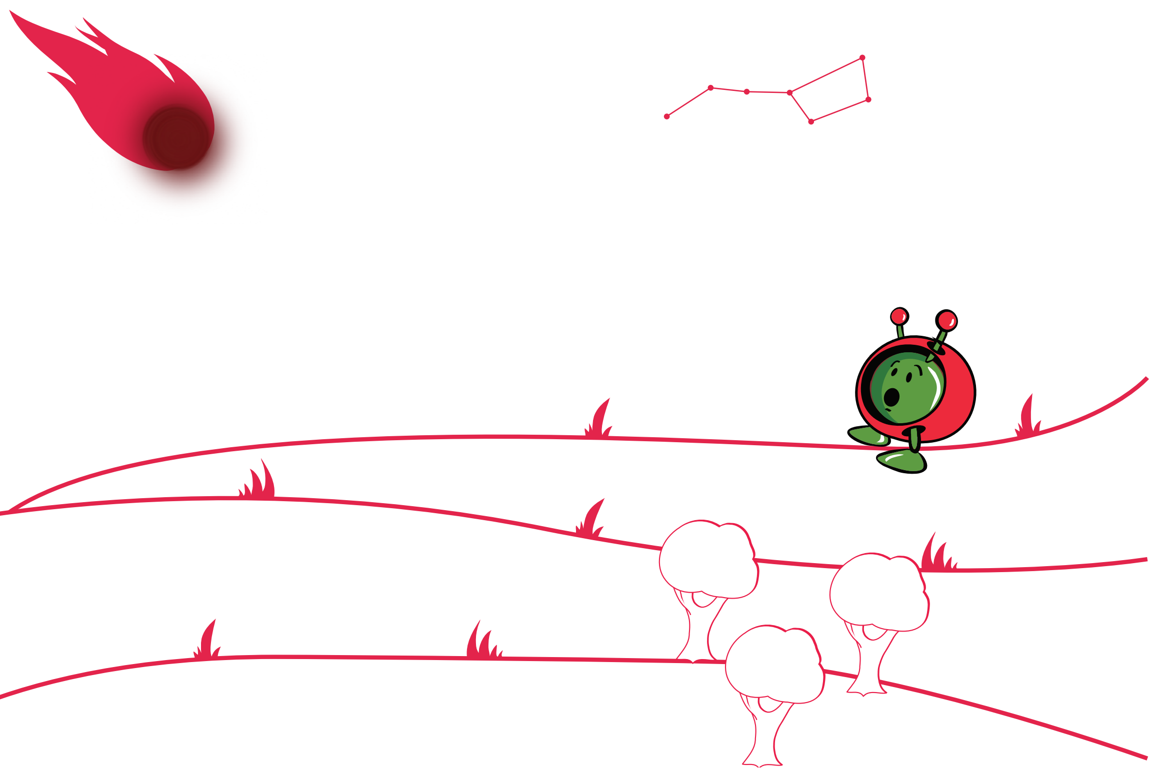
primary | PR04a

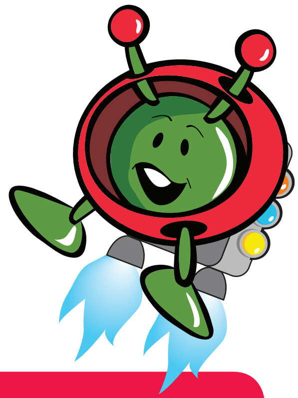
teach with space

→ TELL-TALE SIGNS OF A SHOOTING STAR

Comets, meteors and craters in the Solar System



→ TELL-TALE SIGNS OF A SHOOTING STAR



Comets, meteors and craters in the Solar System

FAST FACTS

Age range: 10–12 years old

Type: teacher demonstration & pupil (group) activity

Complexity: medium

Teacher preparation time: 1 hour

Lesson time required: 2–2.5 hours

Cost per kit: medium (15 euro)

Location: indoor (any classroom)

Includes the use of: fire syringe (optional), camera phone, household items, no hazardous materials

You will also need

1. Extension activities pack (PR04b)

Outline

In this activity pupils will learn that a shooting star, or meteor, is the light produced by a piece of rock as it travels through the Earth's atmosphere. They will also understand why this happens. In groups, pupils will perform simple experiments to investigate how craters are formed when a rock strikes a planetary surface. They will understand that the appearance of a crater depends on the rock size and the angle at which it hits the ground.

Pupils will learn

1. That a shooting star, or meteor, is the light produced by a meteoroid traveling through the Earth's atmosphere.
2. How objects moving at high speeds through the Earth's atmosphere can cause rapid air compression and this leads to a large rise in temperature.
3. How to perform scientific experiments, specifically to investigate how rocks produce craters.

Curriculum relevance

Science

- Plan a study to answer scientific questions
- Recognise and control variables where necessary
- Take measurements with increasing accuracy and precision
- Use test results to make predictions to set up further comparative and fair tests
- Report and present findings from a scientific study in oral and written form
- Identify the effects of air resistance, specifically related to rapid air compression

Literacy

- Ask relevant questions to extend their understanding and knowledge
- Give well-structured descriptions, explanations and narratives for different purposes
- Use discussion in order to learn, elaborate and clearly explain their understanding and ideas
- Maintain attention and participate actively in collaborative conversations
- Speak audibly and fluently
- Make formal presentations and participate in debate

Tell-tale signs of a shooting star

To many ancient civilisations, the tale of a shooting star was an omen of things to come. Today, some people still wish upon shooting stars for good fortune. In reality a shooting star, or meteor, is the light produced by a piece of rock that travels through Earth's atmosphere. This piece of rock is called a meteoroid.

