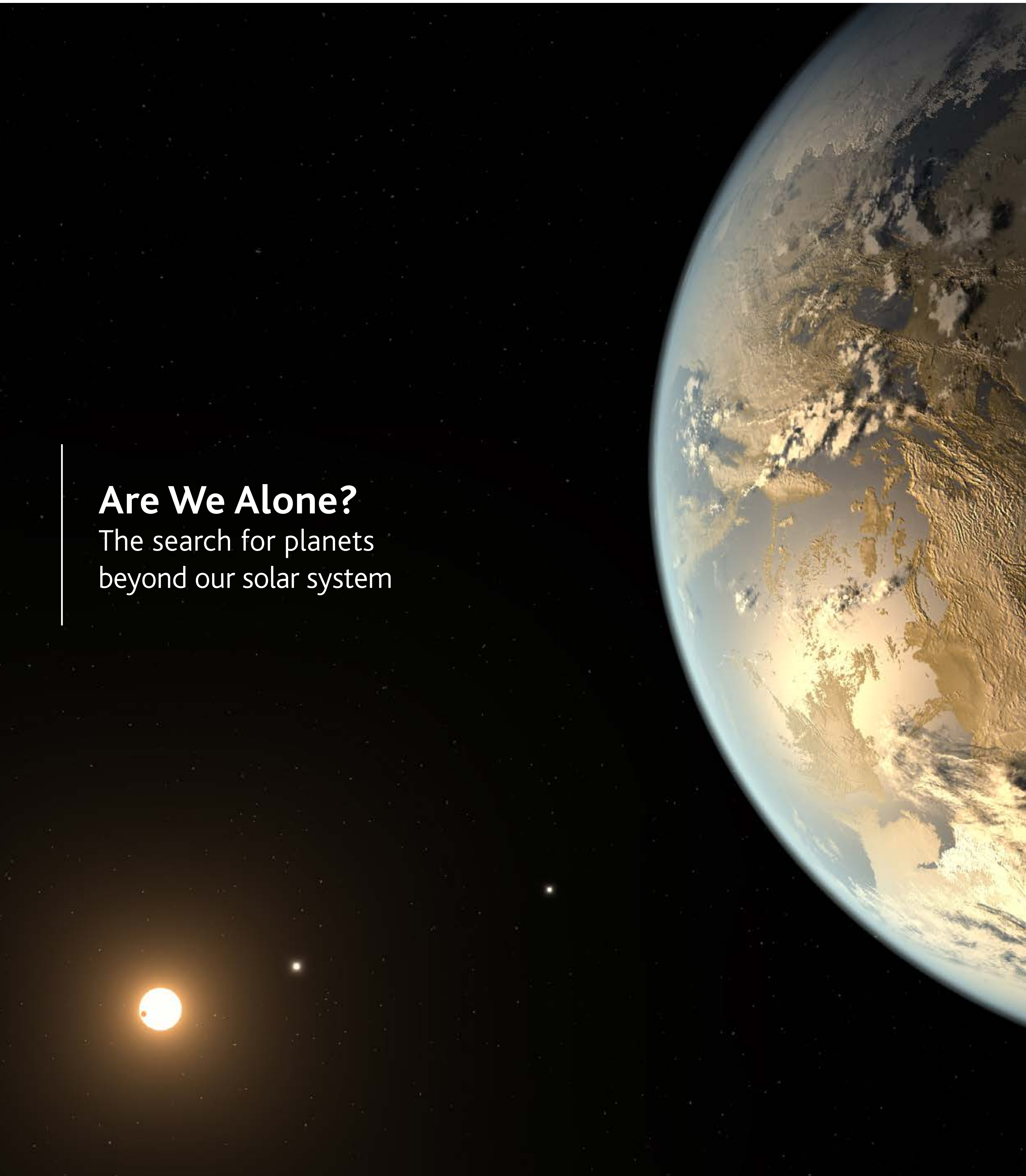

Are We Alone?

The search for planets
beyond our solar system

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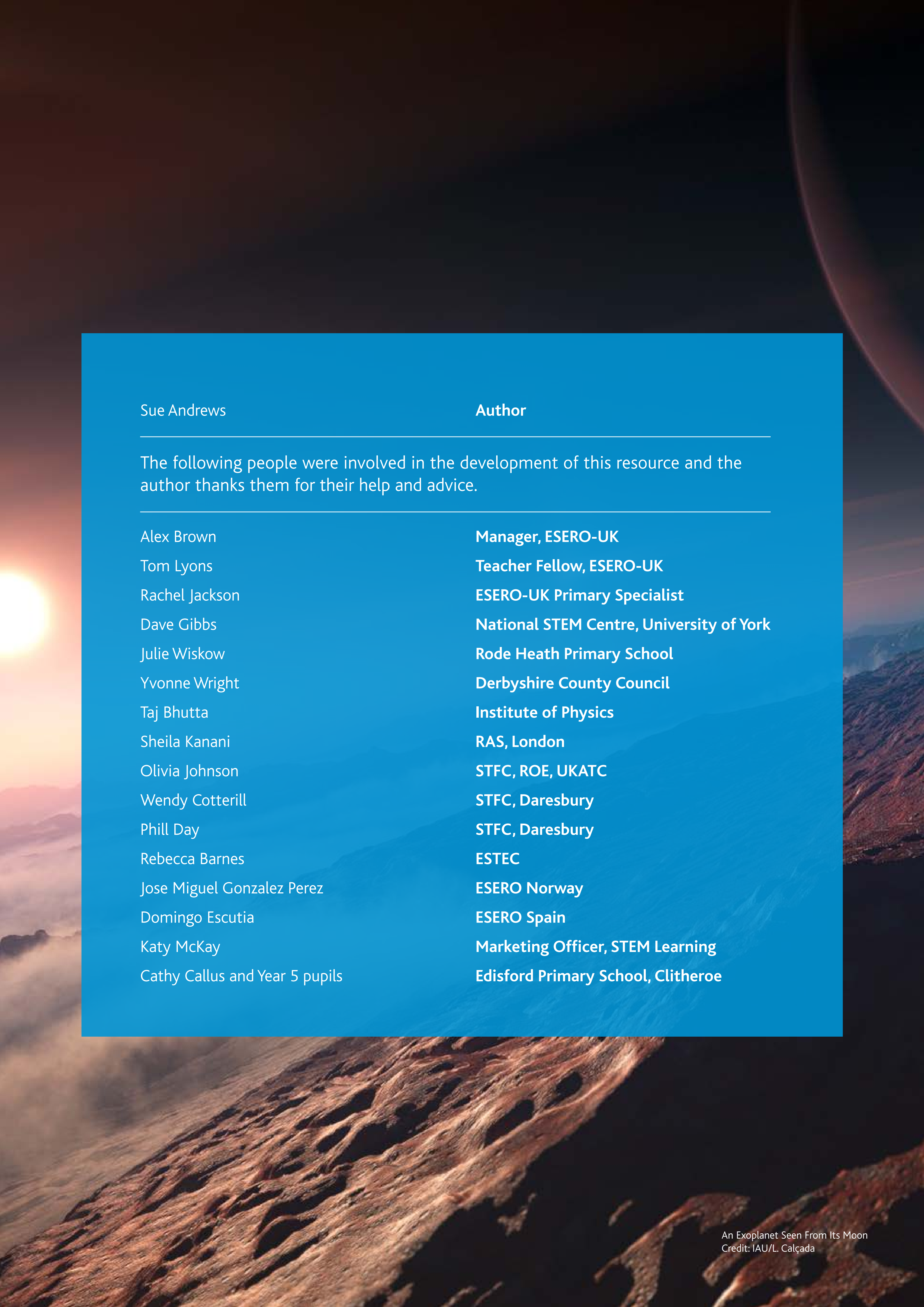

An Exoplanet Seen From Its Moon
Credit: IAU/L. Calçada

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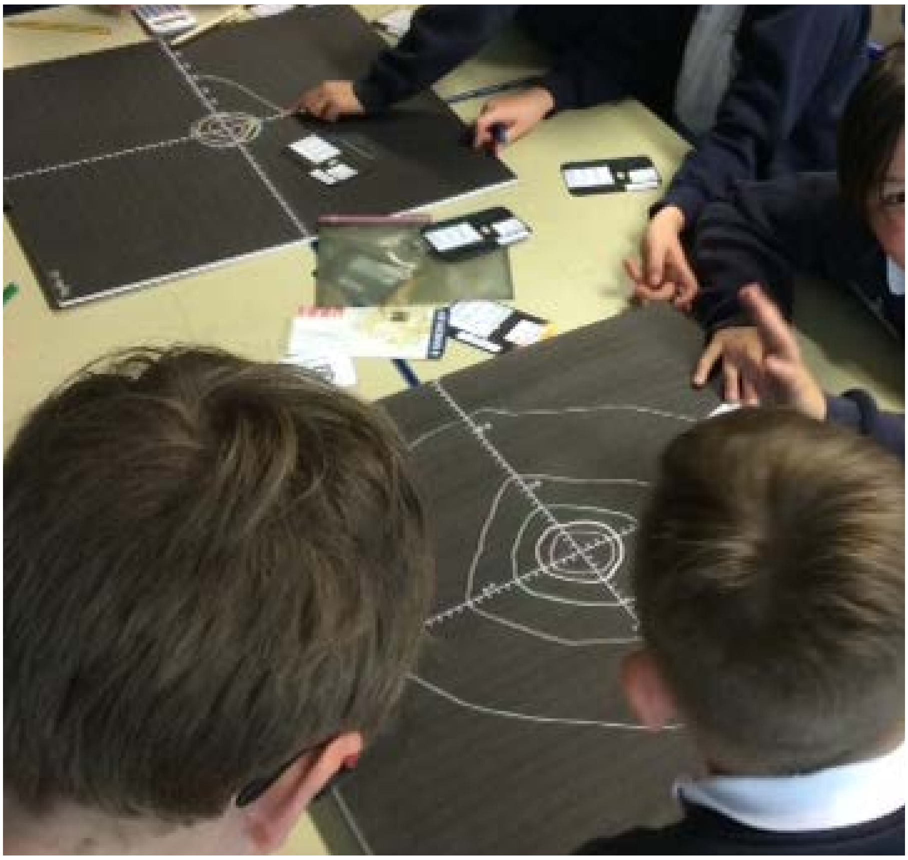


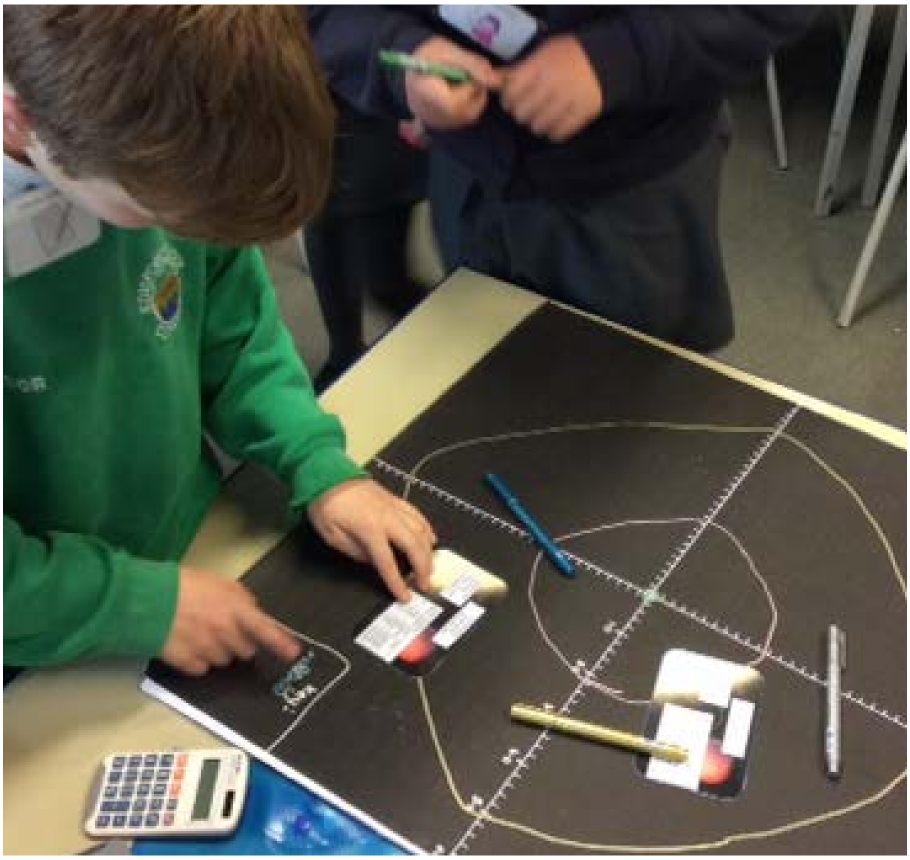
Pupils carrying out Activity 1 - Plot the exoplanet orbits

"It has been really lovely learning about exoplanets and now I think I am a bit more knowledgeable. It was really fun making our solar systems. I hope you come back again."

Feedback from Year 5 pupil - Edisford Primary School

"I really liked the space session and learnt lots of things that I thought I already knew (but I obviously didn't!)."

Feedback from Year 5 pupil - Edisford Primary School



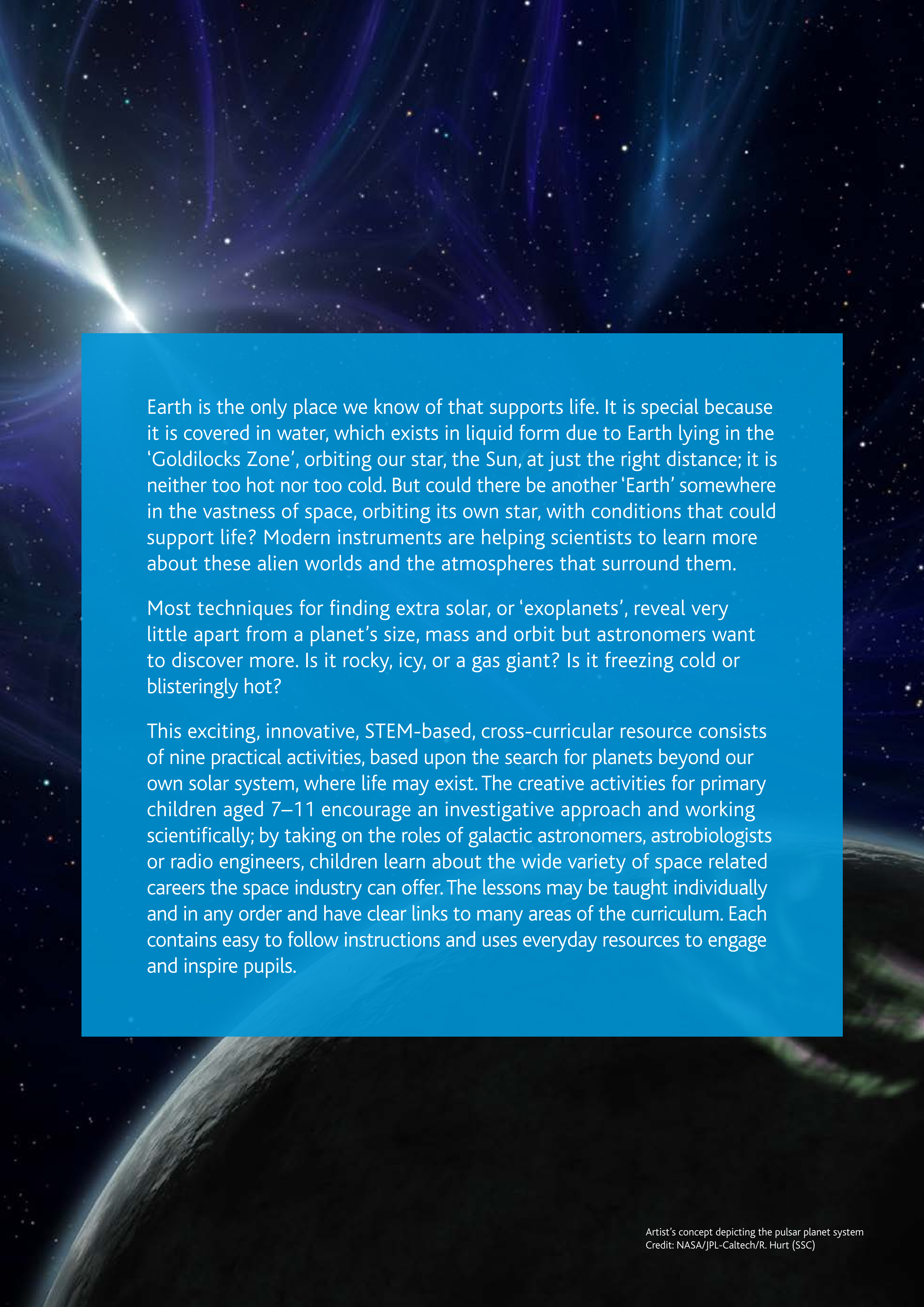
> "I loved the space afternoon. We would love to do it again. I would like to let other pupils know if they do it that it isn't just learning, but it's fun and a first-hand experience. Thank you everybody at ESERO! We enjoyed it!"
>
> Year 5 pupil - Edisford Primary School

Pupils carrying out Activity 1 - Plot the exoplanet orbits

Earth is the only place we know of that supports life. It is special because it is covered in water, which exists in liquid form due to Earth lying in the 'Goldilocks Zone', orbiting our star, the Sun, at just the right distance; it is neither too hot nor too cold. But could there be another 'Earth' somewhere in the vastness of space, orbiting its own star, with conditions that could support life? Modern instruments are helping scientists to learn more about these alien worlds and the atmospheres that surround them.

