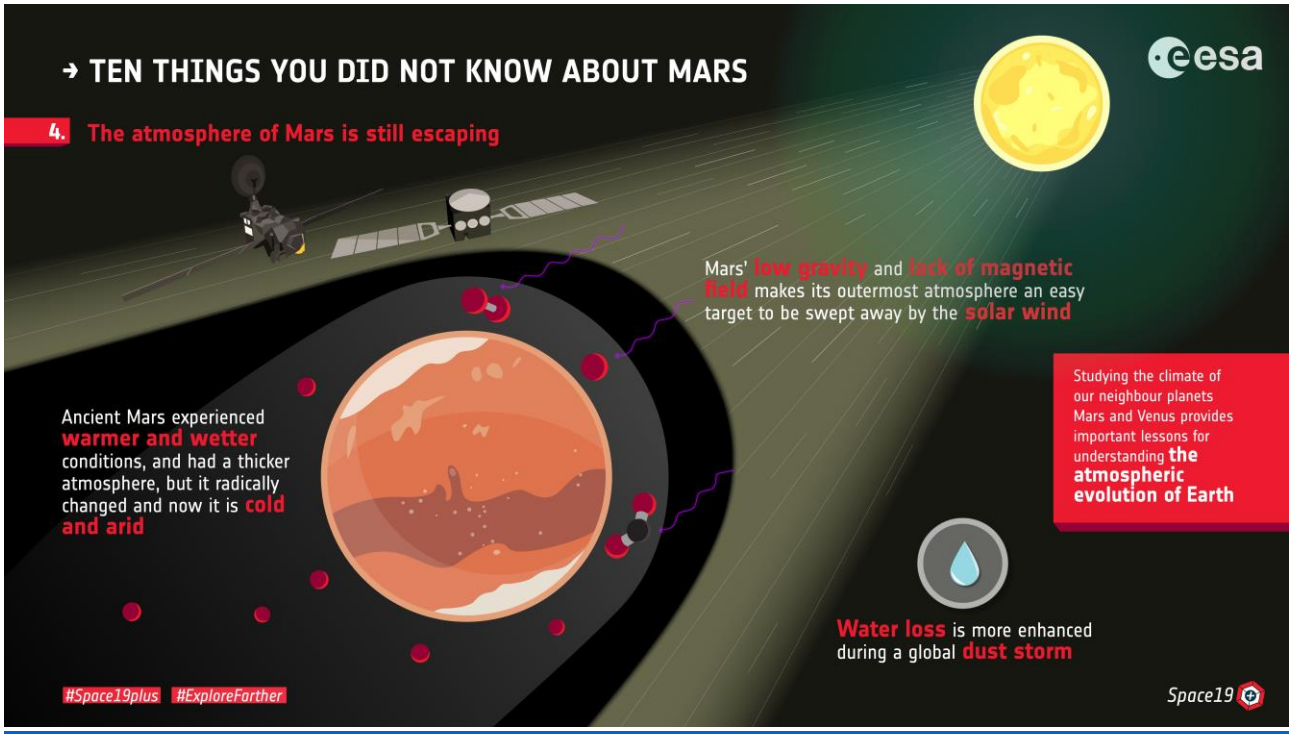
These Mars fact cards can be printed and cut-out to be given to students to complete Table 1 for Activity 1 in their Student Guides. The fact cards are adapted from the ESA All about Mars infographic. The full version of the infographic can be found at:

- https://www.esa.int/Our_Activities/Human_and_Robotic_Exploration/Exploration/ExoMars/Highlights/Ten_things_about_Mars






→ TEN THINGS YOU DID NOT KNOW ABOUT MARS
esa
3. Daily weather reports from Mars are a reality
Landers and rovers on Mars take daily measurements of the local weather, while orbiters monitor changes in atmospheric conditions and the development of planet-wide dust storms
The ExoMars surface science platform will host a complete weather station, providing data on the ground and air temperature, and on the pressure, humidity, wind, radiation and dust at the landing site
#Space19plus #ExploreFarther
Space19


→ TEN THINGS YOU DID NOT KNOW ABOUT MARS
esa