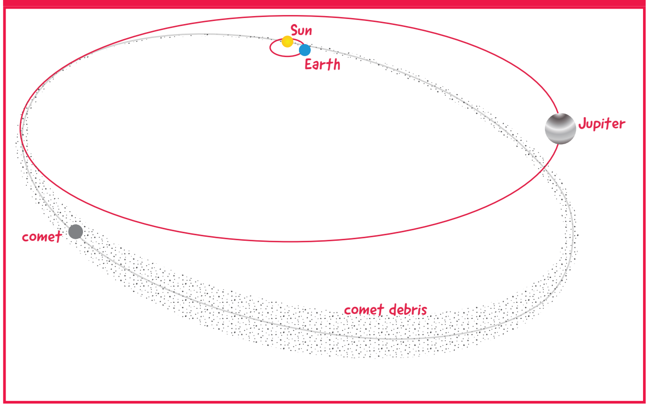
The chance of viewing a shooting star is greater during meteor showers. A meteor shower occurs when the Earth passes through a region of space with a relatively large amount of dust and small particles. These dusty regions of the Solar System are typically associated with the paths (or orbits) of comets - icy visitors from the outer Solar System[1].

A comet is made up mostly of ice and rocky material. When a comet approaches the Sun, it heats up and starts to lose material forming a spectacular tail as shown in Figure A1. The material, or comet debris, does not disappear into space, it continues to follow the comet's orbit around the Sun. If the Earth's orbit crosses the orbit of a comet, as shown in Figure A2, the debris may collide with Earth's atmosphere and result in a meteor shower. Meteor showers therefore occur at certain times during the year. The most visible meteor showers are the Perseid (mid August) and Leonid (mid November) meteor showers. The Perseid shower is caused by comet 109P/Swift-Tuttle and the Leonid shower is caused by comet 55P/Tempel-Tuttle.

Figure A1

↑ Comet Hale-Bopp in 1997 with its spectacular tail pointing away from the Sun.

Figure A2



↑ Comet debris continues to follow the same path or orbit around the Sun. If the orbits of the Earth and the comet cross, debris will collide with the Earth's atmosphere and result in a meteor shower.

The debris from comets ranges in size from small grains of sand and dust to large boulders. Even larger objects may on occasion enter and survive the journey through the Earth's atmosphere. When a meteoroid hits the ground, it results in the formation of a crater. Astronomers often refer to objects that have already hit the ground as meteorites. Figure A3 shows the relatively large Barringer crater. This was the first meteor crater to be confirmed on the Earth.

[1]To learn more about comets we recommend the ESA teach with space – our Solar System | PR01 teacher guide with pupil activities.

Figure A3

↑ Two different views of the 50 000 year old Barringer crater which is 1.2 kilometres in diameter and situated in Arizona, USA. The meteoroid that created the Barringer crater was only about 50 metres in diameter. This was the first confirmed meteor crater on Earth.

In this activity pupils will learn that a shooting star, or meteor, is the light produced by a piece of space rock (a meteoroid) as it travels through the Earth's atmosphere. They will also learn why meteoroids burn in the atmosphere and investigate how craters are formed when a meteoroid strikes a planetary surface. Craters are of great interest to astronomers, geologists and biologists alike because they can reveal how a planet such as the Earth has evolved over millions of years.

Equipment

Teacher Demonstration

- Fire syringe (optional), available in science/physics shops
- Small piece of cotton wool

Pupil Activity (per group)

- Top lid of A4 carton box (typical size 30 x 22 x 7 cm)
- Large plastic bag
- Flour 1 kg
- Glitter 50 g
- Chocolate powder 50-100 g
- 5-10 marbles of different sizes
- Small plastic spoon
- Ruler
- Sieve
- Phone camera
- Copy of Worksheet – The tale of a shooting star (1 copy per pupil)
- Picture of a crater on Mars (see Appendix)

What is a shooting star?

(15 minutes)

Begin with an introductory discussion to bring all pupils to the same level of understanding. Pupils should understand that a shooting star is not a star but the light produced by a meteoroid as it burns through the Earth's atmosphere. Start by showing the class a picture of a shooting star. Figures A4 and A5 show some examples of shooting stars.

Figure A4

↑ Photograph of a shooting star taken during the annual Perseid meteor shower.

Figure A5

↑ An artist's impression of shooting stars in the foreground (streaks) and stars in the background (points of light).

Split the pupils into groups of four or five. Give each pupil a copy of the Worksheet – The tale of a shooting star. Ask the groups to discuss the images in Task 1. What do they see and what do they think the images show? The pupils can complete the questions in Task 1 on the Worksheet.