Most techniques for finding extra solar, or 'exoplanets', reveal very little apart from a planet's size, mass and orbit but astronomers want to discover more. Is it rocky, icy, or a gas giant? Is it freezing cold or blisteringly hot?

This exciting, innovative, STEM-based, cross-curricular resource consists of nine practical activities, based upon the search for planets beyond our own solar system, where life may exist. The creative activities for primary children aged 7–11 encourage an investigative approach and working scientifically; by taking on the roles of galactic astronomers, astrobiologists or radio engineers, children learn about the wide variety of space related careers the space industry can offer. The lessons may be taught individually and in any order and have clear links to many areas of the curriculum. Each contains easy to follow instructions and uses everyday resources to engage and inspire pupils.



Artist's concept depicting the pulsar planet system
Credit: NASA/JPL-Caltech/R. Hurt (SSC)

Lesson 1

Our solar system
Plotting the orbits of planets in our solar system
Calculating the Goldilocks Zone and plotting the orbits of known exoplanets
James Webb Telescope
(Based on an activity developed at the Royal Observatory Edinburgh by the Science Technology Facilities Council and the Institute for Astronomy, University of Edinburgh.)

Lesson 2

What are we looking for?
ESA/NASA Hubble Space Telescope
Producing and testing for carbon dioxide
Game: Design an extremophile (natural selection, adaptation, evolution)

Lesson 3

Spitzer Space Telescope detecting atmospheres
Chromatography
Splitting light
Using spectra to identify atmospheric 'ingredients'
Evaporation and condensation
Cloud in a bottle

Lesson 4

Measuring how hot or cold a planet is
Infrared data collected by Spitzer Space Telescope
Investigating conduction using thermochromic paper and over distance using data loggers
Smartphones/tablets infrared app

Lesson 5

Detecting distant solar systems
Light and shadows
Data loggers measuring light
Analysing transit graphs

Lesson 6

Investigating magnetic attraction
Making an electromagnet

Lesson 7

Sending a message over a distance
String telephones
Listening for Earth's natural signals
Radio waves
Morse code

Lesson 8

TRAPPIST-1 transits
Space music
Scratch programme

Lesson 9

Designing an exoplanet
Considering the distance from its star, temperature, conditions, orbit, mass, magnetic field, alien life
Exoplanet travel bureau

Lesson 1

To infinity and beyond

Plotting the orbits of planets in our own and distant solar systems

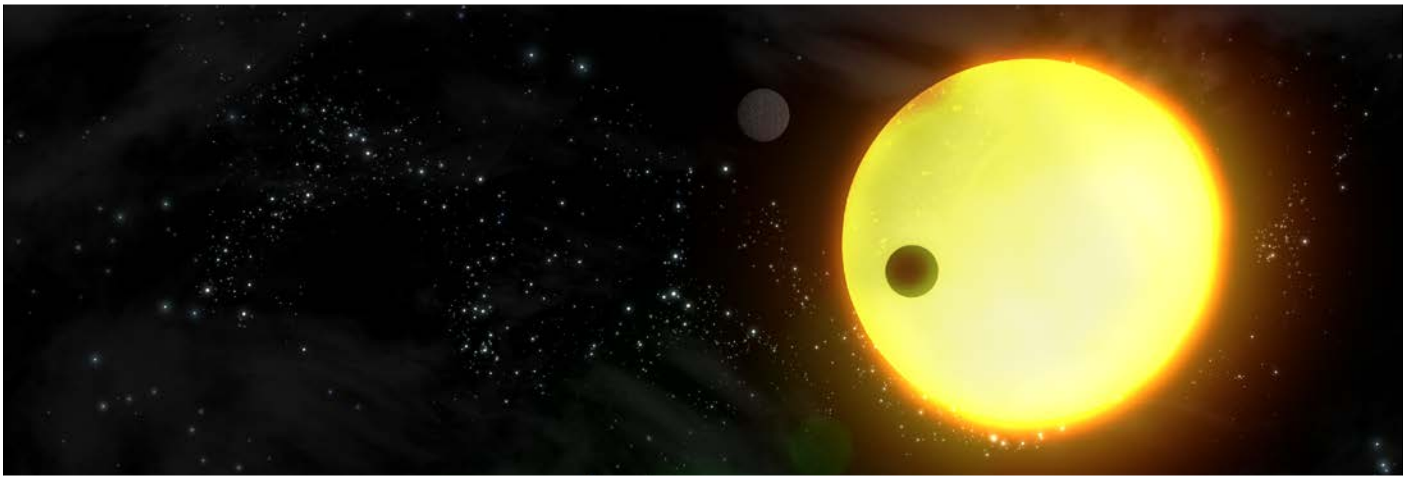
Curriculum links

England Earth and space | Light | States of matter | Living things and environment

Scotland Space

Wales The sustainable earth

Northern Ireland Measures/Number | World Around Us | Place in the Universe



Background

The distances between planets and the stars they orbit are measured in astronomical units or AU. Earth is 1 AU from our star, the Sun. The region around a star that is neither too hot nor too cold and where water could exist in liquid form is known as the Goldilocks or habitable zone. In this activity, the children plot the position and orbits of Earth and other planets in our own solar system; they then calculate the position of the Goldilocks Zone. They learn that there are other solar systems where planets orbit stars other than our Sun; by plotting the positions of these distant exoplanets, they discover which are potentially habitable.

Objectives

To learn:

- our solar system consists of eight planets orbiting our star, the Sun
- Earth orbits the Sun in the habitable or Goldilocks Zone
- other solar systems exist in space
- to interpret information and scales and use decimals to plot orbital distances of planets

Resources per group of four

60cm x 60cm square of black paper x2
60cm square of polystyrene or foam board x 2 (optional)
Plasticine of various colours (optional)
Cocktail sticks (optional)
A4 paper
Metallic pens/coloured chalks/coloured pencils
Calculator

Scissors
Glue stick
Solar system fact cards x 4
Exoplanet fact cards x 4
Solar system Goldilocks Zone calculation cards x 2
Exoplanet Goldilocks Zone calculation cards x 2
Solar system planets order of size template

Advance preparation

All classroom sessions involve the children working in groups of four. A set of role badges for 'galactic astronomer' should be prepared before the lesson if the teacher wishes to use them. (Appendix 1).

Draw the two axes, marked into 1cm divisions on sheets of black paper before attaching to the backing boards. (See the diagram in teacher information).

Two sides of one board may be used instead of two separate boards, by attaching a second sheet of black paper to the reverse of the board. Alternatively, planets cut from paper and coloured in can be stuck onto their orbits on the black paper, without attaching the paper to a board.

Photocopy Activity sheets 1a and 1b onto card, cut into individual cards. Provide solar system fact cards for all groups. In addition, prepare a different set of exoplanet information cards for each group. Goldilocks Zone calculation cards are required for all groups.

Introduction

Ask the children if they know what a planet is. Can they name any planets in our solar system? How many are there? Do they know which planet we live on and the name of our star?

Show an animation of a solar system eg Paxi and the Solar System: https://www.stem.org.uk/rx34sc

In groups, the children act out the orbits of Earth and the moon around the Sun. They can also demonstrate the orbits of other planets in our solar system. If available, 3D models of the planets can be shown. An activity from the Royal Observatory, Greenwich, has a useful activity using fruits to show the relative masses of the planets, placed in order of distance from the Sun. www.stem.org.uk/elibrary/resource/31649/fruit-solar-system

Explain that we need water to exist and life exists on our watery planet but there may be plenty of watery planets with conditions favourable for life without things living on them. How many of these potentially habitable planets that actually have life is a big (and exciting!) open question. At the moment we have the ability to make observations, which tell us which planets might host life, but that alone won't tell us if alien life exists.

Planets too close to the Sun are far too hot for water to exist as a liquid; it would be turned to steam and evaporate; too far away from the Sun and water would freeze. Earth's orbit is just right; neither too hot nor too cold. We call this the Goldilocks or habitable zone. In this activity, the children will become galactic astronomers, using mathematical skills and key facts to plot the orbits of Earth and planets in our solar system before plotting the orbits of exoplanets around their stars.

Activity

Activity sheet 1a provides an information card giving the distance of Earth and the planets in Astronomical Units, or AU, from the Sun. Each group is given a set of fact cards relating to our solar system and a pre-prepared sheet of black paper with two axes intersecting in the middle and divided into centimetre divisions, attached to a backing board. Teachers may prefer to provide just the paper without using the backing board. Scales can be pre-marked in detail on the axes or left to the children to extrapolate, depending upon their abilities. The activity provides opportunities for working with numerals to two decimal places.

Initially, the children work as a class as the teacher demonstrates. The position of the Sun is marked at the intersection of the axes. Explain that the distances between planets and the stars they orbit are measured in astronomical units or AU. Earth is 1 AU from our star, the Sun. Using a metallic pen or coloured pencil, they mark the distance of the Earth from the Sun on the appropriate points of the axes, North, South, East and West from the intersection. They can then join up the four points, forming a circle to represent the orbit. If using the board, a cocktail stick, with a small ball of plasticine attached to represent the Earth, may be pushed into a suitable position on the orbit. Alternatively, a sticker or small circle of paper, coloured to represent Earth, may be stuck directly onto the black paper at a point in the orbit. The children independently plot the distances and orbits of the remaining planets. Finally, they calculate and plot the habitable zone by using the information on the Goldilocks zone calculation card (Activity sheet 1b). Remind the children that this region is called the Goldilocks zone where it is neither too hot nor too cold.

If boards are available, they make models in plasticine of each planet, in order of mass, choosing colours appropriate to their knowledge of the features of each planet. Emphasise that they have some information about their planets – their mass and the length of their orbit – which can help them decide how to represent the planets.

Are they likely to be more like the Earth (rocky) or more like Jupiter (gaseous)? Which are more likely to be habitable? (Rocky). They attach each plasticine planet to a cocktail stick and push the cocktail sticks into position on the orbital rings. Paper circles, or stickers representing the planets, can be substituted for plasticine models, and stuck to the paper.

Next, the groups will need a second sheet of black paper, the axes and scales pre-marked and attached to a board. Alternatively, teachers may choose to attach the papers to the reverse of the boards used for the last activity, after removing the plasticine planets, or simply use paper alone.

Do the children have any idea how many stars with orbiting planets there may be just in our own galaxy, the Milky Way? Explain that scientists have discovered hundreds of multi-planet systems and thousands of stars with at least one planet, in our own galaxy, and estimate that there may be tens of billions more. Each group is given fact cards, Activity sheet 1a, for an exoplanet star system and using the information, they plot the position of the planets from the star. The extrasolar data provided are for 55 Cancri, HR 8799, Gliese 581, Gliese 876, Kepler 62, Kepler 186 and Upsilon Andromedae.

Finally, distribute cards showing how to calculate the inner and outer regions of the Goldilocks zone for each of the stars. Each group uses these measurements to mark the zone for their star system on the paper, revealing which, if any, of their planets lies within the zone and could be habitable.

Examples of Y5 pupil's work

Plenary

The groups share their results with the class. The results may be displayed on the whiteboard.

Which groups discovered a planet orbiting within the Goldilocks zone of their star system?

Why would some not be habitable? Remind the children through discussion that they have many types of information about the planets at their disposal relevant to this point.

Which of their planets would be too hot/cold for life to exist?

Extension

The groups might research other exoplanets and stars discovered in our galaxy and prepare a poster or presentation about their findings.

Lesson 1

To infinity and beyond

Plotting the orbits of planets in our own and distant solar systems

Teacher information

An **astronomical unit (AU)** is the distance of the Earth from the Sun; this distance varies as Earth orbits the Sun, equivalent to 149,597,870,700 metres.

A **planet** is defined as a body that orbits the Sun, which is sufficiently massive for its own gravity to make it spherical and has 'cleared its neighbourhood' of smaller objects around its orbit.

A **light year** or **ly** is the distance light can travel in one year, or 300,000 kilometres/second.
Luminosity is a measure of brightness or power of a star, the amount of energy that a star emits from its surface. It is usually expressed in watts and measured in terms of the luminosity of the Sun.

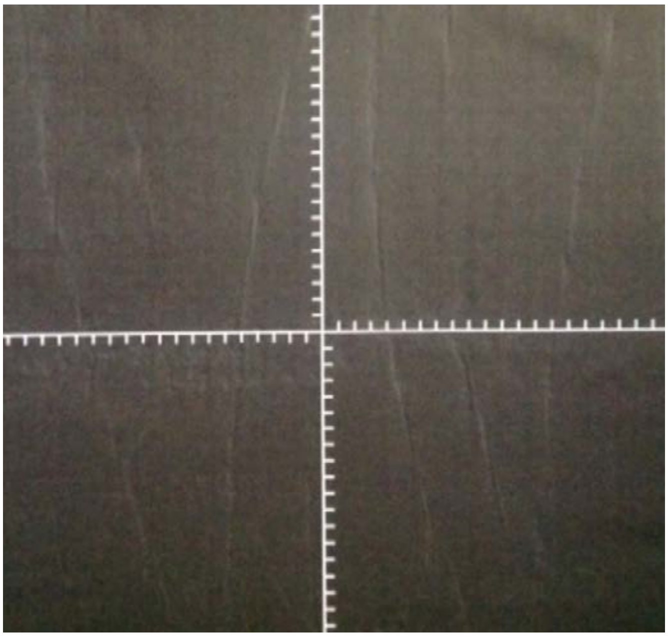


Image of exoplanet plotting sheet with two intersecting axes

Exoplanets in the habitable zone

The habitable zone or Goldilocks zone is the area around a star where the temperature is neither too hot nor too cold for water to exist in liquid form. The closest and furthest distances from the star where liquid water can be found depend on the size and temperature of the star, among other things. The stars Upsilon Andromedae, Gliese 581, Cancri 55, Kepler 62 and Kepler 186 are thought to have planets orbiting within the Goldilocks or habitable zone of their stars. However, data for extra solar systems are liable to change as new information is gathered. The data shown is correct at the time of writing but may be revised as new discoveries are made and more accurate measurements are taken by the latest telescopes. Such is the nature of science.

More able pupils may enjoy calculating the distance in AU of the habitable or Goldilocks zone for the stars featured on their activity sheets using the formula √luminosity of the star x 0.7 for the inner edge of the habitable zone and √luminosity x 1.5 for the outer edge of the zone. Note that luminosity is in solar units or 'Suns' ie, luminosity is compared with our Sun.