4. The atmosphere of Mars is still escaping
Mars' low gravity and lack of magnetic field makes its outermost atmosphere an easy target to be swept away by the solar wind
Ancient Mars experienced warmer and wetter conditions, and had a thicker atmosphere, but it radically changed and now it is cold and arid
Studying the climate of our neighbour planets Mars and Venus provides important lessons for understanding the atmospheric evolution of Earth
Water loss is more enhanced during a global dust storm
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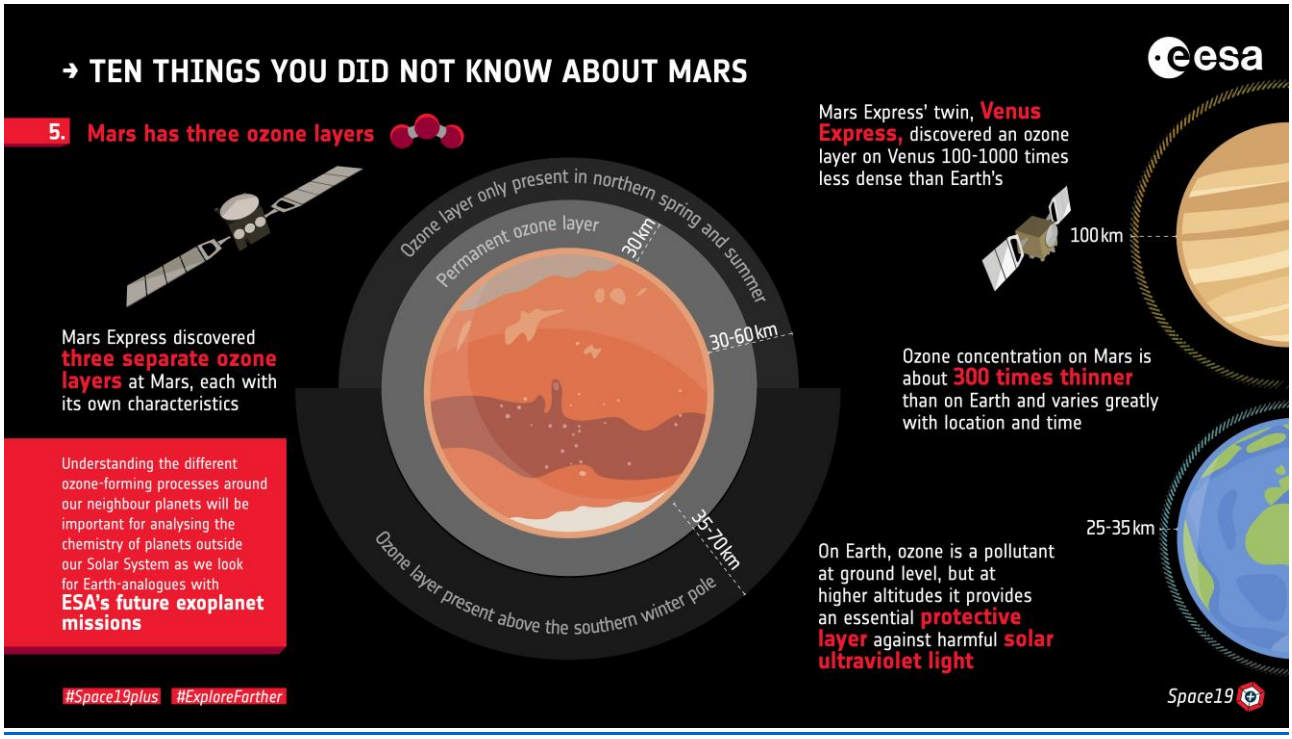
Space19


→ TEN THINGS YOU DID NOT KNOW ABOUT MARS
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5. Mars has three ozone layers
Mars Express discovered three separate ozone layers at Mars, each with its own characteristics
Understanding the different ozone-forming processes around our neighbour planets will be important for analysing the chemistry of planets outside our Solar System as we look for Earth-analogues with ESA's future exoplanet missions