Ask a few pupils if they have come up with an explanation for what the images show. Emphasise that the images show distant stars in the background (small dots) and shooting stars or meteors in the foreground (long streaks). These are the light produced by pieces of dust and rock (meteoroids) that have come into the air (atmosphere) that surrounds the Earth. As they travel through the air, the dust and rocks become so hot that they emit light. That is why we can see them glow and leave a fiery trail in the night sky.

How does a meteor light up? (15 minutes)

Meteoroids move very fast through the Earth's atmosphere. Their speed can range from 11 kilometres per second (approximately 40 000 kilometres per hour) to about 72 kilometres per second (approximately 260 000 kilometres per hour) which is much faster than everyday objects. Following the demonstration described on the next page, it should become clear to pupils that when a fast moving object compresses the air in its path it can become hot and glow.

Table A1

Fastest manned vehicles	Actual speed (kilometres per hour)	A slow meteoroid travels
Typical on motorway	120	330 times faster
Wheeled train: TGV	300 (operational) 575 (record)	132 times faster 69 times faster
Motorcycle: Ack Attack	606	65 times faster
Typical airline cruise speed	900	44 times faster
Car: Thrust supersonic car	1 228	32 times faster
Aircraft: SR-71 blackbird	3 530	11 times faster
International Space Station (ISS) orbiting the Earth	25 200	1.5 times faster
Fastest spacecraft re-entry: Apollo 10	39 938	Similar speed

↑ Comparison of the speeds of human vehicles to a slow space rock. A slow meteoroid travels at 11 kilometres per second which is about 40 000 kilometres per hour.

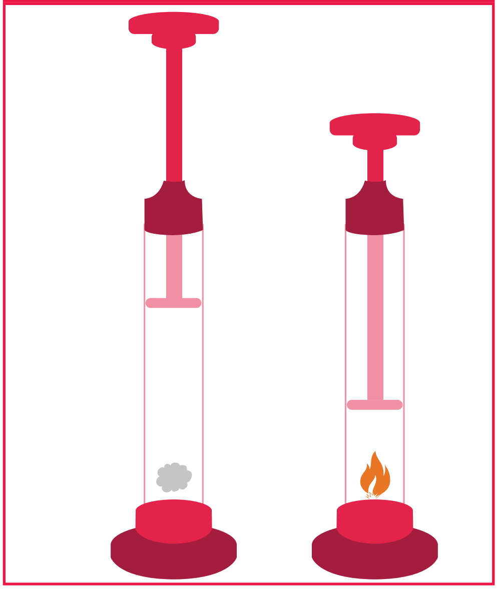
Explain to the class that meteoroids move very fast in the atmosphere. Encourage pupils to think about the fastest human vehicles. You may also use the examples in Table A1 to put the speed of a meteoroid into perspective.

Explain to pupils that when a meteoroid travels through air, it pushes the air in front of it. The pushing results in air being squashed, or compressed, very quickly. It is the high speed at which air gets compressed in front of a meteoroid that causes it to glow. Now demonstrate what happens when air is rapidly compressed in a fire syringe (see Figure A6). Alternatively show the class a video - many are available on the internet.

To help explain the concepts, perform the following demonstration in front of the class:

1. Put a small piece of cotton wool inside the fire syringe. The cotton wool piece should be about the size of a fingernail.
2. Push the piston down gently. The air is compressed slowly. Note that nothing happens.
3. Remind pupils that meteoroids move through the atmosphere at high speeds. Retract the piston back to the top position.
4. Push the piston down fast. The air is compressed rapidly. The cotton wool should auto ignite.
5. Explain that the rapid compression leads to a rapid temperature increase in front of the piston. The same thing happens with a shooting star. The meteoroid and surrounding air becomes so hot that it begins to glow.

Figure A6



↑ Illustration of the fire syringe.

You may want to mention an everyday example of rapid air compression such as pumping up a bicycle or car tire. The bottom part of the pump can become very hot when you inflate the tire. Conclude the demonstration by asking pupils to describe what they just saw.

The fire syringe analogue is true for large objects that come deep into the atmosphere. For smaller objects higher up in the atmosphere, for example most meteoroids, the light is produced in a different way. The meteoroid collides with particles in the air, giving them lots of collisional energy which they then release as light energy. The Aurorae (northern and southern lights) work in a similar way; particles from the Sun hit air particles, which gives them collisional energy that is released afterwards as light energy. The light emission process is similar to the process that occurs in an incandescent lamp.

Did you know?

Meteoroids are not the only objects which heat up when passing through the Earth's atmosphere. In fact, any object moving at high speed through the atmosphere will experience the same effects. When astronauts return to Earth from space, the re-entry vehicle or capsule is covered in thermally insulating materials to shield and protect the astronauts inside. The European Space Agency (ESA) also uses this heating effect to safely dispose of space vehicles at the end of their mission. On 15th February 2015, ESA's fifth and final Automated Transfer Vehicle (ATV-5 Georges Lemaitre) re-entered the atmosphere and burned up safely after successfully delivering supplies to the International Space Station. The other four ATV spacecraft met a similar fate. The spectacular re-entry of ESA's ATV-1 Jules Verne was caught on video (see Links section).

What happens when a shooting star impacts the ground?

(25 minutes)

Small meteoroids typically burn up completely in the atmosphere. Larger meteoroids may survive the trip through the Earth's atmosphere and impact the ground. When this happens, the impact results in the formation of a crater. In this activity, pupils will set up simple experiments to study how craters are formed.