For an introduction to exoplanets, see:
http://www.esa.int/esaKIDSen/SEM3NFXPXPF_LifeinSpace_0.html
https://exoplanets.nasa.gov/
http://eyes.jpl.nasa.gov/eyes-on-exoplanets.html
https://www.stem.org.uk/elibrary/resource/31030/exoplanets

The James Webb Space Telescope is the successor to the Hubble Space Telescope and represents an international collaboration of the European Space Agency, Canadian Space Agency and NASA. It will carry a UK-led instrument that will allow spectroscopic measurements that are expected to revolutionise the study of exoplanet atmospheres. This telescope will be able to observe the first galaxies ever to form in the Universe and will study distant events and objects in the Universe which are currently beyond the reach of current ground-based instruments. Another goal is to understand the formation of stars and planets, including direct imaging of exoplanets. For further information, see:
http://jwst-miri.roe.ac.uk
https://www.jwst.nasa.gov/

Red dwarf A small, old, relatively cool star.

Brown dwarf A celestial object intermediate in mass between a gas giant planet and a small star, believed to emit infrared radiation. They are of different colours despite the name.

Orange dwarf Also known as a K-type main-sequence (hydrogen burning) or K dwarf. Intermediate in size between a red M-type main-sequence star and yellow G-type main-sequence star.

Yellow dwarf Our Sun is a yellow dwarf. These stars have a mass similar to the Sun. As they cool, they are known as yellow white dwarf stars.

Results of calculations for habitable zones

Star	Goldilocks Zone range	Planets within zone
Sun	0.7–1.5	Earth, Mars, Venus
Gliese 581	*0.077 –0.165 or 0.08–0.165	c, g or just g
HR8799	1.54–3.31	none
55 Cancri	0.5–1.125	f
Kepler 62	0.31–0.67	e
Kepler 186	0.04–0.33	b, c, d, e
Gliese 876	0.07–0.15	c
Upsilon Andromedae	1.32–2.83	d

*If the actual value of 0.077 is used, planets c and g are found in the Goldilocks Zone; if the number is rounded up to 0.08, then only planet g is found. This could lead to a discussion on when it is appropriate to round a number to two decimal places. In this case it makes a big difference!

Appendix

Lesson 1
Activity Sheet 1a
Plot the exoplanet units

The Star Gliese 581 Red dwarf

Distance	20.3 ly
Mass	0.3 Suns
Luminosity	0.013 Suns

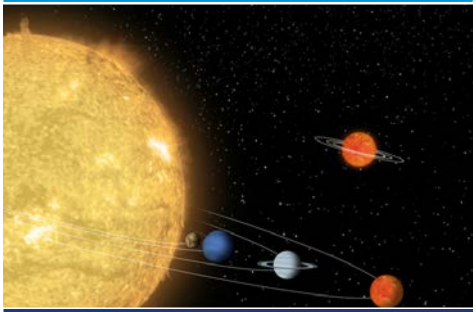
Name	Distance(AU)	Mass (Earths)	Orbit (days)
e	0.03	1.7	3.15
b	0.04	15.8	5.37
c	0.07	5.5	12.91
g	0.13	2.2	32
d	0.22	6.98	66.8

The Star HR 8799 Yellow dwarf

Distance	129 ly
Mass	1.49 Suns
Luminosity	4.9 Suns

Name	Distance(AU)	Mass (Earths)	Orbit (days)
e	14.5	2224	50
d	24	2224	100
c	38	2224	190
b	68	1589	460

The Star 55 Cancri Yellow dwarf



Distance from Earth	40 ly
Mass	0.95 Suns
Luminosity	0.57 Suns

Name	Distance(AU)	Mass (Earths)	Orbit (days)
e	0.02	8.63	18 hours
b	0.115	262.21	14.65 days
c	0.24	54.35	44.34 days
f	0.78	45.7	260 days
d	5.74	1,214.11	14 years

The Star The Sun Yellow dwarf

Distance from Earth	8 light minutes
Mass	332946 Earths
Luminosity	1

Name	Distance(AU)	Mass (Earths)	Orbit (days)
Mercury	0.4	0.05	88
Venus	0.7	0.8	225
Earth	1	1	365
Mars	1.5	0.1	687
Jupiter	5.2	317	11.9
Saturn	9.5	92	29.5
Uranus	19.2	14	84
Neptune	30	17	164.8

Appendix

Lesson 1
Activity Sheet 1a
Plot the exoplanet units

The Star Kepler-62 Orange dwarf

Distance from Earth	1200 ly
Mass	0.69 Suns
Luminosity	0.21 Suns

Name	Distance(AU)	Mass (Earths)	Orbit (days)
b	0.05	2.1	5.71
c	0.09	0.1	12.44
d	0.12	5.5	18.16
e	0.43	4.5	122.38
f	0.71	2.8	267.29

The Star Kepler 186 Red dwarf

Distance from Earth	15.20 ly
Mass	0.37 Suns
Luminosity	0.01 Suns

Name	Distance(AU)	Mass (Earths)	Orbit (days)
b	0.04	N/A*	3.88
c	0.06	N/A*	7.26
d	0.09	N/A*	13.34
e	0.12	N/A*	22.40
f	0.40	1.4	129.94

The Star Gliese 876
Red dwarf

Distance from Earth	40 ly
Mass	0.95 Suns
Luminosity	0.57 Suns

Name	Distance(AU)	Mass (Earths)	Orbit (days)
d	0.02	6.83	1.94
f	N/A*	9.53	10.01
g	N/A*	38.13	15.04
c	0.13	225.65	30.01
b	0.21	724.65	61.12
e	0.33	14.60	124.26

The Star Upsilon Andromedae
Yellow white dwarf

Distance from Earth	44 ly
Mass	1.27 Suns
Luminosity	3.6 Suns

Name	Distance(AU)	Mass (Earths)	Orbit
b	0.06	197	4.62 days
c	0.83	4443	241 days
d	2.54	3257	3.5 years
e	5.25	305	10.5 years

* Data not available

Appendix

Lesson 1
Activity Sheet 1b
Calculating the Goldilocks Zone in Astronomical Units

Upsilon Andromedae

To work out the Goldilocks Zone (AU)

Inner zone	1.90 x 0.7=	
Outer zone	1.90 x 1.5=	

Gliese 581

To work out the Goldilocks Zone (AU)

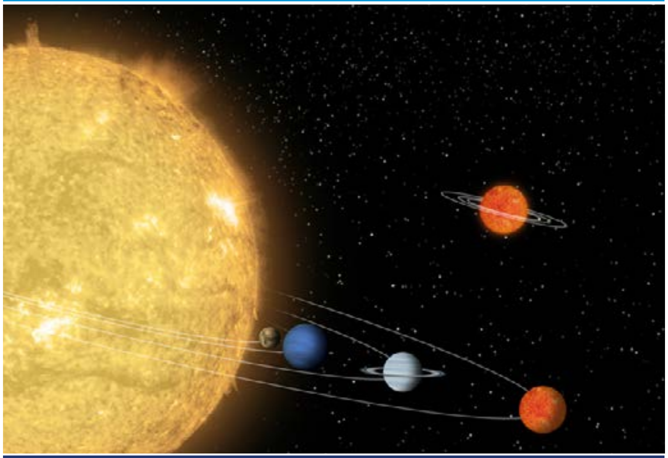
Inner zone	0.11 x 0.7=	
Outer zone	0.11 x 1.5=	

HR 8799

To work out the Goldilocks Zone (AU)

Inner zone	2.21 x 0.7=	
Outer zone	2.21 x 1.5=	

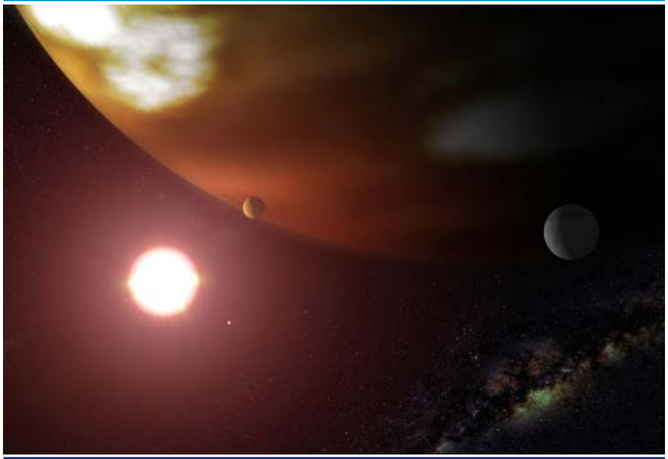
55 Cancri



To work out the Goldilocks Zone (AU)

Inner zone	0.75 x 0.7=	
Outer zone	0.75 x 1.5=	

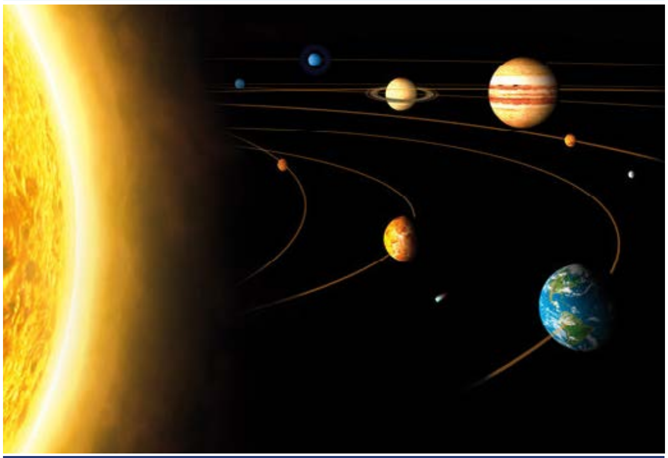
Gliese 876



To work out the Goldilocks Zone (AU)

Inner zone	0.1 x 0.7=	
Outer zone	0.1 x 1.5=	

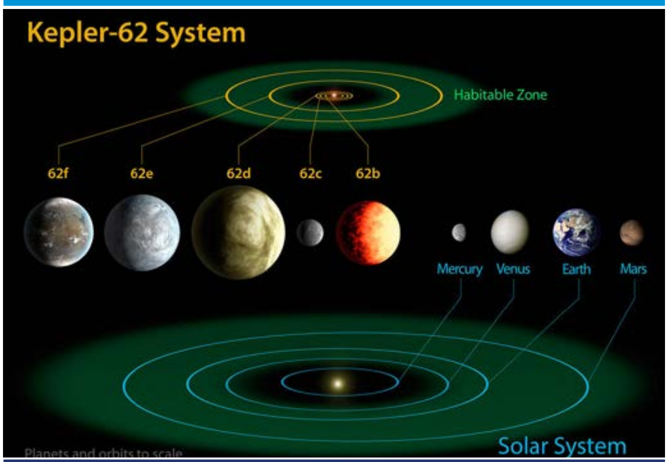
The Sun



To work out the Goldilocks Zone (AU)

Inner zone	1 x 0.7=	
Outer zone	1 x 1.5=	

Kepler-62



To work out the Goldilocks Zone (AU)

Inner zone	0.46 x 0.7=	
Outer zone	0.46 x 1.5=	

Kepler 186

To work out the Goldilocks Zone (AU)

Inner zone	0.22 x 0.7=	
Outer zone	0.22 x 1.5=	

Lesson 2

Signs of life

Searching for life on planets beyond our solar system

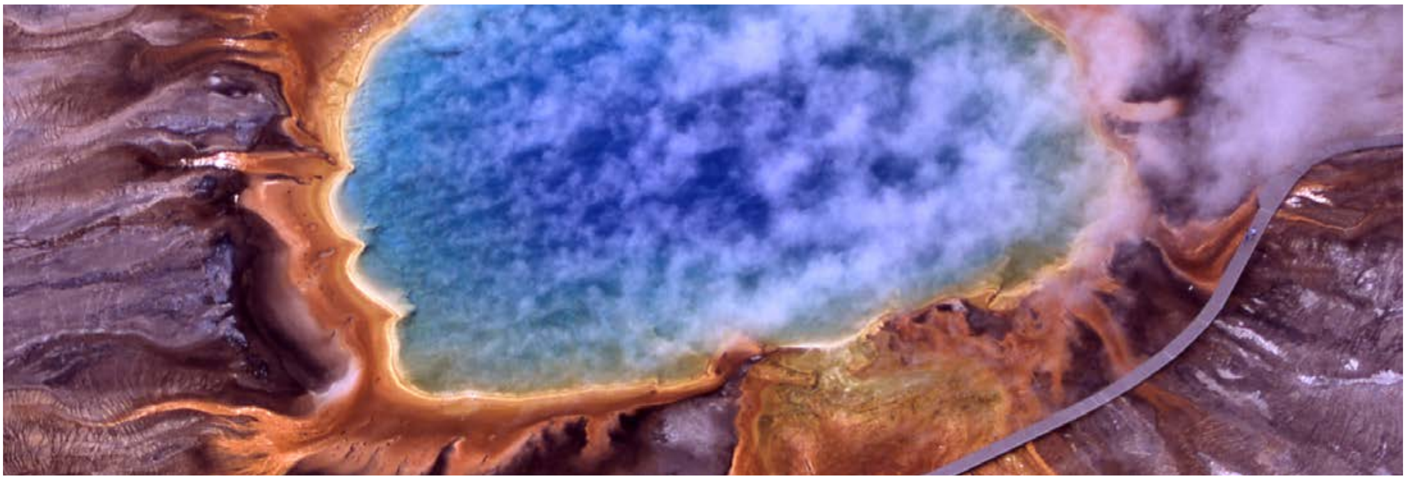
Curriculum links

England Animals including humans | Living things and their habitats | States of matter | Evolution and inheritance | Microorganisms (classification)

Scotland Biodiversity and interdependence | Processes of planet

Wales Interdependence of organisms | Sustainable earth | Properties of materials

Northern Ireland The variety of living things | Adaptations of living things



Grand prismatic spring By Jim Peaco, National Park Service via Wikimedia Commons

Background

Scientists are discovering planets orbiting stars in our galaxy and some may be Earth-like planets with conditions suitable for life. So, what are we looking for when studying these far-off worlds?
In this lesson, the children will learn that the presence of carbon dioxide can be a sign that life could exist. They will set up an investigation to collect carbon dioxide produced by a living organism, yeast.

Objectives

To learn:

- living things produce carbon dioxide
- carbon dioxide has been detected in the atmosphere of distant planets
- the presence of carbon dioxide may indicate life is present
- to work scientifically

Resources per group of four

Straws
Disposable cups x 4
Water
100ml vinegar
Effervescent vitamin C tablet
Half a cup of bicarbonate of soda
Balloons x 4
Sachet dried active yeast x 4
Plastic bottles 500ml x 4
Half a cup of granulated sugar
Teaspoon
Warm water 45–50°C
Thermometer
Activity sheets 2a and 2b

Advance preparation

Repeatedly inflate and deflate the balloons prior to conducting the yeast investigation.
Prepare warm water and store in a thermos flask.
Teachers may wish to prepare astrobiologist role badges for this lesson.

Activity

Introduction

Introduce the activity by explaining that scientists are searching for signs of life on planets beyond our solar system. For this they use powerful telescopes. Images of the Hubble Space Telescope, ESA's COROT telescope and the Spitzer Space Telescope can be shown on the whiteboard. (See links in teacher information) Explain that these telescopes are helping scientists to collect information about the atmospheres of stars and planets as well as providing superb images from space.

Activity a

Explain that living organisms produce carbon dioxide as a waste product and that scientists looking for signs of life beyond our solar system are using special telescopes to detect ingredients such as carbon dioxide in the atmospheres of distant planets. A variety of ways of producing carbon dioxide bubbles can be tried. The children use the straws to blow into the water, drop an effervescent vitamin C tablet into water and observe the bubbles or add vinegar to a teaspoon of sodium bicarbonate and watch the foam rise as carbon dioxide is produced.

Teachers should ensure that effervescent tablets are used only for demonstration purposes and children warned that the tablets are not to be consumed.

Activity b

Today we are going to use an organism called yeast, which produces carbon dioxide from a nutrient, sugar. Show the children how to set up the investigation:

1. Ensure the balloon has been stretched by repeatedly inflating and deflating.

2. Add the packet of yeast and a teaspoon of sugar to a cup of warm water (45–50°C) and stir.

3. Ensure the sugar and yeast have dissolved and pour the mixture into the bottle. You should see bubbles of carbon dioxide produced by the yeast as it feeds on the sugar.