Ozone layer only present in northern spring and summer
Permanent ozone layer
30km
30-60km
35-70km
Ozone layer present above the southern winter pole
Mars Express' twin, Venus Express, discovered an ozone layer on Venus 100-1000 times less dense than Earth's
100km
Ozone concentration on Mars is about 300 times thinner than on Earth and varies greatly with location and time
25-35km
On Earth, ozone is a pollutant at ground level, but at higher altitudes it provides an essential protective layer against harmful solar ultraviolet light
#Space19plus #ExploreFarther
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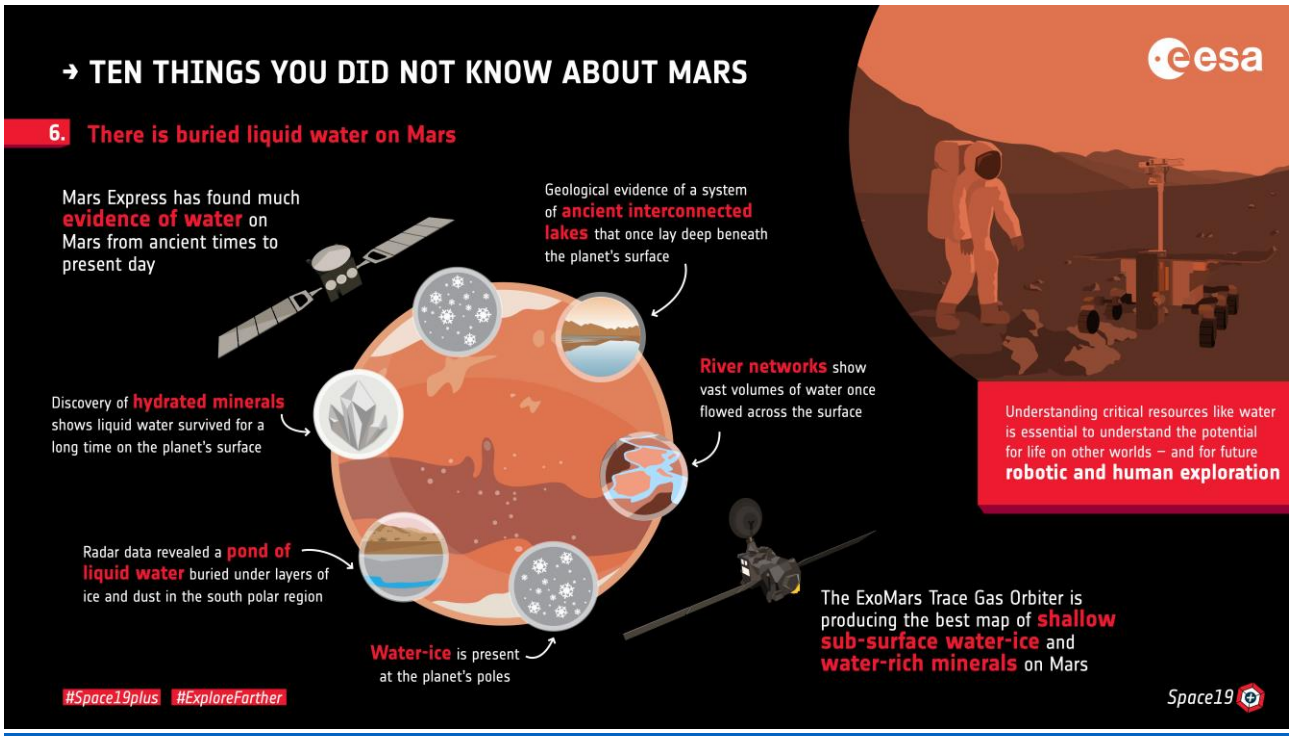
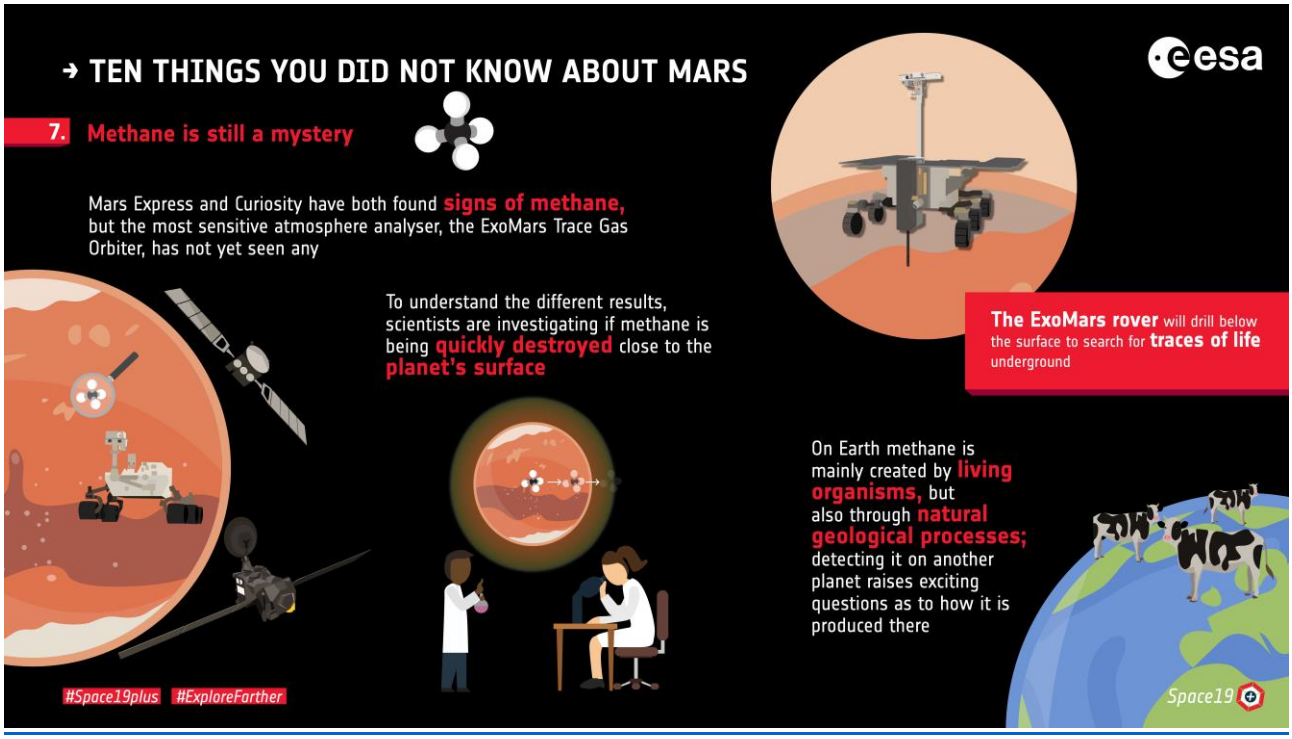
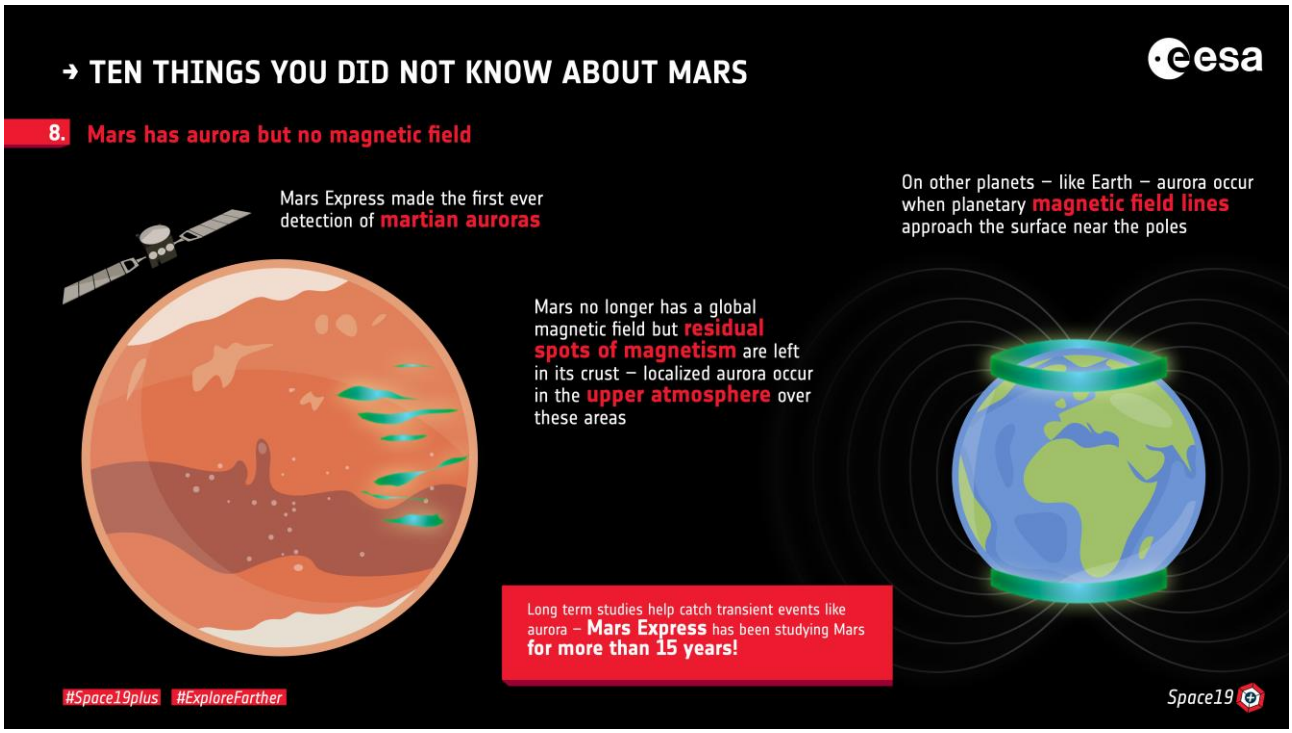

→ TEN THINGS YOU DID NOT KNOW ABOUT MARS
esa
6. There is buried liquid water on Mars
Mars Express has found much evidence of water on Mars from ancient times to present day