Figures A3 and A7 show some examples of craters on Earth. Larger versions of these examples can be found in the Appendix. Explain that these craters were formed by meteoroids impacting the ground. Craters are also found on the Moon and elsewhere in the Solar System. Figure A8 shows craters covering the lunar surface. Encourage pupils to have a look at lunar craters after school using binoculars. They could also do this during school time in the winter months and/or when the moon is visible during the day.

Pupils will now perform an experiment to understand how craters are formed. Go through the experiment setup in Task 2 on the Worksheet – The tale of a shooting star. You may also want to prepare a demonstration of the experiment.

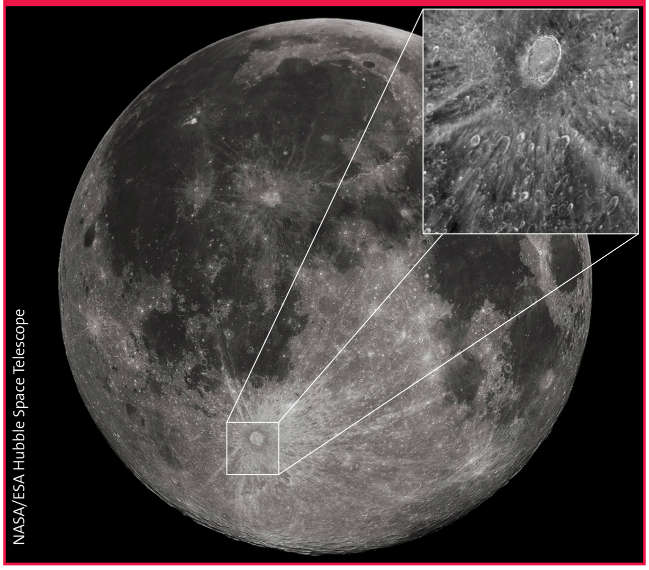
Hand out Task 2 of the Worksheet – The tale of a shooting star and assign each group a different crater on Mars. Table A2 lists some peculiar craters on Mars. Give a picture of the assigned crater to the respective groups (see Appendix). Depending on the class size, it may be necessary to assign the same crater twice.

Following the guidelines in Task 2, each group should come up with a possible explanation of how their assigned crater was formed. They should test their hypothesis in the experiment. Encourage pupils to take pictures of the craters they created to share with the class. You could also consider using a slingshot to fire the marbles to higher velocities.

Figure A7

↑ Pingualuit crater, Northern Quebec, Canada. A large pool of water is present inside the crater.

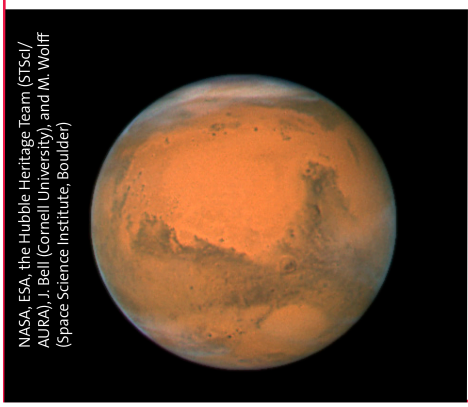
Figure A8



↑ Photograph of the Moon. The Tycho crater in the bottom left is about 102 km in diameter and is clearly visible with a pair of binoculars. Zooming in on the picture reveals a ray-like pattern.

Did you know?

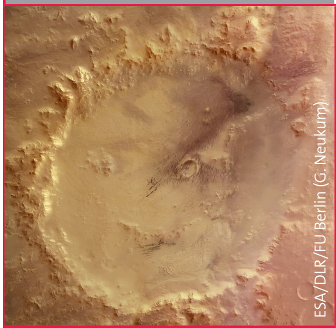
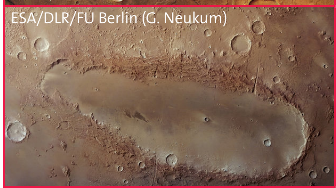
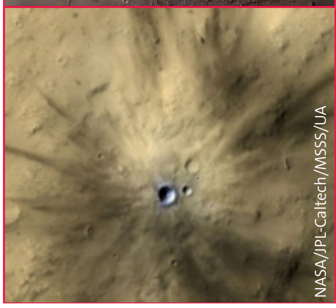
The Hubble Space Telescope is a joint NASA/ESA project and was launched into a low-Earth orbit 600 kilometres above the ground in 1990. The Hubble Space Telescope is one of the largest and most versatile space observatories and is the only space-based telescope designed to be serviced in space by astronauts – since its launch, it has been serviced five times in orbit. From its vantage point outside the Earth's constantly moving atmosphere, which distorts the light reaching the ground from space, Hubble has provided stunning, high resolution images of a variety of astrophysical objects and dramatically changed our view of the Universe.



← The NASA/ESA Hubble Space Telescope took this close-up of the red planet Mars in 2007 when it was just 88 million kilometres away.

→ The NASA/ESA Hubble Space Telescope in low Earth orbit, 600 kilometres above the surface of the Earth.