4. Attach the balloon to the mouth of the bottle.

5. After a few minutes, the balloon should inflate.

Explain that yeast is a living organism and, as it feeds on the sugar, it produces carbon dioxide. Can the children investigate the conditions affecting the production of carbon dioxide by the yeast?

Each group then discusses the variables that could be changed in this investigation. They may suggest varying the amount of sugar or yeast, type of sugar or temperature of the water. They plan their investigation. What will they keep the same? What will they measure? What will they record? What do they think will happen and why? Photographs or videos of the stages of expansion of the balloons could be taken.

Plenary

The children present their results in tables, charts, posters, videos or PowerPoints, explain what their results mean and justify their conclusions. How might they improve their investigation? Emphasise that the presence of carbon dioxide in a planet's atmosphere does not prove the existence of life.

Teacher demonstration

Explain that one of the properties of carbon dioxide is that it is heavier than air and can be used to extinguish flames. Demonstrate this by adding vinegar to a few teaspoons of sodium bicarbonate in a jug. Wait for a couple of minutes for the reaction to take place. Gently 'pour' the gas (but not the liquid or foam) over a lighted candle or tea light in a shallow container and watch the flame being extinguished. Explain that the flame needs oxygen from the air in order to burn; carbon dioxide is heavier than air and sinks to the bottom of the container, replacing the air and extinguishing the flame. Could we test the gas produced in our investigations? Try carefully 'pouring' the gas from the balloons next to a burning tea light and observe the flame being extinguished. This demonstration does not of course prove that it is carbon dioxide and not another heavier than air gas but it shows one of the properties of carbon dioxide. The demo is visual and encourages thinking skills.

Care should always be taken when using tea lights. The children should be warned of the dangers of touching or being too close to naked flames.

Extension

The children could design their own extremophile, using the information on Activity sheet 2b, describing the conditions in which it lives and how it has adapted to those conditions, before finally giving it a name. They might research the Hubble Space Telescope or exoplanet HD 189733b.

Teacher information

Astrobiologist

Astrobiologists study the origin, evolution, distribution and future of life in the universe – both extraterrestrial life and life on Earth.

Telescopes

http://hubble.stsci.edu/the_telescope/hubble_essentials
http://www.bbc.co.uk/science/space/universe/exploration/kepler_mission
https://en.m.wikipedia.org/wiki/Kepler_(spacecraft)
http://www.spitzer.caltech.edu/
http://www.esa.int/Our_Activities/Space_Science/COROT_overview

Yeast

There are approximately 160 known species of yeast. Yeast is a fungus, a tiny organism; just one gram contains 25 billion cells. It can produce a large amount of carbon dioxide, provided it has the sugars it needs for food. It uses its own enzymes to break down more complex sugars, such as granulated sugar, into a form it can consume.

Extremophiles

As far as we know, Earth is the only planet that supports life and that life began at least 3.8 billion years ago, when Earth had cooled, forming a rocky outer layer. It may have begun either in a rocky pool or in the ocean. No life on our planet can survive without water. Some believe comets or asteroids may have brought the ingredients for life from space. Everywhere we look, life of some kind can be found. Scientists once believed that plants and animals could only exist close to Earth's surface where sunlight could reach. However, bacteria metabolising minerals and gases have been discovered several kilometres down in solid rock; they can live in strong acids, in hot springs on the floor of the deepest oceans, in boiling hot thermal pools, in the frozen wastes of Antarctica, in highly radioactive conditions and even in bubbles of methane gas. We call these survivors 'extremophiles' and it appears that wherever there is water, life can survive. Since life is so hardy, there is reason to believe that some form of alien life may exist in space. One marker is carbon dioxide, the gas that life can generate and which plants both give out and use to grow. Carbon is part of the main chemicals in the building blocks of life. In 2008, the Hubble Space Telescope discovered carbon dioxide in the atmosphere of a planet, HD 189733B, of similar size to Jupiter, orbiting another star.

For further information on extremophiles see: https://astrobiology.nasa.gov/
The Life of Extremophiles by Christopher Brooks, BBC Scotland http://www.bbc.co.uk/nature/21923937

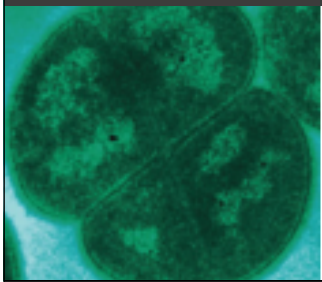
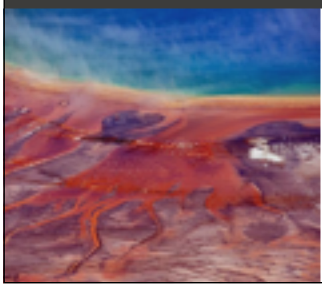
Appendix

Lesson 2
Activity Sheet 2a

Our question is
We will change
We will measure
We will keep these things the same
Our results
We found out

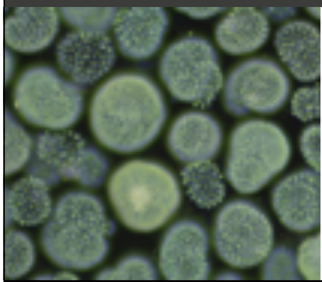
Appendix

Lesson 2
Activity Sheet 2b

Tardigrade	
	Tardigrades, or water bears, are water-dwelling tiny animals that can survive extreme environments. For example, they can withstand extremely low and high temperatures, extreme pressure and doses of radiation that would be lethal for most animals, and they can go without food or water for more than ten years.
Deinococcus radiodurans	
	This one cell organism can survive high levels of radiation, almost 3,000 times as much as humans.
Hesiocaeca methanicola Methane worm	
	A species of worm that is flat and pinkish and 5cm long living in methane ice on the ocean floor.
Thermophile	
	These bacteria that can withstand extreme heat produce the vibrant colours around hot springs in Yellowstone National Park in the USA. The water in the geysers and springs at the park can get to temperatures as high as 70°C.

Appendix

Lesson 2
Activity Sheet 2b

Thermophilic algae	
	Thermophilic algae can survive and flourish in extremely high temperatures. The green algae seen here in Yellowstone National Park grow in water at around 50°C.
Microcystis	
	Microcystis is a type of bacterial algae that grows in waters with extremely high pH levels, such as Mono Lake in California. The cells are usually found organised into colonies like this and can produce and release harmful toxins.
Sea Sandwort	
	Honckenya peploides, commonly known as sea sandwort, is a halophile; this means it can grow in extremely salty conditions – most commonly found near the beach.
Microalgae Dunaliella salina	
	In this aerial view of a salt pond, the microalgae Dunaliella salina, which love extremely salty conditions, create the bright pink colouring.

Lesson 3

Atmospheric

A unique fingerprint of an exoplanet

Curriculum links

England States of matter | Separating mixtures | Reversible change
Scotland Space | Light
Wales How things work-light | Interdependence of organisms | Enquiry
Northern Ireland Properties of materials and their uses

An Exoplanet Seen From Its Moon. Credit: IAU/L. Calçada

Background

Several planets beyond our solar system have been observed to have atmospheres. When an exoplanet is eclipsed by its star scientists have found a method of measuring not just the planet's brightness, but by using a spectrograph to capture a planet's spectrum, they can discover exactly what chemicals are in the atmosphere surrounding that planet.

In this activity, the children investigate splitting coloured inks using chromatography, split white light into separate colours using a CD prism and interpret spectra from exoplanets to identify key elements in their respective atmospheres.

Objectives

To learn:

- white light comprises several colours
- scientists can detect the key ingredients in a planet's atmosphere
- the presence of water, carbon dioxide or oxygen in atmospheres might indicate that life could exist
- to interpret data and identify key features

Resources per group of four

Felt tips
Filter paper
Coloured stickers
Smarties or M&Ms
Pipettes x 2

CD
Light source
Sheet of white paper
Activity sheets 3a and 3b

Advance preparation

Prepare examples of coloured patterns produced when water is dripped onto circles of colour drawn on the filter paper using felt-tipped pens.

Have available a 500ml clear plastic bottle with sports cap and matches for demonstration of cloud in a bottle. Practice may be required.

Teachers may wish to prepare role badges from Appendix 1 to enable the children to work as spectroscopists (scientists using spectroscopy) to investigate patterns of light.

Introduction

Explain that chromatography is a technique used to separate out mixtures. Show how chromatography can be used to separate pigments in dyes and inks. Display the prepared samples of patterns produced by dripping water onto circles of colour drawn by felt-tipped pens on filter paper. Challenge the children to predict which pens produced the patterns on each of the samples. Which colours stayed the same? Which separated into different colours?

Explain that just as some coloured inks comprise many colours, the atmospheres surrounding planets contain many different ingredients. Scientists are collecting information from space to help them discover exactly which gases and other ingredients surround those planets. The presence of some of these, such as hydrogen, carbon dioxide or oxygen, may indicate that the planet is habitable or that life might exist on the planet.

Activity

The children investigate the technique using felt tips of several colours including black. They stick a small coloured sticker in the centre of a piece of filter paper to represent a planet and draw a circle around it using a felt-tipped pen. They add a couple of drops of water to the coloured circle, wait and observe the effects. The children can try different colours including black. What do they notice? They can also investigate dripping water onto Smarties or similarly colour-coated sweets placed on the paper and observing what happens. Explain that some coloured inks use a mixture of pigments that travel at different rates across the paper, enabling the different colours to be seen.

Explain that light can be split into its separate colours too. Has anyone ever seen a rainbow? Raindrops bend the light passing through them, splitting visible light into colours. We call this a spectrum. A CD can be used to split light. The children investigate either by holding up a CD to sunlight, or by shining a torch or other light source onto the CD to view the spectrum of white light. They should try to capture the spectrum on a sheet of white paper by changing the angle of the CD. **Children should be reminded not to look directly at sunlight.**

Lesson 3

Atmospheric

A unique fingerprint of an exoplanet

Explain to the children that atmospheres around planets contain different chemicals or 'ingredients' and each ingredient has a unique pattern of colours or 'spectrum'. When light from a star travels through these atmospheres, ingredients can absorb some of these colours in the light, seen as black lines. From the pattern that is left, scientists can work out which ingredient is present.

Provide each group with Activity sheets 3a and 3b. Sheet 3a gives information about four exoplanets, identification spectra for key ingredients, plus the spectrum for white light. Activity sheet 3b is a quiz. It has a brief description of each exoplanet and spectra for three planets, A–C. The spectrum for planet D has been deliberately omitted for completion in the extension activity. The children compare the spectral patterns with those shown on Activity sheet 3a to identify which elements match each spectrum. After identifying the ingredient in a planet's atmosphere, they can then name each exoplanet.

Plenary

Each group presents its results to the class, identifying planets A, B and C, explaining why they reached the conclusions made.
Which ingredients did they identify?
Which, if any, of the planets could possibly support life? Why/why not?

Extension

The children consolidate their learning by recreating the spectrum for hydrogen, using information provided. Point out the full spectrum for white light shown on Activity sheet 3a. Explain that hydrogen has been detected in the atmosphere of exoplanet D. Hydrogen absorbs some light blue, purple and dark blue from the spectrum. Can they draw the spectrum for exoplanet D? (See teacher information for the hydrogen spectrum)

Teacher demonstration

An 'atmosphere' or cloud in a bottle can be produced quite easily to model a simple example of an exoplanet atmosphere. Pour 50ml warm water into a clear plastic bottle that has a sports cap, light a match, extinguish it and suck the smoke from the extinguished match into the bottle by squeezing and releasing the sides of the bottle a few times. Now close the cap. Squeezing the bottle increases the pressure inside the bottle, increases the temperature and causes the water molecules to become vapour. Releasing the pressure reduces the temperature, allowing the water molecules to condense around the smoke particles, producing a 'cloud'. Teachers may need to practise this before demonstrating.

Further activities

A simple spectroscope using a CD inserted into a box could be built. Instructions for this activity together with several other light and colour related tasks may be found in The Magic of Light, a resource from the European Space Agency. This set of eight enquiry-based activities, aimed at 8–10 year olds, allows pupils to study light and colour using spectroscopes and colour wheels. https://www.stem.org.uk/elibrary/resource/120656

Teacher information

Light consists of electromagnetic radiation of different wavelengths. Substances that emit light have an emission spectrum. Also, each element absorbs certain wavelengths of light and they produce an absorption spectrum. When chemical elements or compounds are heated, they emit energy in the form of light. These spectra of frequencies of electromagnetic radiation can be seen using a machine called a spectrometer. Each chemical element can be identified by its unique spectrum or 'fingerprint'. Early spectroscopes used prisms to bend the light but later models use slits called diffraction gratings through which the light passes. The light is then spread into different wavelengths. The CD has little ridges on its surface and these reflect the light in different directions. It acts as a diffraction grating splitting visible or 'white light' into colours of the rainbow.

The European Space Agency's mission, EUCLID, is a satellite which uses a spectroscope to study why the universe is expanding: http://sci.esa.int/euclid/

Exoplanet A is HD 189733B, a gas giant. Iron has been detected in its atmosphere.

Exoplanet B is HD209458b, a hot Jupiter, with sodium in its atmosphere.

Exoplanet C is Cancri 55e, with helium detected as one of the chemicals in its atmosphere.

Exoplanet D is Gliese 436b, a hot Neptune whose atmosphere contains hydrogen.

Spectra for helium, iron and sodium were used in this activity and when detected in a planet's atmosphere, would not be considered as markers for life, however, hydrogen would be. Hydrogen is a source of chemical energy for microbes that live in the Earth's ocean floor near hydrothermal vents. The detection of a source of hydrogen in an exoplanet atmosphere is an exciting discovery, suggesting that alien life is not impossible.

Spectroscope is an instrument that measures the spectrum of light.

Spectrograph is an instrument that separates light into a frequency spectrum and records the signal using a camera.

Spectroscopists are scientists who use spectroscopes; they investigate and measure the spectra or patterns produced when ingredients or 'matter' interact with or emit electromagnetic radiation.

Hydrogen

Spectrum for hydrogen (teacher to show to children after extension activity)

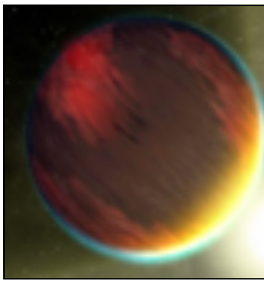
Appendix

Lesson 3
Activity Sheet 3a

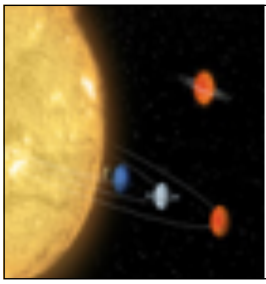
	**Spectrum for white light**

Spectra	Ingredients
	Sodium
	Iron
	Helium

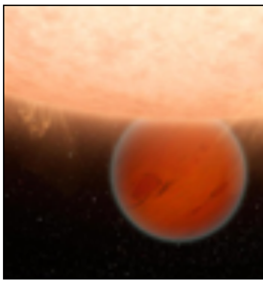
Name	HD 189733b
Type	Gas Giant
Mass	1.162
Orbit	2.2 days
Atmosphere	Iron



Name	HD209458b
Type	Hot Jupiter
Mass	0.71
Orbit	3.5 days
Atmosphere	Sodium



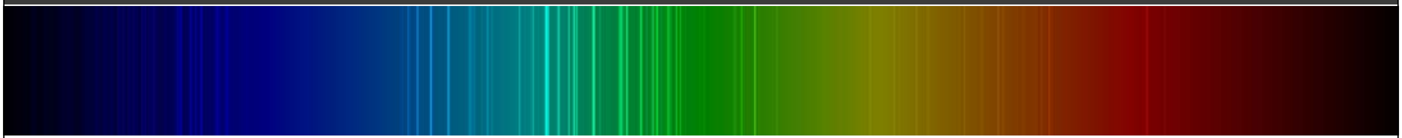
Name	55 Cancri e
Type	Super Earth
Mass	8.63 x Earth
Orbit	0.7 days
Atmosphere	Helium



Name	Gliese 436b
Type	Hot Neptune
Mass	22.2 x Earth
Orbit	2.64 days
Atmosphere	Hydrogen

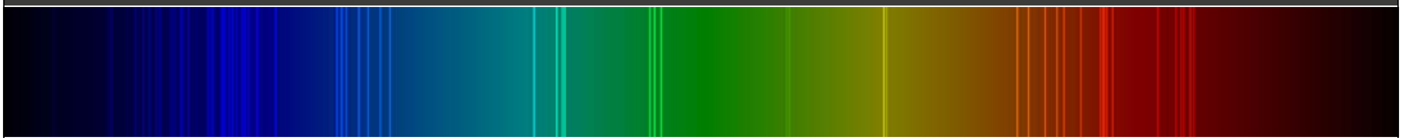
Lesson 3
Activity Sheet 3b

Exoplanet A is:



This exoplanet is a huge gas planet. It has huge winds up to 5,400 miles per hour. It looks blue and its atmosphere is very hazy. It rains molten 'glass.' Scientists have taken this picture of its atmosphere.

