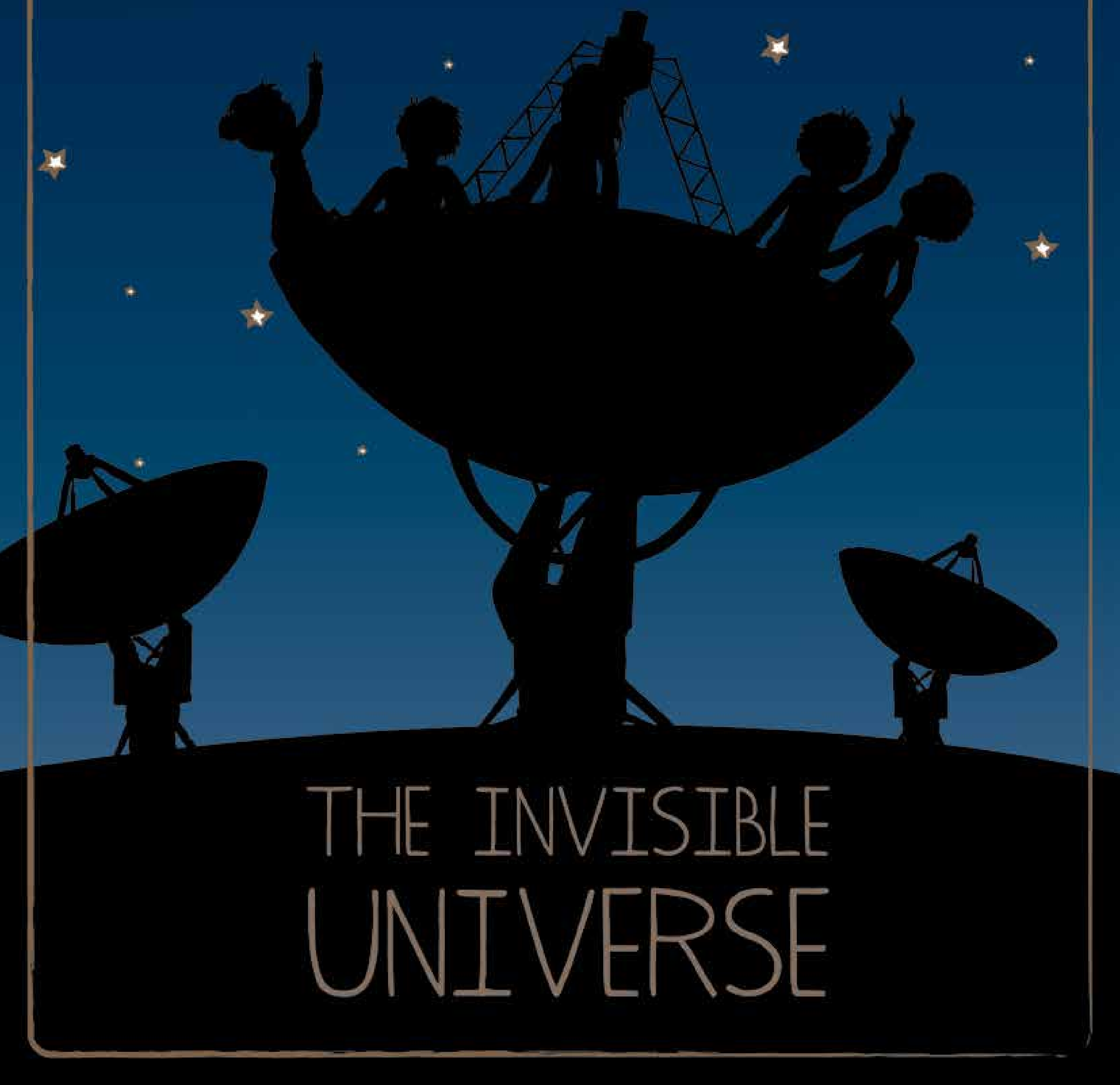
EU UNIVERSE AWARENESS



THE INVISIBLE UNIVERSE

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Preface

Since ancient times, people have been fascinated by the starry sky. However, only since the telescope was invented in 1608 have we been able to study astronomical objects in detail. This means that astronomy is a relatively young science, with much yet to discover. Unravelling all of the secrets of the Universe will take many generations of future astronomers to come. Inspiring young children is therefore essential to the future of astronomy, and science in general.