Table A2

crater	name	how did it form?	description
	Galle or 'Happy Face' crater	Single impact	With a little imagination, this crater looks like a smiling face. This effect is caused by the interplay between light and shadow in the image.
	The 'Hourglass' crater	Two impacts	This is actually a pair of craters close together. It is thought that a stream of ice with large amounts of rocks later filled the craters.
	The 'Butterfly' crater	Low angle impact	The angle at which the meteoroid was travelling was likely less than ten degrees from horizontal. The curving features visible in the north of the image are caused by tectonic activity.
	Orcus Patera	Low angle impact	This crater was likely made by a small body that struck the surface at a very low angle, perhaps less than five degrees from the horizontal.
	The 'Octopus' crater	Single impact	This crater is very young. From observations of Mars, scientists know that the crater was formed between December 2005 and May 2008. The dark lines or streaks on the image are fresh material which was thrown across the surface (called **ejecta***) during the impact.

↑ Images and descriptions of peculiar craters on Mars.

***Ejecta**: particles ejected from an impact area.

Did you know?

ESA’s Mars Express spacecraft was launched on 2 June 2003 and represents ESA's first visit to another planet. Since its launch, the mission has produced a range of significant results in its search for answers to fundamental questions about the geology, atmosphere, surface environment, history of water and the potential for life on Mars. Mars Express also looked for signals from a more recent ESA visitor to Mars - the Schiaparelli lander that was dropped onto the Martian surface in 2016. Schiaparelli was sent along with a spacecraft which orbits around Mars, called the Trace Gas Orbiter (TGO).

← ESA's ExoMars rover will head to the red planet in 2018.

→ An artist impression of ESA's Mars Express spacecraft.

What have we learned? (25 minutes)

Following the experiment, invite pupils to present their work to the class. Encourage a classroom discussion by using the example questions below:

- Were the pupils able to reproduce some of the peculiar craters found on Mars?
  Refer to Table A2.
- What did they notice when they dropped a marble from a greater height?
  A rim should have formed when the impact velocity was high.
- What did they notice when they dropped a marble from an angle?
  A fresh **ray pattern*** indicating the angle of impact should have emerged.
- What happened when they dropped a marble from a very low angle?
  The crater should have become more elongated.

Explain that craters can tell us a lot about a planet’s geology. Having few craters indicates that a surface is (geologically) young. Having many craters indicates an old surface. Erosion, weathering and other geological processes, such as plate tectonics and volcanism, remove evidence of craters over time. This is obvious when we compare the surface of Earth with that of the Moon. The Moon is littered with craters, whilst on Earth they are difficult to find. The craters themselves may also look young or old. A crater with a ray pattern is a very young crater. The rays are called ejecta; their presence means that the surface has not been weathered or eroded away.

Come to the conclusion that a crater’s appearance depends on the meteoroid size, impact angle and whether it broke up in the atmosphere.

***Ray pattern**: radial streaks of fine material that is thrown out during the formation of an impact crater.

Round off the activity by summarising what they have learned so far:

- A shooting star, or meteor, is not a star but is the light produced by a piece of rock (a meteoroid) that burns in the Earth's atmosphere.
- A shooting star travels at high speeds through the atmosphere. It is the rapidly compressed air that causes the glow around a shooting star.
- A crater is formed by a meteoroid (or meteorite) that has survived its journey through the Earth's atmosphere.
- The crater appearance depends on meteoroid size and the angle at which it hits the ground.

Did you know?

The ESA Space Situational Awareness programme is currently using amateur and professional telescopes to actively detect and track near Earth objects, asteroids or comets with sizes ranging from metres to tens of kilometres whose orbits come close to that of Earth's. They could potentially hit our planet and, depending on their size, produce considerable damage. Although the chance of a large object hitting the Earth is very small, it would produce a great deal of destruction. ESA's aim is to have a fully integrated system that can warn civil authorities if necessary.

Suggested extension activities

There are many ways to extend this exciting topic further. Please refer to the accompanying document 'ESA teach with space - tell-tale signs of a shooting star extension activities | PR04b' for suggested activities with instructions and worksheets.

→ CONCLUSION

In this activity pupils are introduced to shooting stars, meteors and crater formation and learn what happens to fast moving objects as they pass through the Earth's atmosphere. Peculiar images of craters on Mars provide an engaging context for pupils to conduct a scientific experiment to explore how craters are formed. They will also strengthen key skills such as documentation, presentation and discussion.

Tell-tale signs of a shooting star

What do you need to do?

Task 1: Lights in the night sky

1. Describe the white dots in the pictures below (Figure W1). What do you think they are?

____

____

2. Describe the streaks in the pictures below. What do you think they are?

____

____

Figure W1

↑ Lights in the night sky.