Exoplanet B is:



Sometimes called Osiris. This exoplanet is very hot and gas has been seen rising from its surface. It orbits close to its star. It is much larger than the Earth. Scientists have taken this image of its atmosphere.

Exoplanet C is:

This is a super Earth planet, more than 8 times more massive than our Earth. It takes less than a day to orbit its star. Scientists have detected this gas in its atmosphere.

Exoplanet D is:

This is an enormous gas giant, many times bigger than Earth. It orbits its star quickly in just under three days. Its atmosphere contains a gas that absorbs some light blue, purple and dark blue from the spectrum. Can you name the planet and draw the spectrum for the gas detected in its atmosphere?

Lesson 4

'Not too hot, not too cold'

The Goldilocks Zone

Curriculum links

England Change of state | Thermal conductivity, reversible change | Light

Scotland Energy sources

Wales Sustainable earth | Properties of materials and their uses | Enquiry skills

Northern Ireland Properties of materials and their uses | Design and production of everyday objects

Credit: NASA Ames/JPL-Caltech/Tim Pyle

Background

Infrared is a form of electromagnetic radiation but it is not visible light. We can sometimes feel its heating effect on our skin. Everything that is warm also emits infrared radiation; this includes planets, stars and people. As energy is transferred away from a heat source, it is dispersed over an ever-increasing area. This means that the further away an object is, the more difficult it is to detect. Astronomers looking for exoplanets use infrared telescopes to reveal the faint glow of objects in outer space; they can detect objects too cool and therefore too faint to be seen in visible light.

In this lesson children will use data loggers to measure temperature over distance and use thermochromic paper to measure the rate of energy transfer through different materials.

Objectives

To learn:

- planet Earth orbits the Sun in the Goldilocks Zone at just the right distance and temperature
- exoplanets beyond our solar system range from very hot to very cold depending upon their distance from their star
- astronomers use special infrared telescopes to detect these very distant bodies
- energy is transferred from a higher temperature to a lower temperature and its intensity decreases as the distance from its source increases
- to work scientifically by predicting, observing, recording and using data to draw conclusions

Resources per group of four

Tablets or mobile phones with thermal imaging app (if available)
Colour-changing thermochromic paper cut into small squares
Variety of materials and surfaces
Plastic petri dish with lid
Timer
Insulated cup eg coffee cup with lid
Metal skewer or spoon
Adhesive tape
Two cans (optional)
Thermometer x 2 (optional)

Advance preparation

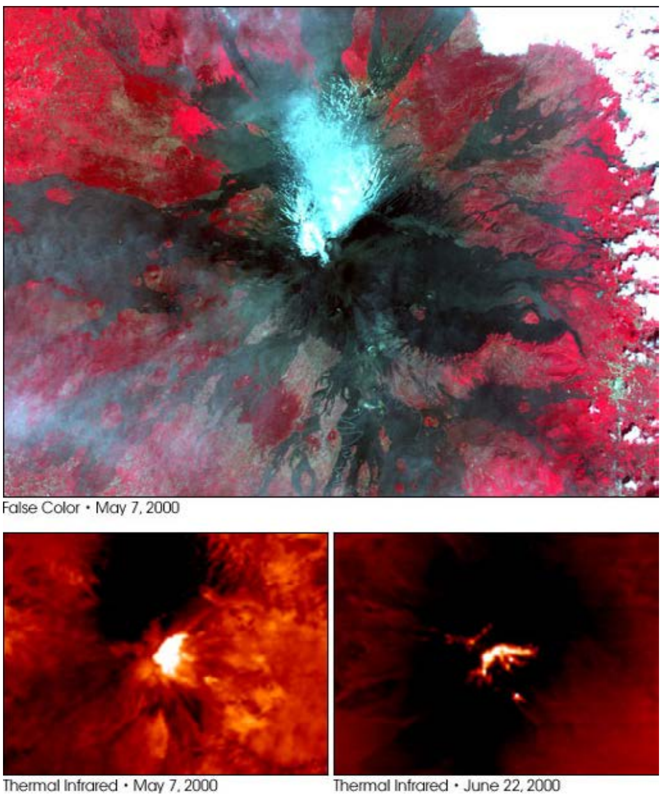
Selection of infrared/ normal images for display

https://spaceplace.nasa.gov/ir-photo-album/en/

Data loggers and laptop for demonstrations.

Remove labels from two cans. Paint one can black, using matt acrylic paint or cover the can with black paper. Prepare a set for each group if required.

Hot water (max 50c).



Above are views of Mount Etna erupting. The bottom two are taken by NASA's thermal infra red detector. Copyright: NASA.

Activity

Introduction

Show the children a few images on the whiteboard of telescopes which collect information from space. Some telescopes, such as the Spitzer Space Telescope, collect information about the temperature of planets, stars and dust; we call these infra-red telescopes. Another example is the James Webb Space Telescope, due to be launched in 2018. See http://jwst-miri.roe.ac.uk or https://www.jwst.nasa.gov/.

Play the infra red game on the whiteboard using https://spaceplace.nasa.gov/ir-photo-album/en//. By passing the 'camera lens' over the images, the children can experience how the world would look if our eyes could see infra red radiation. Explain that some smart phones and tablets have technology to detect infra-red radiation. The children can investigate how thermal / infra-red imaging applications on smart phones or tablets, if available, can be used to detect temperature differences. Can the children think of any every day uses?

Teacher demonstration

Place a lit candle behind a 2 litre bottle of cola, so that the candle is not directly visible. Point a mobile phone in camera mode towards the centre of the bottle; the candle should now be seen clearly glowing brightly on the phone screen. The near infra-red part of the spectrum is just a bit further into the red than our eyes can see. Some smart phone cameras do not have a near infra-red filter fitted, especially on the front facing camera. This enables us to see some of the electromagnetic radiation (light) that is produced by hot objects. One example of this is viewing a candle flame through a bottle of coke. The flame is much more visible using the camera than with the naked eye. It is also possible to modify a webcam to remove the infra-red filter.

http://www.instructables.com/id/Infrared-IR-Webcam/

Further examples of images in the visible and infra-red can be found by following this link http://coolcosmos.ipac.caltech.edu/image_galleries/shoe.html

Provide each group with a few squares of thermochromic paper and let the children explore its properties by handling. Can they explain what is happening? Briefly explain how the material works. (See teacher information). In groups, the children further investigate the properties of the thermochromic paper. They can try placing the paper on different surfaces or in hot or cold hands and observing the colour changes.

After exploring the colour changes, the children plan an investigation to compare the effectiveness of various materials as heat conductors. They heat the thermochromic paper by placing the squares on the lid of a petri dish half filled with hot water (max 50c). When the paper has changed colour, they quickly place the squares onto the materials to be tested. The children can investigate the thermal conductivity of a variety of materials and surfaces, by first predicting and then measuring the time taken for the paper to lose heat and revert to its original colour. They decide the method of recording their results, such as in tables or charts, placing the materials in order of thermal conductivity.

Plenary

The results from each group may be collated on the whiteboard and discussed and can later be displayed in graph form.

Which material was most effective at conducting heat?

Which material was not a good thermal conductor?

How would these results be useful?

Can they think of any practical uses for thermochromic materials?

Explain that energy travels from a source and is conducted or travels through a material; the further away from its source, the lower the temperature. Some materials such as metals are very good heat conductors, allowing heat to pass through them whilst others are insulators, meaning that the material is not very effective at letting heat travel through. In space, heat energy is carried through the vacuum of space by a process called radiation.

Extension

To show conduction of energy through a metal: The groups half fill an insulated disposable cup with hot water (max 50c). Place a metal skewer or spoon into the cup, replacing the lid, so that one end of the metal is below the surface of the water and the rest of the metal threaded through the hole in the lid. Seal any gaps around the metal using tape. The children predict what they think will happen to the temperature of the free end of the skewer or spoon. One member of the group holds the end of the metal, whilst another starts the timer, and informs the group when a temperature increase can be detected; the time is noted. The groups then compare and discuss their results. If data loggers are available, the temperature sensors could be used to record temperature changes of the spoons or skewers; teachers could then connect the data logger to a laptop and display to the class the graph of temperature over time drawn from the data collected.

To demonstrate the radiation of heat

Teachers may decide to use this as a class demonstration or allow each group to set up its own experiment. Pour the same volume of cold water into each of two identical metal cans, one painted with thick black matt acrylic paint or wrapped with black paper and insert a thermometer or data logger temperature probe into each. Place both cans in direct sunlight or under a heat source such as a lamp. Over time, the water in the black can should be warmer than that in the shiny can. The shiny can is a poor absorber of heat because it reflects much of the heat energy away. The black surface is a good absorber of radiant heat and so the water temperature rises.

Lesson 4

'Not too hot, not too cold'

The Goldilocks Zone

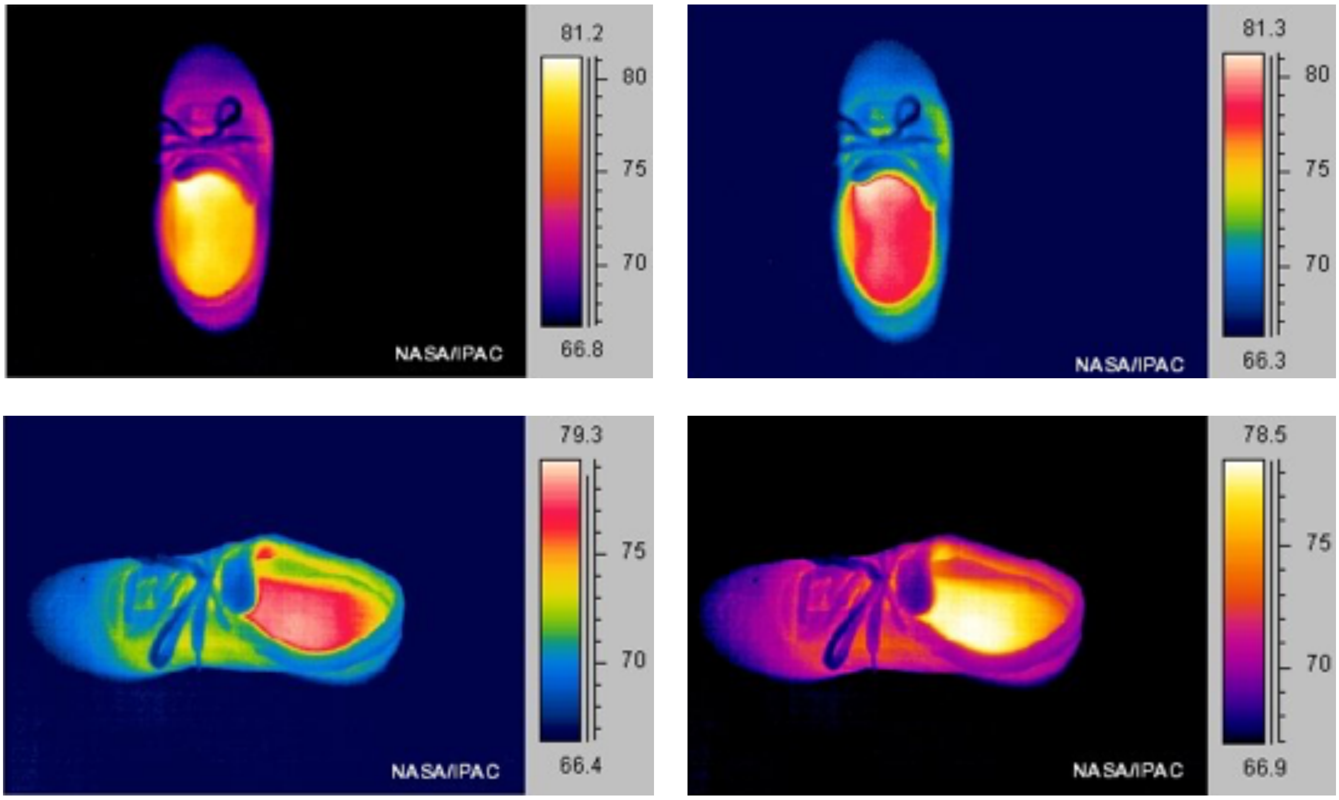
Teacher information

Heat energy moves from hot objects to cold ones by three methods: convection, conduction and radiation. Of these, only radiation does not require contact. In space, heat energy has nothing to travel through and travels in waves through the vacuum of space by radiation. Infra-red is a form of light that falls just outside visible light on the electromagnetic spectrum. Light waves carry energy; shorter wavelengths have higher energy whilst longer wavelengths have lower energy. Cooler objects will glow at longer wavelengths whilst warmer objects will glow at shorter wavelengths. No particles are involved in this process, unlike in conduction, so radiation can occur through the vacuum of space. Astronomers looking for exoplanets use infrared telescopes to reveal the faint glow of objects in outer space. Exoplanets are easier to detect when they are large and orbit their star every few days. 51 Pegasi b is one example and is known as a hot Jupiter. Such planets reach very high temperatures as they are so close to their star and glow strongly in infra-red light. Spitzer became the first Space telescope to enable astronomers to detect the light from hot Jupiters.

Image shows the Spitzer Space Telescope. Copyright: NASA.

Thermochromic paper contains pigments sensitive to temperature. They change colour when they are heated up or cooled down. Thermochromic materials can be used to test a material's 'thermal conductivity' or ability to conduct heat.

Metals are extremely conductive materials. Conduction allows hot, energetic atoms to collide with cooler atoms further along the metal and in turn makes those atoms more energetic. In this way, heat energy moves along the object.



Infrared images showing a training shoe just after being worn.

Further examples of images in the visible and infrared can be found by following this link:
http://coolcosmos.ipac.caltech.edu/image_galleries/shoe.html

Lesson 5

In Transit

Detecting exoplanets by measuring a dip in light

Curriculum links

England Light
Scotland Light
Wales How things work – light | Enquiry skills
Northern Ireland Light and shadows

Artist's impression of a transiting Jupiter-mass exoplanet around a star. Credit: ESO

Background

When a planet orbits its star, it may pass between Earth and the star, preventing some of the light from that star from reaching us. This is called a transit. Measuring the intensity of light over a period of time can help scientists to detect distant planets and their stars. In this activity, the children learn about light and shadows, the transit of exoplanets around a star, stars as light emitters and the absorption of light.

Objectives

To learn:

- when an opaque or translucent object blocks a light source, a shadow is produced
- the closer the object to a light source, the larger the shadow produced
- stars emit light
- planets orbit stars blocking some of the star light
- planets can absorb and reflect light

Resources per group of four

Wooden lollipop sticks or skewers
Card
Scissors
Adhesive tape
Polystyrene spheres 3 sizes (or substitute with card circles)
Light source eg torch or LED lamp
Whiteboard
Datalogger and laptop (optional)
Activity sheets 5a and 5b

Advance preparation

Have available balls of several sizes eg football, sponge ball, tennis ball

Prepare role badges for 'transit photometrist' if required

Activity

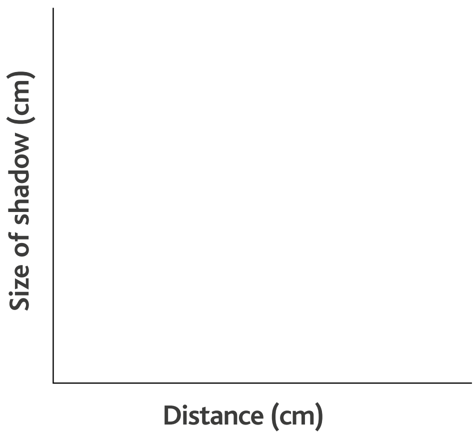
Introduction

Ask the children what happens when an opaque object passes in front of a light source. Demonstrate moving an object across the beam from the class projector and capturing the shadow on the whiteboard. Alternatively, use a torch or lamp and capture the shadow on a white card or children's whiteboard placed behind.