Geological evidence of a system of ancient interconnected lakes that once lay deep beneath the planet's surface
River networks show vast volumes of water once flowed across the surface
Discovery of hydrated minerals shows liquid water survived for a long time on the planet's surface
Radar data revealed a pond of liquid water buried under layers of ice and dust in the south polar region
Water-ice is present at the planet's poles
Understanding critical resources like water is essential to understand the potential for life on other worlds – and for future robotic and human exploration
The ExoMars Trace Gas Orbiter is producing the best map of shallow sub-surface water-ice and water-rich minerals on Mars
#Space19plus #ExploreFarther
Space19


→ TEN THINGS YOU DID NOT KNOW ABOUT MARS
esa
7. Methane is still a mystery
Mars Express and Curiosity have both found signs of methane, but the most sensitive atmosphere analyser, the ExoMars Trace Gas Orbiter, has not yet seen any
To understand the different results, scientists are investigating if methane is being quickly destroyed close to the planet's surface
The ExoMars rover will drill below the surface to search for traces of life underground
On Earth methane is mainly created by living organisms, but also through natural geological processes; detecting it on another planet raises exciting questions as to how it is produced there
#Space19plus #ExploreFarther
Space19


→ TEN THINGS YOU DID NOT KNOW ABOUT MARS
esa
8. Mars has aurora but no magnetic field
Mars Express made the first ever detection of martian auroras
Mars no longer has a global magnetic field but residual spots of magnetism are left in its crust – localized aurora occur in the upper atmosphere over these areas
On other planets – like Earth – aurora occur when planetary magnetic field lines approach the surface near the poles
Long term studies help catch transient events like aurora – Mars Express has been studying Mars for more than 15 years!