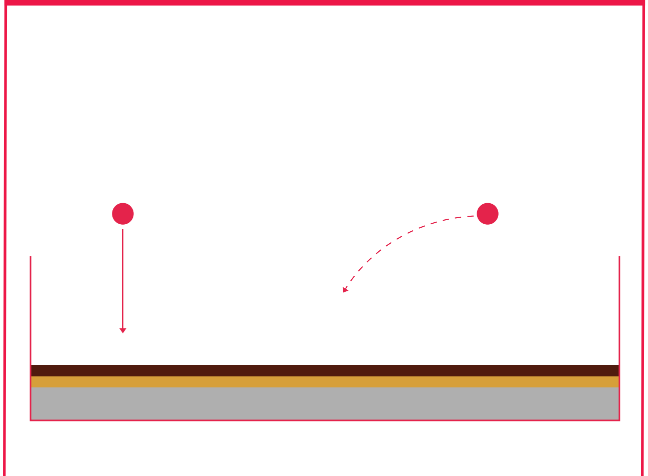
Task 2: Crater formation

In this experiment your group will study how craters are formed.

Equipment per group

- Top lid of A4 carton box (typical size 30 x 22 x 7 cm)
- Plastic bag
- Flour 1 kg
- Glitter 50 g
- Chocolate powder 50-100 g
- 5-10 marbles of different sizes
- Ruler
- Sieve
- Small plastic spoon
- Phone camera
- Copy of Worksheet – The tale of a shooting star (1 copy per pupil)
- Picture of a crater on Mars

Figure W2



↑ Illustration of the experiment box. Grey: a layer of flour. Yellow: glitter. Brown: chocolate powder. Red dots: the marbles being thrown.

Figure W3

↑ Example of how the setup looks like after a few marbles have been dropped.

Instructions

1. Wrap a plastic bag around the top lid of an A4 carton box.
2. Put flour into the plastic wrapped box. Use a ruler to make sure this layer is level. This layer represents the base material.
3. Sprinkle a thin layer of glitter on top of the flour. This layer represents rocks.
4. Sprinkle chocolate powder on top of the glitter. This layer represents the top soil.

Your teacher has given your group an image of a crater on Mars. How do you think this crater was formed?

To answer this question, you should first study what happens when a rock (or marble) impacts a surface. You should make notes of your observations. Take a few photos of the craters that you make to compare with the picture of a crater on Mars. You may want to use the small plastic spoon to retrieve the marbles.

Drop marbles from various heights. What happens?

____

____

Drop two or more marbles next to each other. What happens?

____

____

Throw marbles from different angles. What happens?

____

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Throw marbles from very low angles. What happens?

____

____

Based on your observations, how do you think the crater on Mars was formed?

____

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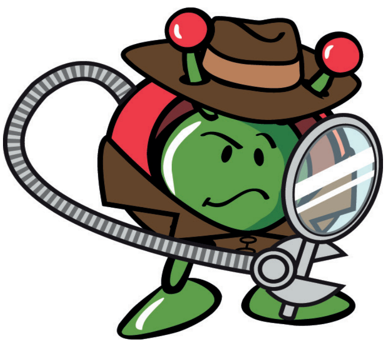
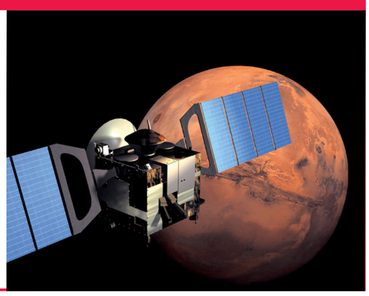
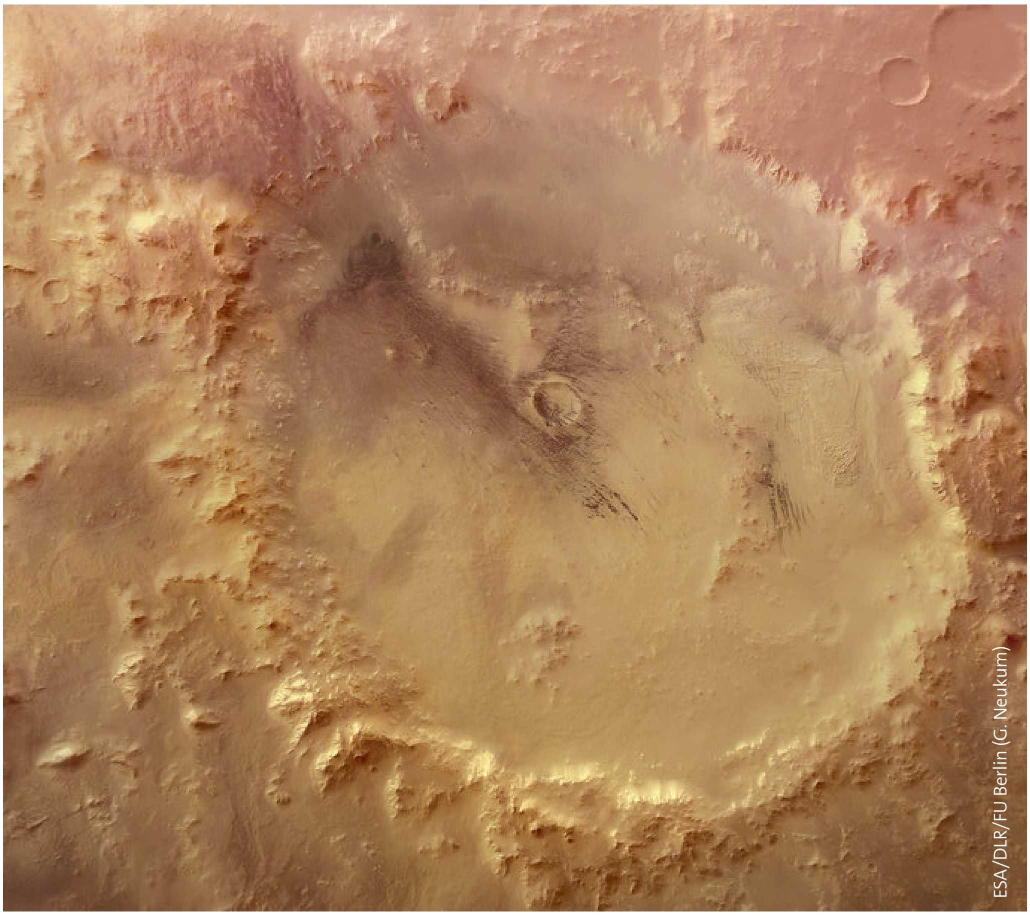