Pose the questions: What happens to the size of the shadow when an object is moved closer to or further away from the light? How could you find out?

In groups, the children cut out a small figure or shape from card and attach it to a card base so that it stands upright. The children plan their investigation, make predictions and carry out the activity, taking careful measurements and recording their results. They may wish to use the recording example on Activity sheet 5a. The groups share their findings and explain their conclusions. What did they discover? What happened to the size of the shadow when the figure moved closer/further from the light source? How did they ensure a fair test each time? Can they use the data to plot a graph showing size of shadow versus distance from light?

Graph to show size of shadow versus distance from the light



Show this animation, Transiting Exoplanet Graph, showing the simulated light curve as a planet orbits a star: http://youtu.be/OX_QWa_v5rw

Model the transit of a planet across its star using the whiteboard and the class projector as the star. The class should notice the shadow on the screen as two children throw a ball from one side of the whiteboard to the other. Try varying the size of ball used.

Lesson 5

In Transit

Detecting exoplanets by measuring a dip in light

In groups, the children model the transit of a planet around its star using polystyrene spheres (or circles of card) for exoplanets and wooden skewers or lollipop sticks to hold the planets. A light source, such as a torch or an LED lamp, represents the star. Connecting a data logger to a laptop and measuring light intensity should show a drop in light measured when the planet passes across the light source.

The children are shown Activity sheet 5b displaying a set of graphs showing level of light over time as an exoplanet orbits a star. Graph a also shows how the graph would look if a larger planet orbited. On diagrams b, c and d, can they draw a line to show the graph obtained if a smaller, faster or slower planet orbits the star?

Plenary

Challenge each group to model one of the light curves shown on Activity sheet 5b. Can they explain how the light curve is changed by speed of transit or size of planet orbiting the star? Discuss the main learning points from the practical activities. Remind the children that by carefully observing a star's brightness over a period of time, scientists can detect a tiny drop in the amount of light we see from the star. They can measure this brightness and create a graph called a light curve. Planets are usually tiny compared with their star and so the drop in light is extremely small. Earth-sized planets are particularly difficult to spot. Exoplanets that are big are easier to spot, especially when we can detect many orbits. NASA's Kepler Mission has been observing the same patch of sky for years, roughly 100,000 stars, hoping to detect transits: https://kepler.nasa.gov/index.cfm

Show the following: an interesting animated video explaining the work of the Kepler Mission and how the telescope discovers planets:
https://kepler.nasa.gov/multimedia/Interactives/HowKeplerDiscoversPlanetsElementary/flash.cfm

Lightgrapher: https://kepler.nasa.gov/education/ModelsandSimulations/lightgrapher/

Extension

A lightbox can be made from a shoebox. At one end, make a hole through which to shine a light source, such as an LED torch. At the other end, make a hole directly opposite the light source. Cut a half circle in the lid near to the end where the light source is located. Insert a stick through the slit and attach a ball of plasticine to one end of the stick to represent the planet; ensure that the planet is in the beam of light. Move the stick with planet attached from one end of the semi-circular slit to the other, to represent part of the orbit. To avoid looking directly at the light, use a mobile phone or iPad positioned at the viewing hole, to take a video of the passage of the planet as it is moved around the slit.

Appendix

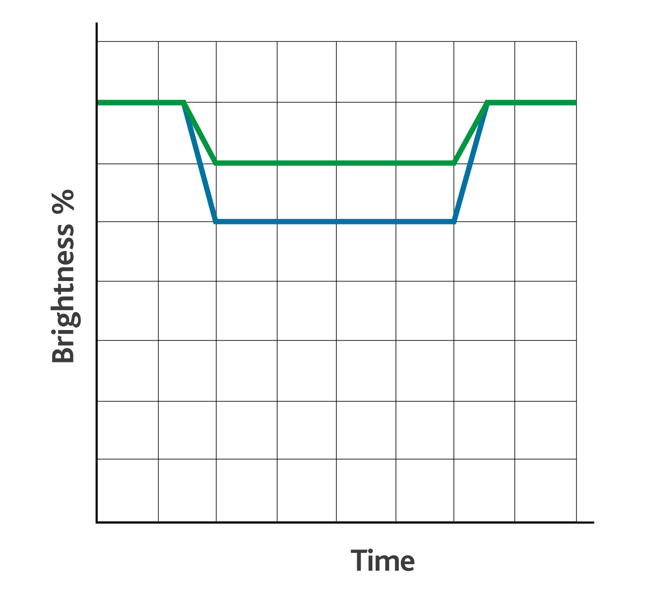
Lesson 5
Activity Sheet 5a

Our question is	
We predict	
We will change	
We will measure	
We will keep these things the same	
Our results	
Distance from light (cm)	Size of shadow (cm)
Our results show	

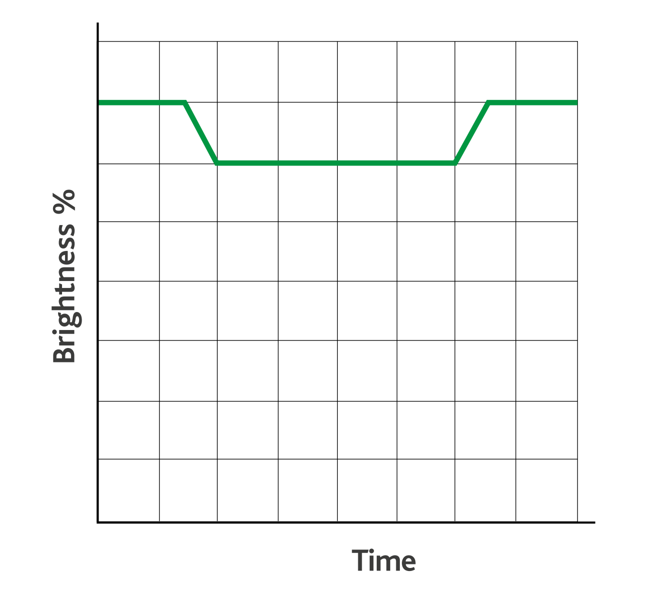
Lesson 5
Activity Sheet 5b

Here are four copies of the same light curve plotted during the transit of a planet across its star.
Graph a) also shows the curve (shown in blue) obtained when a larger planet orbited the star.
Draw another curve on the graphs to show: b)a smaller planet, c)a faster transit and d) a slower planet

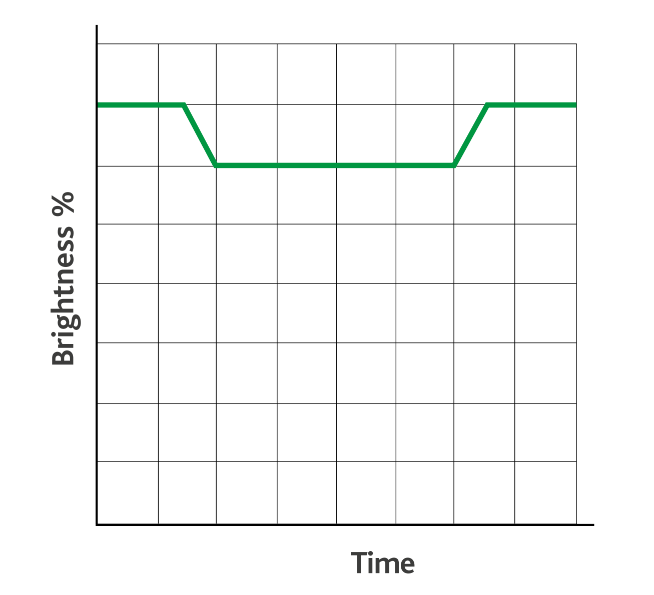
Graph A



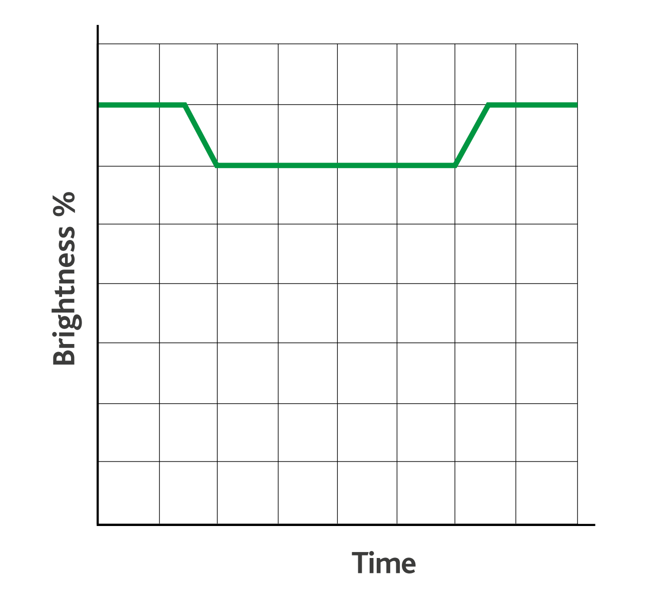
Graph B



Graph C



Graph D



Lesson 6

May the force be with you

Making an electromagnet

Curriculum links

England Forces and magnets | Electricity | Properties of materials

Scotland Forces | Electricity

Wales How things work-magnetic forces | Uses of electricity and its control | Enquiry skills

Northern Ireland Properties of materials and their uses

Exoplanet with high levels of elctromagnetic radiation. Credit: NASA/JPL-Caltech/R. Hurt (SSC)

Background

The discovery of exoplanet Proxima b, a potentially Earth-like world orbiting Proxima Centauri, the closest star to our own Sun, gave rise to several questions concerning its potential to host life. Huge amounts of radiation emanating from its star bombard this exoplanet. Since it is closer to its star than Earth is to the Sun, for life to survive, it would require a very strong magnetic field. On Earth, a magnetic field around the planet protects all living creatures from dangerous cosmic rays.

In this activity, the children investigate magnets, make a simple electromagnet and investigate its properties.

Objectives

To learn:

- magnetic poles are in pairs
- opposite poles attract and like poles repel
- some materials are attracted by magnets
- an electric current in a wire produces a magnetic field around the wire

Resources per group of four

Magnets: bar, circular, horseshoe x 2
Plastic container holding:
Insulated wire (minimum 2m)
Wire strippers
Large iron nails x 2 (thick and thin)
Paper clips
AA battery x 3
Battery holder
Switch
Wire with crocodile clips x2
Tape
Scissors

Advance preparation

Teachers could make simple electrical switches with the children if commercial switches are not available. (Instructions in teacher information)

Teachers may wish to prepare badges for the role of astrophysicist.

Make and test one electromagnet prior to the activity. Magnet strength will vary according to the number of coils of wire.

Activity

Introduction

Show the children an image of exoplanet Proxima b, explaining that it is a distant planet orbiting a star called Proxima Centauri, the closest star to our Sun. Although the planet orbits its star in the habitable zone, it experiences huge winds 2,000 times those on Earth and is bombarded with radiation. A magnetic field around the planet would be needed to protect any potential life.

In this activity, the children freely investigate magnets of various kinds, testing attraction and repulsion between poles, and magnetic strength; they also investigate materials attracted by magnets. After discussion of their results, explain that electricity can be used to make a magnet; this is called an electromagnet.

Each group uses the materials provided in the containers to make an electromagnet. They first test its effectiveness using paper clips. Next, the groups discuss materials they would like to test with their electromagnet before collecting a variety of materials.

Investigate

How many paper clips will the electromagnet attract?

Does changing the number of coils of wire alter the strength of the magnet?

Is there a link between the number of coils and number of paper clips the magnet can attract?

Can you add a switch to turn on and off the flow of electricity and thus your magnet?

What effect does increasing the voltage by using a more powerful battery, or adding more batteries, have upon the magnet?

Does using a longer, shorter, thinner or thicker nail affect the strength of the magnet?

What materials can you lift using magnetic attraction?

The data collected during their investigation into the link between number of coils of wire and number of paper clips attracted could later be displayed as graphs. The children present their findings in the form of a presentation or poster.

Lesson 6

May the force be with you

Making an electromagnet

Number of coils:	Number of paper clips:

Plenary

Each group chooses a method of sharing its findings with the class. Summarise the results on the whiteboard. Did the groups find a connection between the number of coils of wire and the strength of the electromagnet? Did they increase the strength of their magnet? How? What materials were attracted to the magnet? Do the groups agree?

Extension

The children might research exoplanet Planet HD 209458b Osiris, a Hot Jupiter, approximately one third larger and lighter than Jupiter. Proxima b could also be researched. https://www.nasa.gov/content/goddard/hubbles-new-shot-of-proxima-centauri-our-nearest-neighbor/

https://en.wikipedia.org/wiki/Proxima_Centauri_b

Teacher information

Our planet's magnetic field is thought to be generated deep down in the Earth's core. As the Earth spins, liquids in the planet's core swirl around. The liquid iron conducts electricity, generating electric currents which in turn create magnetic fields. Scientists have developed a method which allows them to estimate the magnetic field of a distant exoplanet outside our solar system orbiting a different star. They used the Hubble Space Telescope to observe when the planet passed across the star. Next, they studied the absorption of the star's radiation by the planet's atmosphere before finally estimating the size of the magnetic fields around the planet.

Magnetic fields are produced when electrons in a metal object are spinning in the same direction. An electromagnet is a type of magnet that uses electricity, and a magnetic material such as iron, to produce magnetic fields. We cannot see magnetic fields but we can measure their effects.

To make a simple electromagnet:

- Strip the insulation from the ends of the wire
- Set up the resources in a plastic container that won't conduct electricity
- Hold the wire approx. 20cm from its end. Place it at the head of the nail and wrap it around the nail. Continue wrapping the wire around the nail without overlapping the wire, until reaching the tip of the nail
- Ensure that you wrap the nail with the wire running in the same direction so that the electricity can flow in one direction
- Connect the ends of the wire to the two terminals, the positive and negative ends of the battery, placing a piece of tape or elastic band across each to maintain a connection.
- When the second end of the wire is attached, the battery will begin to conduct electricity through the wire coil and the nail will become magnetised
- Swapping the connections will also switch polarity of the magnetic field created
- Test the electromagnet by placing it next to a paper clip or other metals.

Simple switch

To make a simple switch: Two small nails, each with a paper clip placed under the tip of the nail, are tapped into a small wooden block. Wires are attached to the head of each nail using crocodile clips. Swinging the paper clips into contact with one another completes the circuit. Follow the link below for instructions on making this and another example of a simple switch.
http://homeschoolandthings.blogspot.co.uk/2013/03/making-simple-switch-for-electrical.html

Lesson 7

Can you hear me?

Communication through space

Curriculum links

England Sound | Uses of materials
Scotland Vibrations and waves
Wales How things work-sound | Enquiry skills
Northern Ireland Properties of materials and their uses

Artist rendition of CLUSTER spacecraft. Copyright: NASA

Background

ESA's four Cluster spacecraft have found that Earth and other planets with magnetic fields such as Jupiter and Saturn emit radio signals that travel through space in a narrow beam. These messages can only be detected and understood by using large radio telescopes.

In this activity, the children model different ways of sending messages across distances including the journey of radio waves through space, they work scientifically by investigating string telephones and listen to Earth's natural sounds.

Objectives

To learn:

- electromagnetic waves travel through space
- scientists collect these waves by using radio telescopes
- these waves are then changed into sounds
- to work scientifically by predicting, setting up a fair test, collecting and interpreting data

Resources per group of four

Disposable cups x 2
Cans x 2
String
Wire
Nylon thread
Metre stick/tape measure
Activity Sheet 2a

Resources for teacher demonstration

Airzooka or cardboard box
Length of aluminium foil
Polystyrene cups
Soft balls of different colours
Umbrella

An airzooka can be purchased online or made from a cardboard box if a commercially bought airzooka is not available. (See teacher information)
Have an analogue radio at hand.
Make a small hole in the base of each can and cup.
Teachers may wish to prepare role badges for 'radio astronomers' for this investigation.