It has only recently become possible to look at the Universe using light outside of the 'visible' range. Radio, infrared, gamma, UV and X-rays give astronomers a peek at a completely new world: the 'invisible' Universe. 'The Invisible Universe' activity guide was created to inspire primary school students and introduce them to this 'invisible' world.

How to Use

Different lessons require different levels of understanding. The lessons in this activity guide are suitable for students aged between 8 and 12. This activity guide contains lessons laid out in ascending order of age suitability.

A list has been included at the end of this activity guide explaining different technical terms that appear throughout the lessons.

Though the astronomical concepts are explained in the lessons, it is useful to also read the general background science before starting each lesson. Nevertheless, the specific background science in each lesson suffices for the teacher to lead the lesson.

Lesson layout

Each lesson consists of a manual for the teacher, followed by a template for students. These templates are on a new page so they are easy to photocopy. The structure of each lesson is as follows.

Materials

For each lesson, the suggested materials have been calculated for a class of 26 children. If you have more students in your class, you can adjust the numbers as necessary.

Short description

The lesson is described in a few sentences.

Learning objectives

The learning objectives of each lesson detail the knowledge and skills that the students should acquire during the lesson.

Background science

This section, together with the 'General Background Science' in the introduction of this book, provides the information necessary to teach the lesson and answer any questions the children might have.

Full description

The full description consists of a step-by-step guide that the teacher can follow to introduce the subject and teach the lesson.

Keys

Age

Time


Group


Individual


Supervision

General Background Science

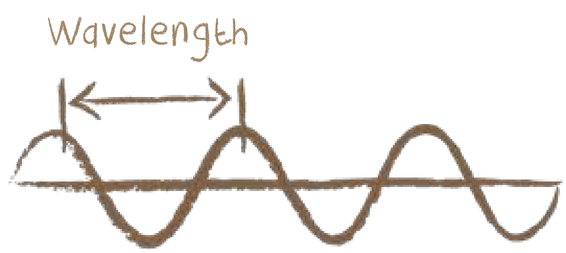
If you look up at the sky on a clear night in a remote area, you will see an overwhelming number of stars. With a little bit of luck, you might even see the centre of the Milky Way – the galaxy we live in – as trails of dust gracefully stretching across the sky, standing out pale against a background of billions of bright, shining stars. The lights we see in the night sky are not only stars from the Milky Way, but also planets from within our Solar System or sometimes even entire galaxies. These objects are very far away from us.

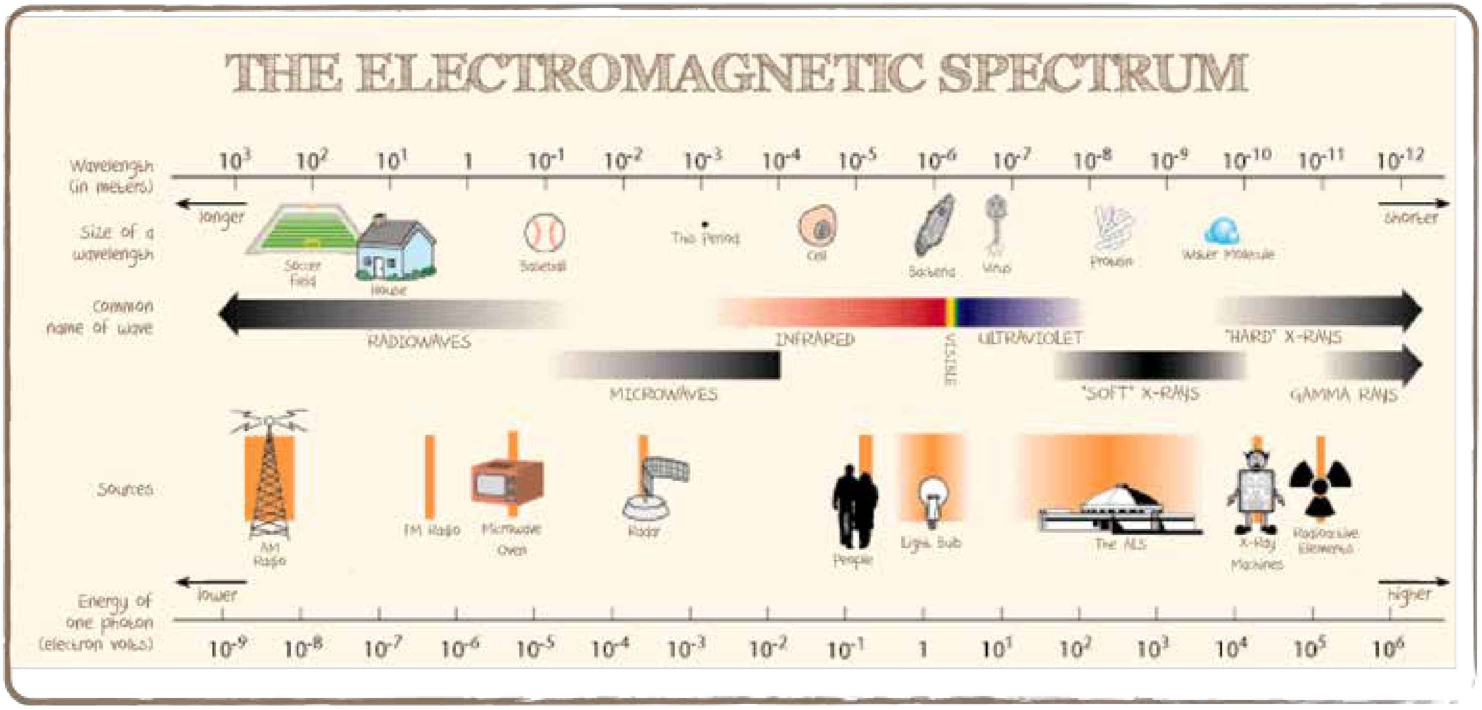
No matter how breathtaking the starry sky looks, there doesn't appear to be much colour in it. Most celestial bodies seem to be plain white. With a telescope you can see some colour in the planets, like the rusty-red planet Mars and the beige giant Jupiter, but in general the Universe looks like a plain black and white picture to us. In reality, stars shine with all colours of the rainbow but together this adds up to the colour white, just like red and yellow merge to become orange. In addition to this array of colours, stars also shine with many different types of light, but people cannot see these with their eyes.