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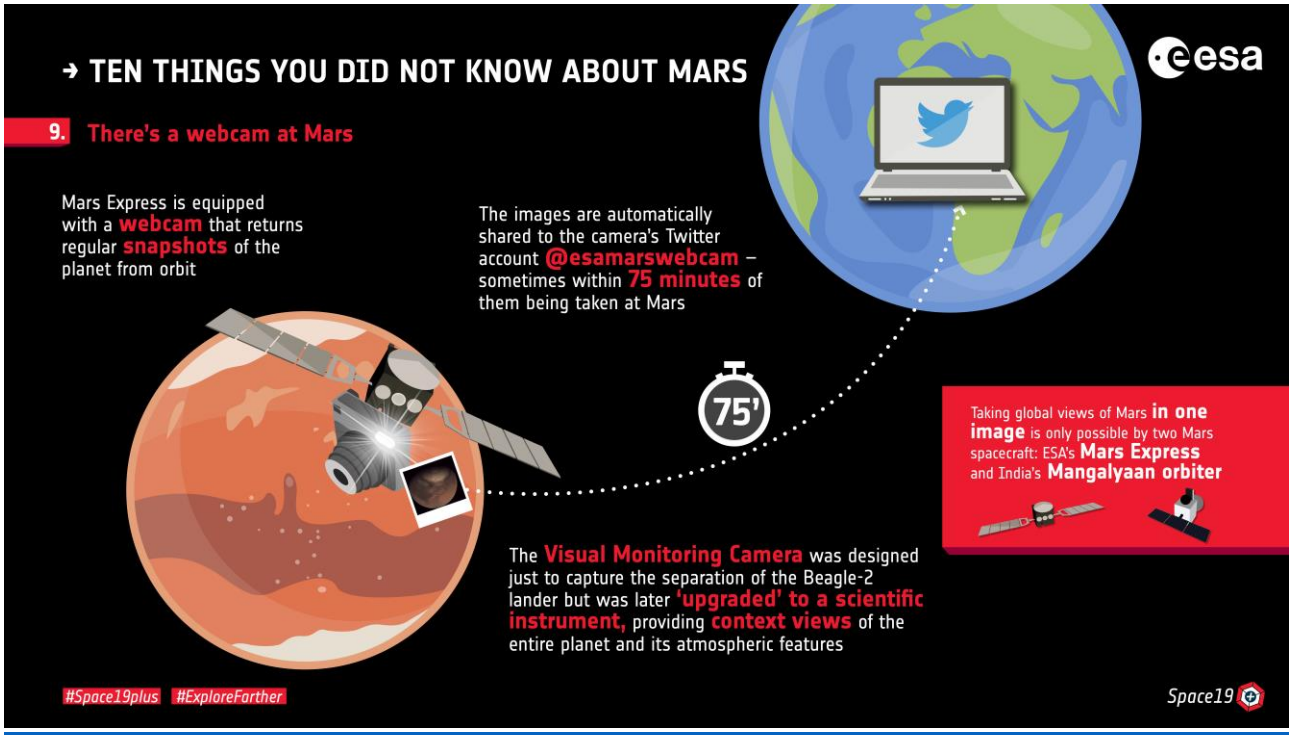
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9. There's a webcam at Mars
Mars Express is equipped with a webcam that returns regular snapshots of the planet from orbit
The images are automatically shared to the camera's Twitter account @esamarswebcam – sometimes within 75 minutes of them being taken at Mars
75'
Taking global views of Mars in one image is only possible by two Mars spacecraft: ESA's Mars Express and India's Mangalyaan orbiter
The Visual Monitoring Camera was designed just to capture the separation of the Beagle-2 lander but was later 'upgraded' to a scientific instrument, providing context views of the entire planet and its atmospheric features