Did you know?

ESA's Mars Express spacecraft was launched in 2003. It is currently orbiting around Mars. Its mission is to study the planet's surface and atmosphere.

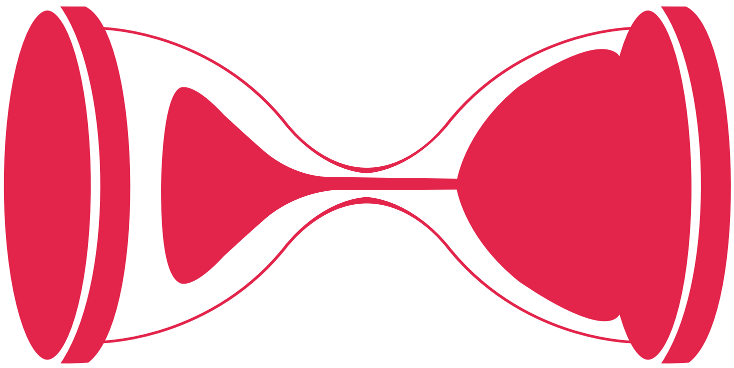


→ APPENDIX



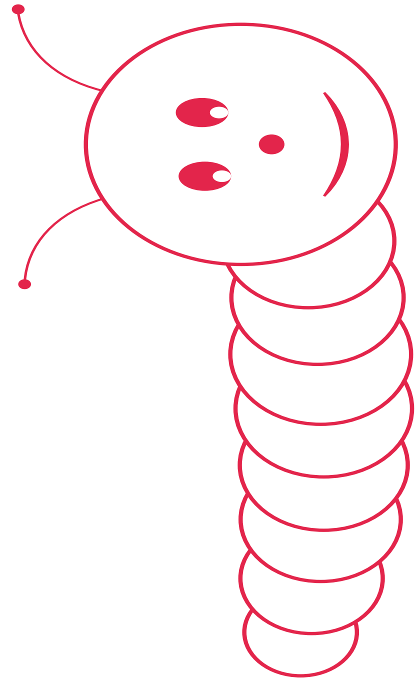
Gale or "Happy Face" crater on Mars

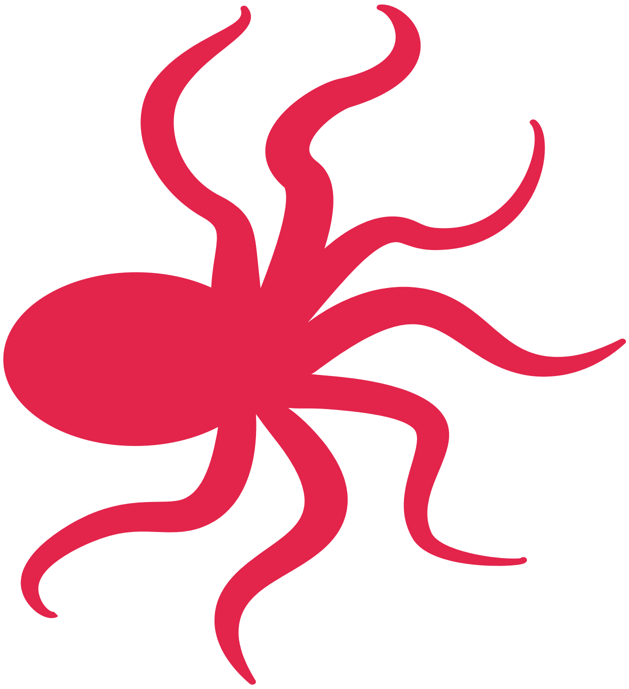
The "Hourglass" crater on Mars

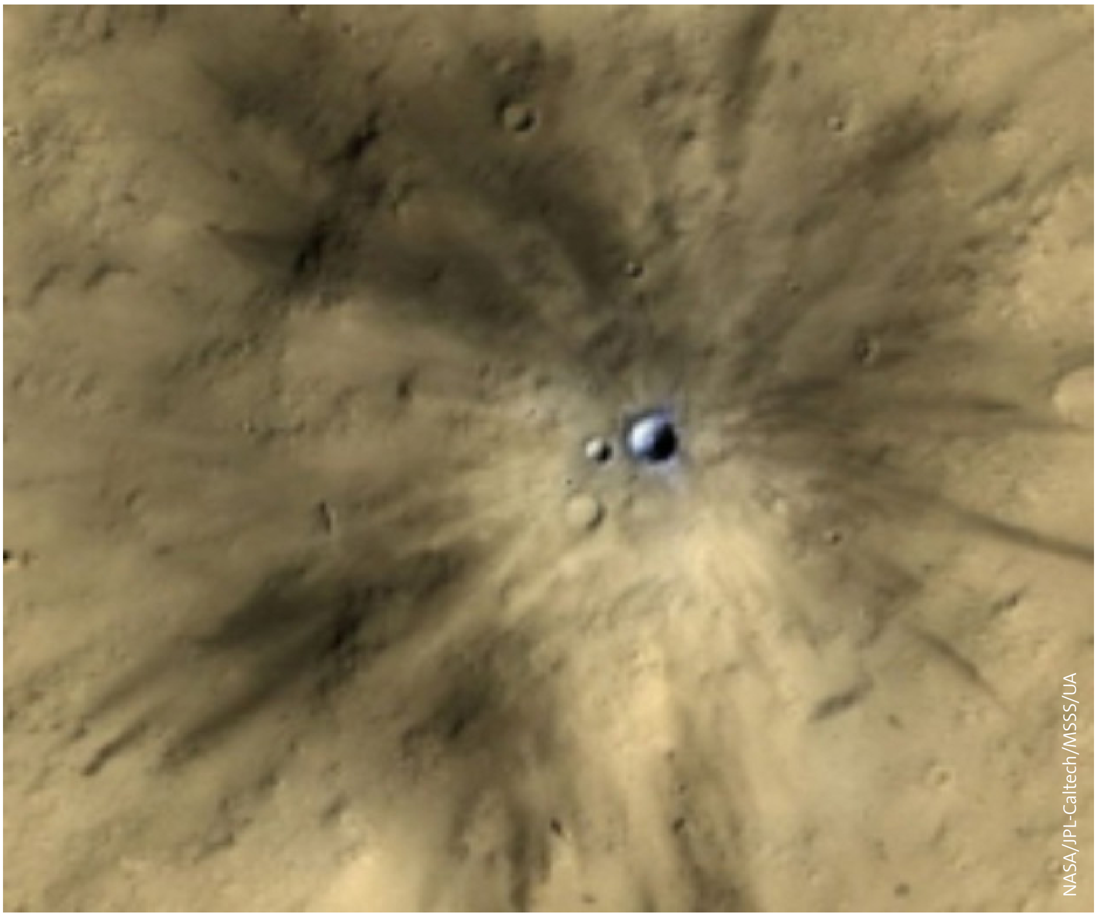


The "Butterfly" crater on Mars

The "Orcus Patera" crater on Mars







The "Octopus" crater on Mars

Links

Teach with space

ESA teach with Rosetta website: ww.esa.int/Teach_with_Rosetta/

ESA Kids (child-friendly fun & information in several European languages)

ESA Kids homepage: www.esa.int/esaKIDSen/
Comets and meteors: www.esa.int/esaKIDSen/Cometsandmeteors.html
Spot the Asteroids: www.esa.int/esaKIDSen/SEMYE7MPQ5F_OurUniverse_0.html
ESA Mars Express: www.esa.int/esaKIDSen/SEMI1CXJD1E_OurUniverse_0.html
Paxi fun book: esamultimedia.esa.int/multimedia/publications/PaxiFunBook/

ESA Missions

Space situational awareness programme: www.esa.int/Our_Activities/Operations/Space_Situational_Awareness/Near-Earth_Objects_-_NEO_Segment
ESA/NASA Hubble Space Telescope: spacetelescope.org
Mars Express: www.esa.int/Our_Activities/Space_Science/Mars_Express