Colour

Light is a form of electromagnetic radiation. This radiation consists of electromagnetic waves that we can measure, just like sound waves. In the case of sound, air makes a waving motion and the length of these waves (called the 'wavelength') determines the pitch: the shorter the wavelength, the higher the pitch. For light, it is a similar story: the wavelength of electromagnetic waves determines the colour of the light. For example, red light is made up of waves that are 700 billionth of a metre (700 nanometres) from crest to crest. Blue light has an even shorter wavelength: 400 nanometres. The wavelengths of all other colours our eyes can see are between 400 and 700 nanometres. Radiation within this range is called optical radiation or, in popular terminology, 'normal' light or 'visible' light. Electromagnetic radiation with a wavelength shorter than 400 or longer than 700 nanometres is invisible to the human eye.

There is a lot of radiation coming from the Universe with wavelengths longer or shorter than optical radiation. Spectacular fireworks are constantly lighting up the sky, but we can't see them! This invisible radiation has different properties at different wavelengths, in the same way that all colours look different. We divide the electromagnetic spectrum into multiple categories based on their wavelength: radio, microwave, infrared, visible, ultraviolet, X-ray and gamma radiation (see figure below).





Radiation in Everyday Life

All electromagnetic radiation, apart from visible light, is a kind of invisible light: it all has a wavelength that our eyes cannot detect. Though we cannot see these invisible rays, we actually make use of them in daily life: listening to music through the radio (radio radiation), heating up meals in the microwave (microwave radiation), switching TV channels with a remote control (infrared radiation), tanning in the sun (ultraviolet radiation) and checking for a broken arm in the hospital (X-ray radiation). Gamma radiation isn't used in everyday life, because it is harmful due to its high energy levels. Gamma radiation has the shortest wavelength of all, and therefore it carries the largest amount of energy. The shorter the wavelength, the higher the energy.

Radiation in Astronomy

With the naked eye or with an optical (normal) telescope, we catch just a small part of the information the Universe throws at us. By looking into space with telescopes that detect different types of light, such as radio telescopes, astronomers are able to study much more of the Universe. Without these telescopes, some objects would be completely invisible. For example, when a star hides behind a cloud of space dust, the visible light it emits is blocked, but its radio waves can pierce through the cloud and reach our telescopes.

Lesson 1: I Spy with My Little Eye!

EU UNIVERSE AWARENESS
ACTIVITY

8-10

30mn

Short description

Think of, choose and draw devices that use radio waves.