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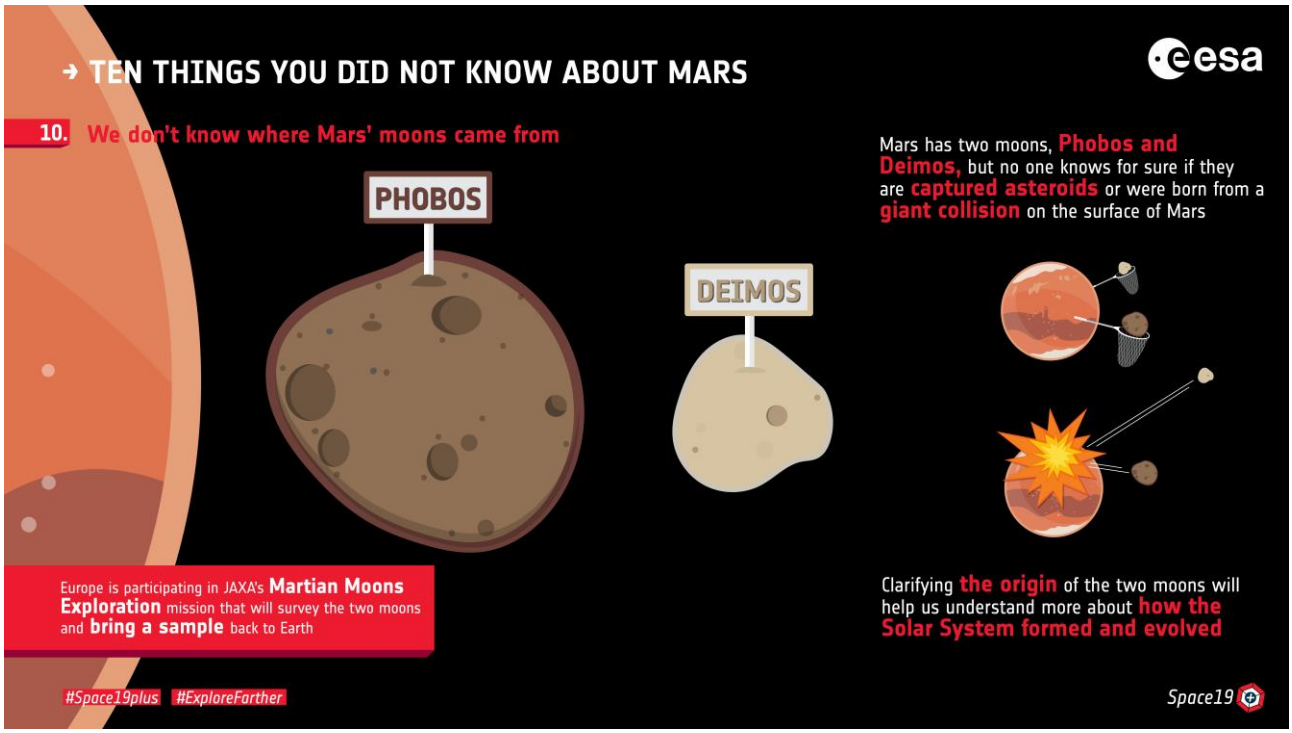
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10. We don't know where Mars' moons came from
PHOBOS
DEIMOS
Mars has two moons, Phobos and Deimos, but no one knows for sure if they are captured asteroids or were born from a giant collision on the surface of Mars
Europe is participating in JAXA's Martian Moons Exploration mission that will survey the two moons and bring a sample back to Earth
Clarifying the origin of the two moons will help us understand more about how the Solar System formed and evolved
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