ExoMars: exploration.esa.int/mars/48088-mission-overview/
ATV: www.esa.int/Our_Activities/Human_Spaceflight/ATV
Re-entry of ATV1 video: www.esa.int/spaceinvideos/Videos/2015/02/ATV-1_reentry

More information on craters

Hourglass shaped crater: www.esa.int/Our_Activities/Space_Science/Mars_Express/Hourglass_shaped_craters_filled_with_traces_of_glacier
Happy face crater: www.esa.int/Our_Activities/Space_Science/Mars_Express/Happy_face_crater_on_Mars
Butterfly crater: www.esa.int/Our_Activities/Space_Science/Mars_Express/Butterfly_impact_crater_in_Hesperia_Planum
Orcus Patera crater: www.esa.int/Our_Activities/Space_Science/Mars_Express/Mars_s_mysterious_elongated_crater
www.esa.int/Our_Activities/Space_Science/Mars_Express/The_scars_of_impacts_on_Mars

More information on surface renewal

Volcanoes: www.esa.int/esaKIDSen/SEMMZKXJD1E_Earth_0.html
Earthquakes and plate tectonics: www.esa.int/esaKIDSen/SEMD1LXJD1E_Earth_0.html
www.esa.int/Our_Activities/Observing_the_Earth/Highlights/Africa_s_ups_and_downs

Other useful links

Down2Earth impact calculator: simulator.down2earth.eu/index.html

teach with space – tell-tail signs of a shooting star | PR04a
www.esa.int/education

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teachers@esa.int

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