Key words

- Radio telescope
- Devices

Materials

- (Coloured) Pencils

Learning objectives

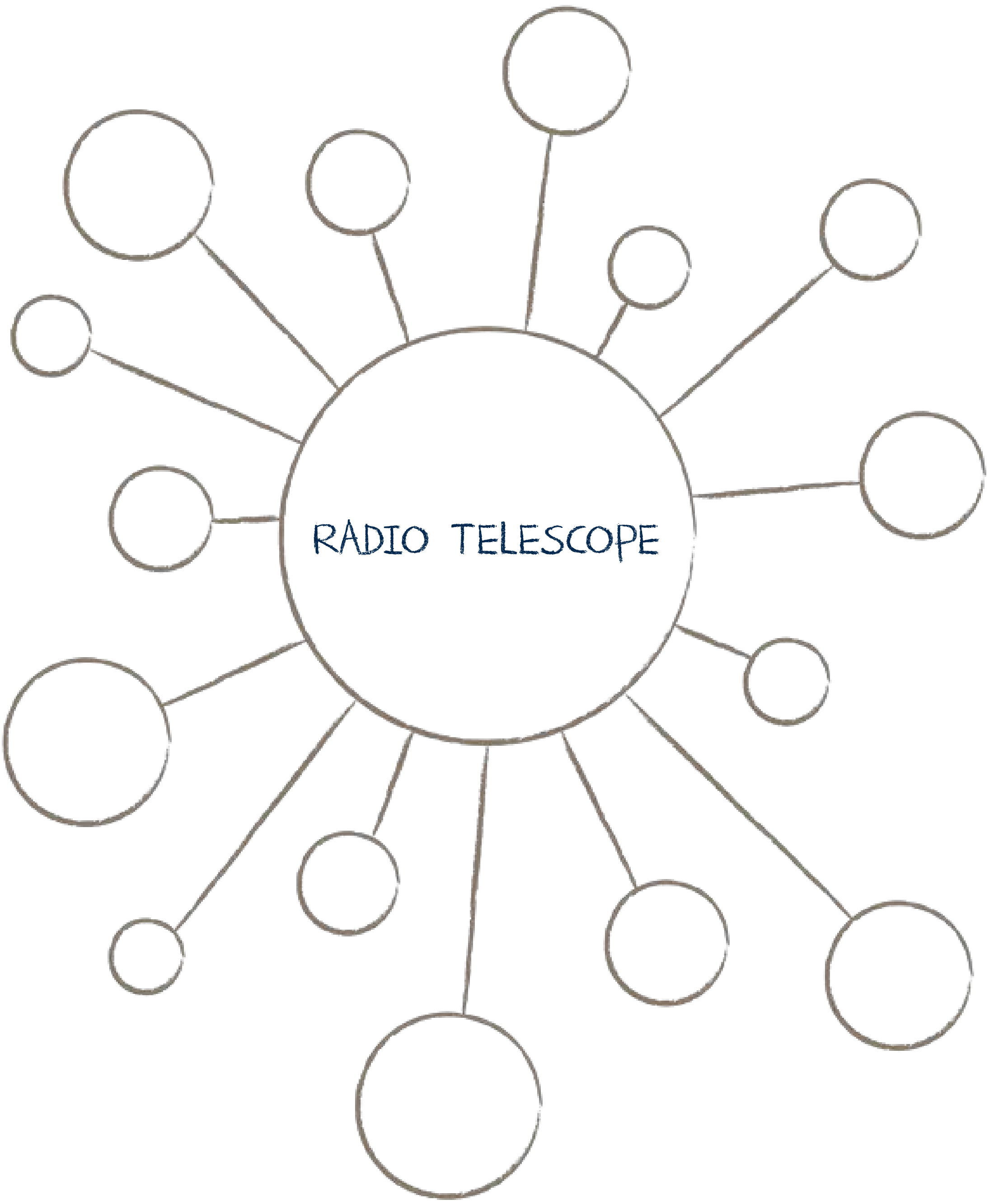
Become acquainted with devices that use radio waves.

Background science

People can communicate using light, for example, with sign language or Morse code. With certain devices, we are also able to send information with other kinds of electromagnetic radiation (see 'General Background Science'); our eyes are not capable of seeing radio waves, but a portable radio can detect them. A radio telescope is not much different from a portable radio. It's just much more sensitive, making it capable of collecting much weaker radio signals. How it does this will become clearer in lesson 2. Old televisions, walkie-talkies and navigation systems also detect radio waves.

Full description

- Let the children connect the dots in exercise 1.
- Ask them if they recognise what they have drawn.
- Explain that it is a radio telescope. Write the words on the blackboard.
- Ask the children what they associate with 'radio telescopes' and write down their responses, creating a mind map.
- Let the children do exercises 2 and 3.