Activity a To investigate ways of sending messages across a distance

Introduction

Start the lesson with a demonstration to capture imagination. Set up a line of string across the classroom and suspend a length of aluminium foil from the string or have one of the children hold up the foil. Use an airzooka to send an airwave across the room to vibrate the length of foil. Next, ask volunteers to place a polystyrene cup on their heads. Aim the airzooka at each cup and fire, causing the cups to wobble and fall. Can the children explain what they think is happening? (Clashing cymbals can also be used to demonstrate producing an airwave to put out a candle flame.)

Explain that although we could not see the air moving across to the foil or cup, we could see or feel the result of that movement. Similarly we cannot see radio waves travelling vast distances across space but we know that they are there once they are collected and changed into sound.

Ask the children if they can think of ways to send messages over a distance here on planet Earth. Discuss their suggestions. Show the children two simple items – paper cups and string – that could be used to send a message. Can they suggest how? Challenge them to test their ideas. In pairs, the children explore sending messages using paper cups and string. In groups, they identify the variables that could be changed and plan how they might set up an investigation. They may like to use Activity sheet 2a , (from lesson 2) to support their planning to answer such questions as:

Does the length of string/type of string affect the sound received?

What happens when the string is taut/loose?

Does the type or material of the cup have an effect?

Will the string telephones work around corners?

The children collect and record the data and share their results with the class.

Which type of string or cup would they recommend and why?

Plenary

Explain that sounds are produced by vibrations that can travel through air, solids and liquids. Vibrations produced from speaking into the cup travel along the string to reach the second cup; air in the cup and bones in the skull vibrate and these vibrations reach our ears. Our brains decipher this information into recognisable sounds. The following short video could be used to consolidate learning: https://www.youtube.com/watch?v=HMXoHKwWmU8

Activity b Investigating radio waves

Introduction

Emphasise that radio waves are very different from sound waves. Explain that electromagnetic waves can travel through space without air being present. Some of these waves are called radio waves. Scientists have found a way of collecting the radio waves and turning them into signals which travel to our ears.

Activity

Next, the children model the journey of electromagnetic waves through space to the radio telescope. Using soft balls of different colours to represent the electromagnetic waves, volunteers on one side of the room throw the balls towards the 'radio telescope', an opened umbrella held concave side towards the class by a volunteer at the other side of the room. Choose one of the colours to represent the useful radio waves. When all the balls have been thrown, only the balls of the chosen colour 'caught' by the umbrella are kept, whilst the others are removed. Explain that a lot of radiation, represented here by the various coloured balls, is emitted by stars, represented by the children, and travels through space; it is collected by the radio telescope, represented by the umbrella. Only radiation of certain wavelengths, called radio waves, can be used by the telescope, where it is changed into signals that we can understand.

Teacher demonstration

Use an analogue radio to let the children experience the sound we hear when a radio station is not tuned in and how tuning produces a clear sound. Similarly, we would be unable to make sense of radio waves unless their energy was changed into vibrations that we hear as sounds.

Plenary

Explain that Earth and other planets have a way of shouting "I'm here!" to the rest of the Galaxy. However, the messages can only be heard and understood by using large radio telescopes. Listen to a recording of Earth's natural 'sounds': http://www.esa.int/esaKIDSen/SEM5QPSHKHF_LifeinSpace_0.html

Extension

Enthusiasts could build or buy a transmitter to enable the children to send messages.

The children could also make their own radio recording.

Morse code could be researched. There is an iPhone app called Morse-It that translates text into Morse beeps or flashes. The children might construct an electrical circuit including a buzzer and send messages using the patterns of Morse code. An LED lamp could be substituted for a buzzer. Alternatively a torch could be used to send messages as patterns of flashes. Explain that light can be used in this way to transfer information.

A	•—	J	•———	S	•••	1	•————
B	—•••	K	—•—	T	—	2	••———
C	—•—•	L	•—••	U	••—	3	•••——
D	—••	M	——	V	•••—	4	••••—
E	•	N	—•	W	•——	5	•••••
F	••—•	O	———	X	—••—	6	—••••
G	——•	P	•——•	Y	—•——	7	——•••
H	••••	Q	——•—	Z	——••	8	———••
I	••	R	•—•	0	—————	9	————•

Morse code shown on above chart

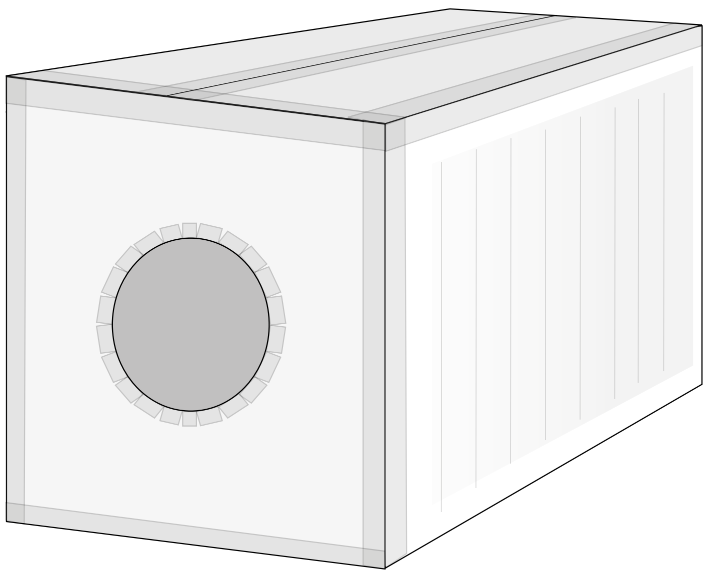
Lesson 7

Can you hear me?

Communication through space

Teacher information

Objects in space, such as planets, exoplanets, stars, dust and gas emit electromagnetic waves at many different wavelengths. Some of the light they emit has very long wavelengths, some as long as a mile. These long waves are known as radio waves and are part of a larger group of waves classified all together as the electromagnetic spectrum. Since the radio waves are so large, special telescopes called radio telescopes are used to capture them. They are much larger than the telescopes used to capture visible light. These huge telescopes are pointed towards the stars or planets and astronomers can learn about their structure, motion and composition by studying the radio waves originating from them. Astronomers can use instruments to convert the radio waves into sounds and pictures.



To make an airzooka
You will need:

Cardboard box
Tape
Scissors
Compass
Pen

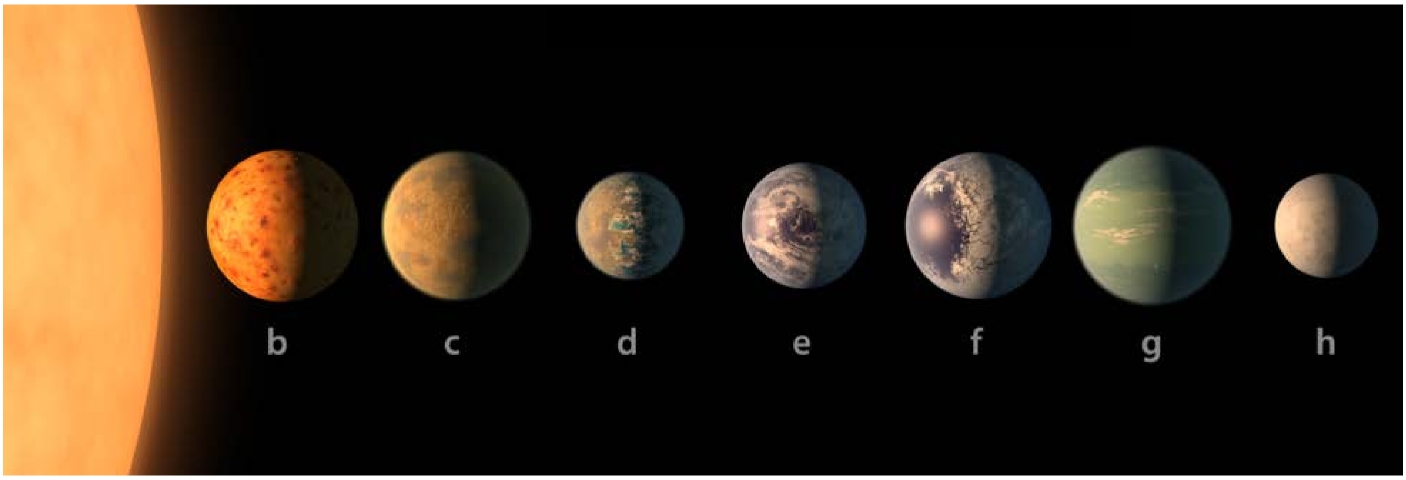
Completely seal all edges of the box. Draw a circular hole in the centre of one side of the box, cut it out and seal the edges of the hole with tape. Hit opposite sides of the box simultaneously with your hands, forcing air to travel out through the hole. Direct the escaping air towards a target, such as a pile of paper cups and try to knock them down.

Lesson 8

Making music 'exoplanet style'

Curriculum links

England Sound
Scotland Vibrations and waves
Wales How things work-sound
Northern Ireland Sound



TRAPPIST-1 System - Illustration Copyright: NASA

Background

The Spitzer Space Telescope recently revealed seven Earth-like planets astronomically named b, c, d, e, f, g and h, orbiting the TRAPPIST-1 star. The planets could be detected as they transited across the front of the star, periodically blocking a tiny bit of the star's light. There is a pattern to the way in which the planets orbit the star.

In this lesson, the children use everyday materials to make simple instruments such as pan pipes from straws, to produce seven notes and use their imaginations to devise melodies using permutations of those notes.

Objectives

To learn:

- sounds are produced by vibrations
- the pitch of a sound can be changed
- exoplanets may transit their stars in a regular pattern

Resources per group of four

Straws (preferably paper)
Scissors x 2
Bottles or jars filled to different levels with water
Drumsticks x 2
Elastic bands (various sizes)
Empty tissue box
Plastic rulers x 2

Lesson 8

Making music 'exoplanet style'

Advance preparation

Teachers may wish to prepare badges for the role of sound engineer.

Activity

Introduction

Introduce the children to the star TRAPPIST-1 and its seven planets, revealed by the Spitzer Space Telescope. (Show image of TRAPPIST-1)

http://cdn.sci-news.com/images/enlarge3image_4728e-TRAPPIST-1.jpg

Watch the animation of the TRAPPIST transits. The orbits have been speeded up to fit into a one-minute video.

http://www.spitzer.caltech.edu/explore/blog/371-Making-Music-from-Exoplanets

Explain that using the transit patterns of these seven Earth-like planets, a musician has composed some music based on the timing of these transits. He accompanied each planet transit with a musical note of the same name and added some simple background instruments and a drum track.

Give examples of some other exoplanet systems such as Gliese or Kepler, involving different numbers of orbiting planets.

https://exoplanets.nasa.gov/resources/174/

https://www.nasa.gov/ames/kepler/kepler-186-and-the-solar-system

The children cut the straws to make seven 'pan pipes' of different lengths, each having one pointed flattened end, producing a different note or vibration when blown through the flattened end. Can the children blow them in turn to make a melody? In groups, the children use the seven notes as a basic tune and add music of their own.

We have made music based on the TRAPPIST transit. Can they make a melody based on the other systems? They could try tapping bottles or jars filled with water to different levels, drumming, twanging rulers extending over the edge of a table or elastic bands stretched across an empty tissue box.

Can the groups compose a rap to accompany their rhythms?

Plenary

Each group performs its composition for the class. Can they suggest any improvements to the musical pieces?

In Lesson 7, the children learned that planets with a magnetic field produce signals that are detected by using radio telescopes. An alien race picking up Earth's natural radio signals will hear a series of chirps and whistles, a bit like listening to R2-D2, the robot from Star Wars!

Listen again to Earth's chirps and whistles on ESA Kids: http://www.esa.int/esaKIDSen/SEM5QPSHKHF_LifeinSpace_0.html

Listen to a clip from Star Wars, the five-note signature from the film Close Encounters of the Third Kind, or other space-themed music.

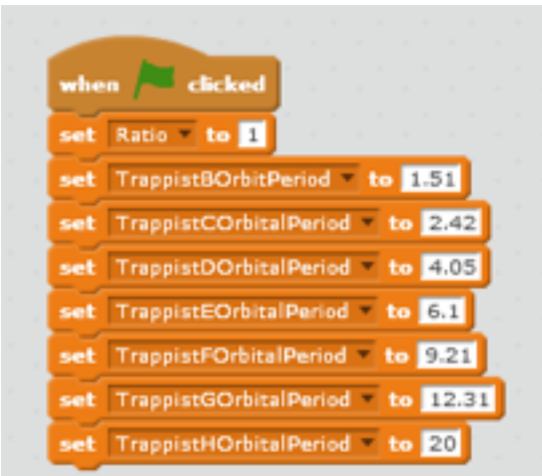
Extension

The children could be introduced to a computer program to produce their own musical compositions based on the TRAPPIST-1 orbiting pattern. Beatwave is an interesting app that can be used on the iPad. The app provides opportunities for composing simple rhythms, melodies, parallel melodies and adding background instruments.

Scratch program

Each of the Trappist-1 planets takes a different time to orbit its parent star. Kepler's Law tells us that the further away a planet is from the star, the longer the duration of the orbit.

In this Scratch project, the period of each orbit is proportional to the real orbital periods of the Trappist exoplanets. Each time a planet completes one orbit, the model makes a different sound.
https://scratch.mit.edu/projects/153216618/



The sounds are allocated as follows but are easily changed within the model:

B – Chomp
C – Boing
D – Cricket (chirp)
E – Meow
F – Alien Creak2
G – Bass beatbox
H – Goose

The time taken for each orbit can be found in the Scratch model and is given in seconds.

The ratio slider on the model can be used to give multiples of each orbital period. For example, if the ratio is set to 2, then the period for Trappist-1b will be 3.02 seconds, and for Trappist-1h will be 40 seconds.

Lesson 8

Making music 'exoplanet style'

Activities

Click the arrow: Identify the different noises being played. Put them in order (from shortest period to longest). Click stop to end the sounds.

Time each one: Create a table of orbital period (seconds). Check by clicking on each planet to play each sound on its own. The actual planet data can be found on Wikipedia here: https://en.wikipedia.org/wiki/TRAPPIST-1#/media/File:PIA21425_-_TRAPPIST-1_Statistics_Table.jpg

Children could model the orbits by walking around a 'star' and trying to time their orbits so that they pass by the same point when the sound of their planet is made. Physically modelling the orbits, each child representing a planet walking or running around a central star, might help them understand the planet's distance away from the star and the speed at which it is travelling in relation to the other planets. It may also help them to understand what they are actually doing with the Scratch programming activity – that the different noises represent a complete orbit. They would need to scale the distance of the orbits, otherwise some might take days to orbit, so a useful maths activity would be to create a suitable scale that could be represented in class. This would have to assume that they are all circular orbits. By playing with the ratio slider, the children can find the best option to enable all planets to safely complete their orbits. They calculate how long the period of their particular sound will be, then check.

Keen programmers could take this further by adding the orbits of the planets to the model. An example of circular motion in Scratch can be found here: https://scratch.mit.edu/projects/11439426/

Extension activities

Use the orbital period data to create a similar musical composition for our solar system and compare the two systems.

Create a Scratch animation of the exoplanets rotating around TRAPPIST-1.

Lesson 9

Exoplanet Travel Bureau

Explore Alien Worlds

Curriculum links

England Opportunity to link with several science topics eg requirements for plant life, animal nutrition, rocks, light, magnetic force | Food chains, states of matter, sound

Scotland Biodiversity and interdependence

Wales Interdependence of organisms | Enquiry

Northern Ireland The variety of living things | Adaptations of living things

Credit: IAU/L. Calçada

Background

In this activity, children research information about exoplanets and based upon this information, they use their imaginations, working creatively to design and describe a new exoplanet. They consider the key features and the adaptations that living things would have to make to survive the planet's environment.