Related lessons: lesson 2, lesson 11

Exercise 1

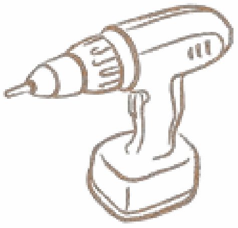
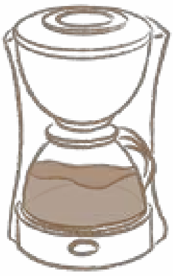
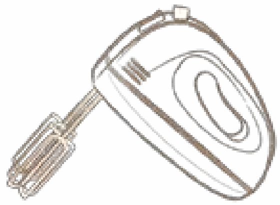
Connect the dots, but make sure you do it in the correct order! If you do it right, you will see an object used by astronomers. Do you know what it is?

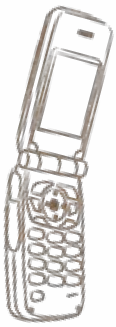
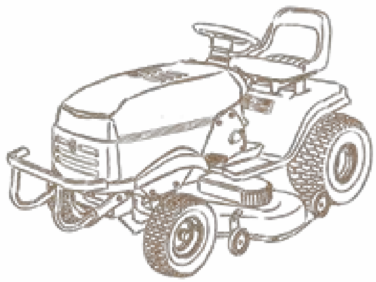
It is a ....

Exercise 2

Which of the following devices don't use radio waves?
Fill in the table with your answer:

Doesn't use radio waves	Uses radio waves

Exercise 3

Try to think of three other devices that use radio waves.

1. ....

2. ....

3. ....

Lesson 2: Did You Hear That?

Short description

Amplify your voice by talking into a horn and/or placing your hands behind your ears. A dish antenna uses the same principle.

Keywords

- Radio telescope
- Dish

Materials

- Paper

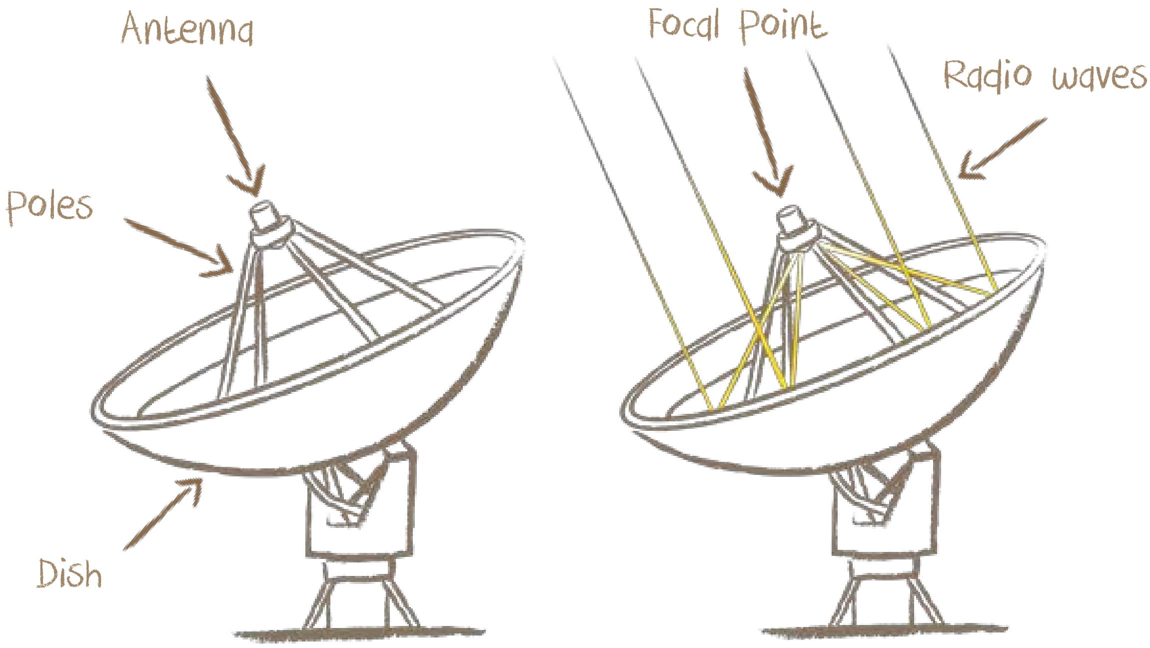
Learning objectives

Learn the use of the dish on a radio telescope.