Objectives

To learn:

- exoplanets and their stars are millions of light years from our solar system
- conditions on these planets are diverse
- living things adapt in different ways over time to survive environmental conditions
- life may exist in other solar systems in a different form from that on Earth

Resources per group of four

Paper
Coloured felt tips and pencils
Access to books, tablets or computers

Lesson 9

Exoplanet Travel Bureau

Explore Alien Worlds

Advance preparation

Prepare role badges for exogalactic astronomer and astrobiologist if required.

Introduction

Explain to the children that in this lesson, they will first be taking on the role of exogalactic astronomers to research and design a distant exoplanet. As astrobiologists, they will then research and design unique alien life, describing how it has adapted to conditions on their far-off world.

Begin by taking the children on an exciting trip to far-off worlds using the interactive http://eyes.jpl.nasa.gov/eyes-on-exoplanets.html

Show the children the images from the NASA website:

www.exoplanets.nasa.gov/alien-worlds/exoplanet-travel-bureau

There is a selection of posters on this website advertising a variety of exoplanets and highlighting the unique features of each.

TRAPPIST-1_Planet hop from TRAPPIST-1

PSOJ3188.5-22 _Where the night life never ends

HD4037G_Experience the gravity of a super earth

KEPLER-16B_Where your shadow always has company

51 Pegasi-b_Greetings from your first exoplanet

KEPLER-186F_Where the grass is always redder

These exoplanets range in size from super-Earths to mini Neptunes; some are rocky, some dry as deserts, some volcanic, some blisteringly hot or icy cold; some are ravaged by powerful winds or bombarded by intense radiation.

Activity a

Each group researches several exoplanet systems and, using this information, the children create a detailed description of their far-off world. They next design a poster to advertise their planet’s key features.

Activity b

If life could be supported, what form would it take? What kind of adaptations would living things have had to make to survive the planet's environment? Astrobiologists are interested in discovering the conditions required for life and what form that life might take. The children assume the role of astrobiologists, researching extreme conditions on Earth and the adaptations of living things surviving in those environments. They use this information to describe the kind of alien life that may exist on their imaginary new world. They draw and label this new life, pointing out key features.

Plenary

The groups present their designs to their own or another class, describing their alien world in detail. They explain how the living things have adaptations making them suited to their environment.

Extension activities

If it were possible, which exoplanet would the children travel to or send a probe to investigate and why? Emphasise that travelling to these far-off exoplanets is impossible due to the vast distances involved. What kind of place would it be? If they could choose its characteristics, what would make it ideal for their happiness and well-being?

Each group may like to compose music to accompany their poster. They could also design, build and decorate a model to show the key features of their chosen distant world. Further cross-curricular activities could be linked, such as art, drama, technology, engineering, geography, literacy and computing.

Voyager

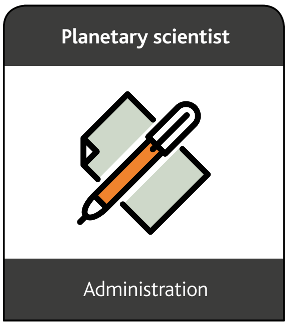
In 1977, twin spacecraft, Voyager 1 and 2, were launched to explore regions of space, where nothing from Earth has ever reached. They are both further from the Sun than Pluto and from data being sent back to Earth, scientists hope to learn more about the region between stars, called the interstellar space. The spacecraft are carrying a 12-inch gold-plated copper disc containing sounds and images selected to portray the diversity of life and culture on Earth.

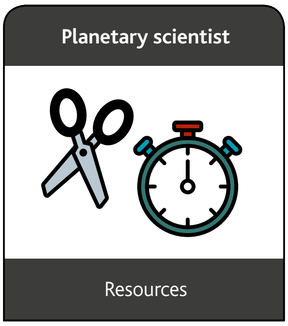
What would the children wish to be put on such a disc to be sent on a mission to a planet far away beyond the edge of our galaxy?
How would they describe human beings?
What makes them happy?
What qualities do they feel are desirable in a human being?
What hobbies, animals, geographical features or music would they include?
If they were asked to write a letter to an alien, what would they want to say?

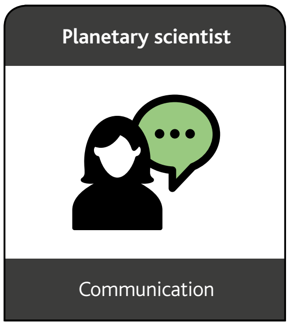
The children might record a video or spoken message, musical compositions, computing, robotics, art or photography. There are many opportunities in this activity for a broad cross-curricular approach appealing to all ages and abilities.

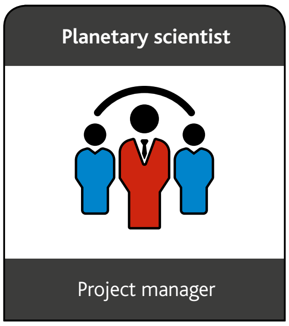
Appendix 1
Role badges

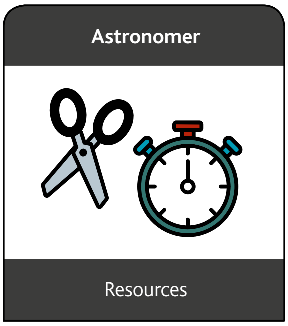
All classroom sessions involve children working together in groups of four. Each child is responsible for a different job or role within the group and wears a badge to identify this. Such role play may help the children to understand the variety of career opportunities that exist within the space sector. The images below may be photocopied onto card and made into badges. Children should be encouraged to swap badges in subsequent lessons; this will enable every child to experience the responsibilities of each role.

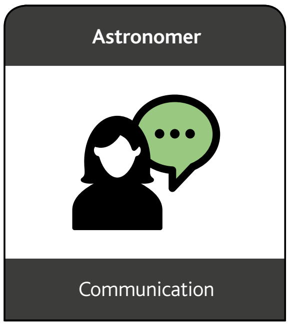


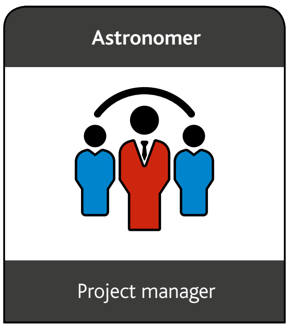






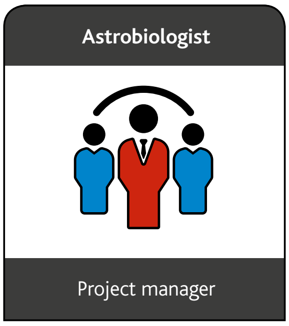






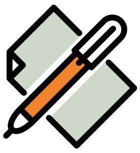
Appendix

Appendix 1
Role badges



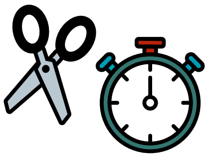
Appendix 1
Role badges

Galactic/exogalactic astronomer



Administration

Galactic/exogalactic astronomer



Resources

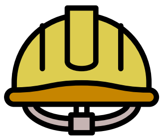
Galactic/exogalactic astronomer

Communication

Galactic/exogalactic astronomer

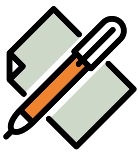
Project manager

Galactic/exogalactic astronomer



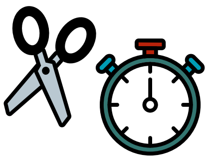
Health & safety

Spectroscopist



Administration

Spectroscopist



Resources

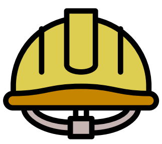
Spectroscopist

Communication

Spectroscopist

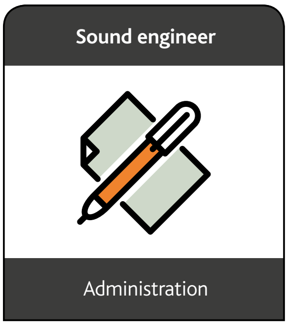
Project manager

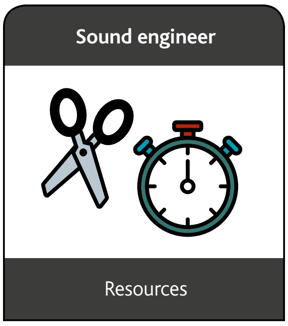
Spectroscopist

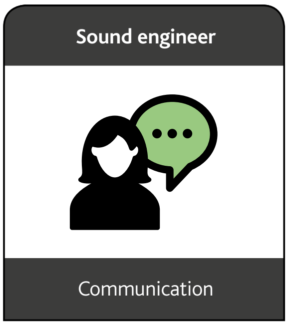


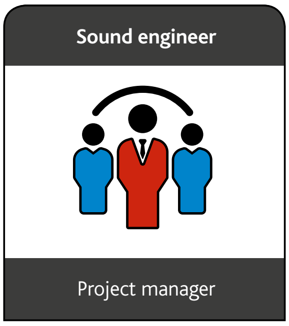
Health & safety

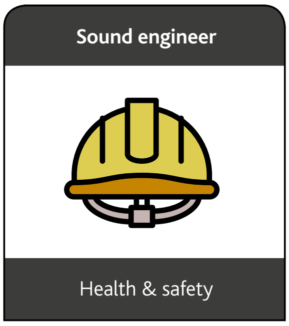
Appendix 1
Role badges

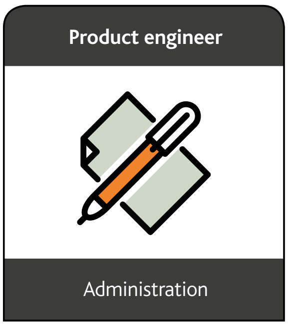


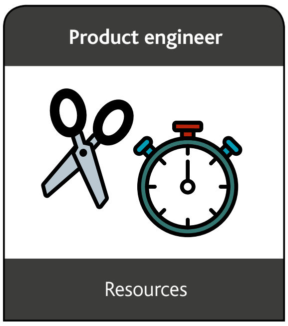


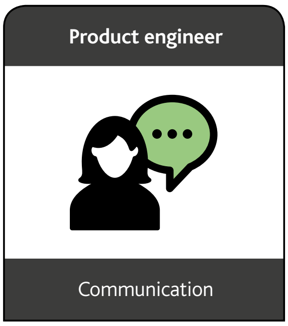


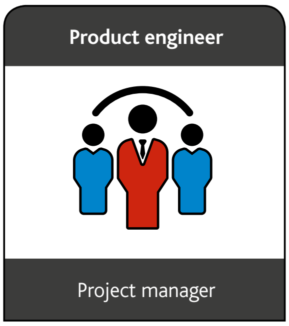




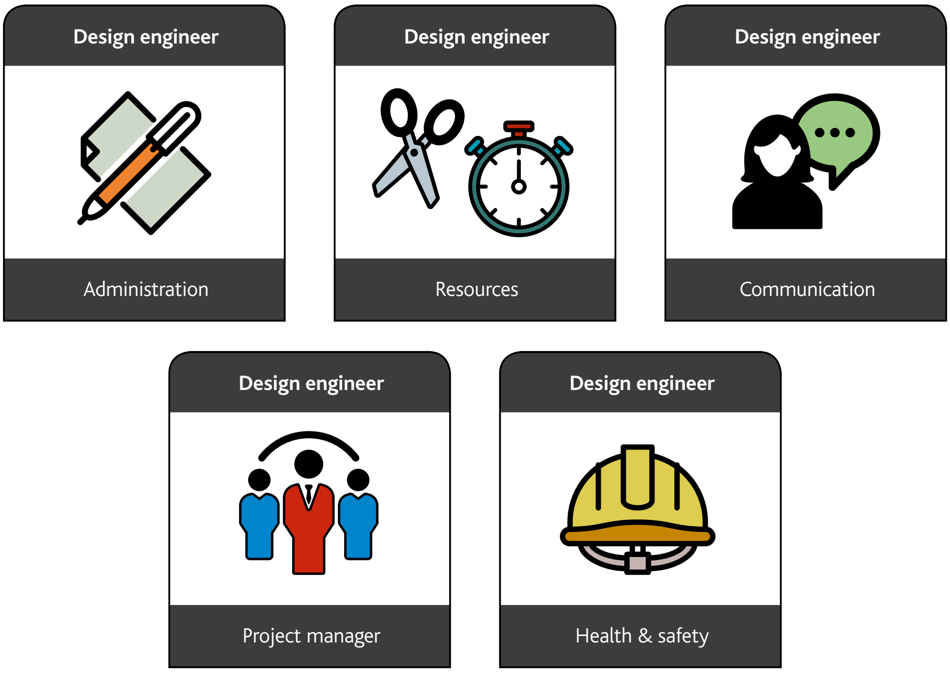


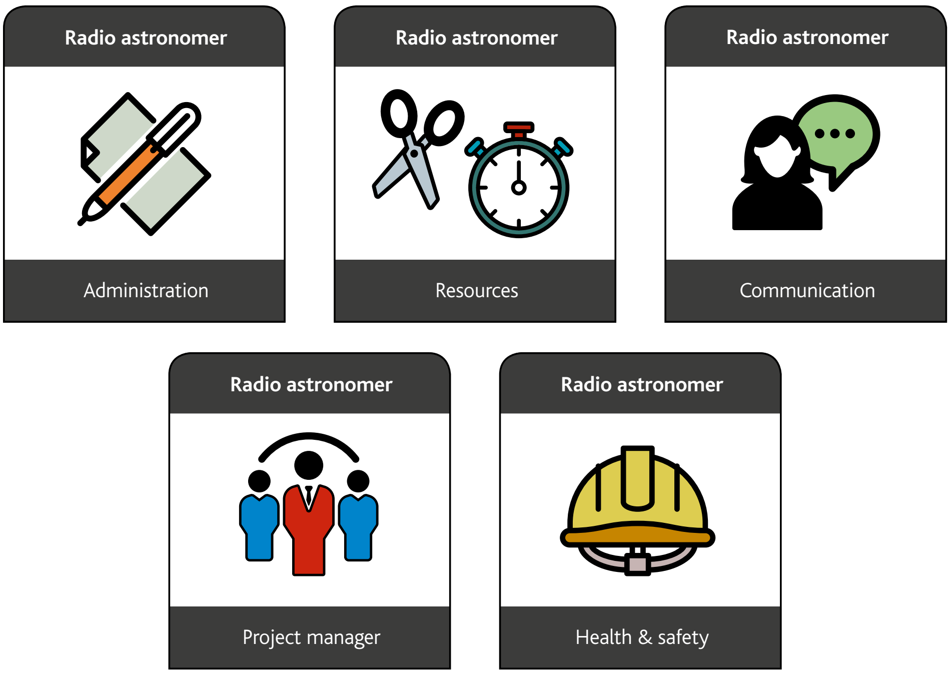






Appendix 1
Role badges





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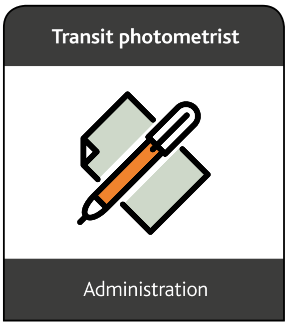
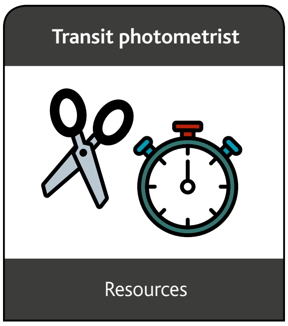
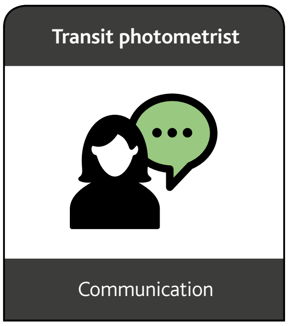
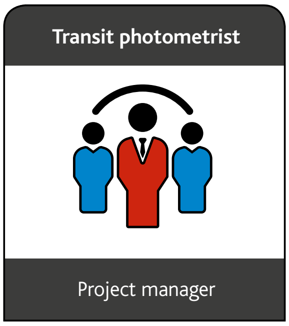
Role badges









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