Background science

As mentioned in lesson 1, a radio telescope is actually very similar to a radio. Due to the large size of its dish, it can also detect very weak radio radiation. The dish reflects radio waves to the antenna (see illustration). You can compare this reflection with the way an ordinary mirror reflects visible light. In optical telescopes, which detect visible light, there is often a mirror that serves the same purpose as the dish of a radio telescope. The dish is shaped in such a way that just the rays coming from one specific direction are redirected to the antenna. In this way, astronomers can 'zoom in' on a specific celestial body and collect much more radiation from it than they would using just an antenna, without a dish. This means they can detect even the weakest radio objects in space.

Actually, our ears are also a kind of dish, they catch sound waves and reflect them towards our eardrums, which you can think of as antennas in this analogy. If we place our hands behind our ears, we enlarge the 'dish' and therefore improve our hearing.



Full description

- Ask the students to make soft noises. A good example is whispering.
- Ask them to produce loud noises. Of course, one option is to scream, but can they think of another way? Let them think for a while, and if they're not sure, show them image 1 from the appendix.
- Ask the children what they see on image 1. Explain that you can direct a sound towards a specific direction with a horn, so that the person you're trying to reach can hear you better.
- Tell them that in the past, there were no headphones or speakers—instead, gramophones were used to amplify electronic sound. Show the children image 2 from the appendix.
- Ask the students to describe what they see in image 2. Tell them that this is a gramophone, and it amplifies sound in the same way their horn does.
- Let the children do exercise 1 from the template.
- Discuss the exercise with the children individually or together with the class. Teach them a basic rule: the larger the horn, the louder the noise!
- Explain that our ears are actually inverted horns. Let the students do exercise 2 from the template.
- Discuss the exercise together with the class. Tell the children that this experiment shows that you hear sounds better when you place your hands behind your ears.
- Tell the children what a radio telescope looks like, by showing them image 3 from the appendix. Explain that the shape of the dish is comparable to the shape of our ears. Let them do exercise 3 from the template.
- Discuss the exercise. The shape of the radio telescope means that all signals coming from one specific direction are reflected towards the antenna. Explain the answer to the second question by referring to the experiment in which the children placed their hands behind their ears, improving their hearing. Radio telescopes use the same principle: the larger the dish, the more radio waves it reflects.

Related lessons: lesson 1, lesson 4, lesson 10, lesson 12

Exercise 1

You will perform an experiment in pairs. Take a sheet of paper and roll it into the shape of a horn. Say something to your partner through the horn, from about 2 metres away.

Now say the same thing without the horn.

What did you notice?

....

....

....

Exercise 2

Again, form pairs and sit down 2 metres from each other. One of you read the text below to the other.

You can hear sounds softly or loud.
Sometimes you can't hear people clearly,
and sometimes you hear them just fine.

When you're finished, switch roles!

Now perform the experiment again. One of you read the same text and the other listen, but this time the listener needs to put their hands behind their head. Make sure you read the text at the same volume as before.

Again, switch roles!

What difference did you notice?

....

....

....

Exercise 3

The Universe gives off many radio waves. On Earth, we try to collect this radiation with radio telescopes. These have a special shape.

Why do radio telescopes have this shape?

....

....

....

Do you think it matters how big the dish of a radio telescope is?

Yes / No, because ....

....

....

8-10

30 mn

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Lesson 3: Why Don't You See a Flash at the Doctor?

Short description

Explain what 'invisible' light is using X-ray images.

Keywords

- X-rays
- X-ray image
- Flash

Materials

- Camera with a flash light

Learning objectives

Get familiar with X-rays as an example of invisible light.

Background science

X-ray is one kind of electromagnetic radiation that people cannot see. It is one of the categories with short wavelengths and therefore carries a high level of energy. This is why X-rays can harm the human body. A doctor will only take an X-ray image if it's really necessary, because you shouldn't be exposed to X-ray radiation too often.

An X-ray camera uses the same principle as an ordinary camera, which produces a flash while taking a photograph in the dark. The X-ray camera emits a flash of X-rays that pierce through the skin and reflect off the (broken) bone, back to the camera. Doctors use these special cameras because X-rays, unlike visible light, penetrate our skin, allowing doctors to look through skin and muscle and check for broken bones.

Full description

- Ask the class if anyone has ever broken a bone in their body.
- Ask them if the doctor took a special photograph of the broken bone. Explain this was an X-ray image. They can see an example of an X-ray photograph below in exercise 1 from the template.
- Take a picture of the class and make sure to use the flash on your camera. Do this in a darkened classroom (for example, with closed curtains). This way, the flash will be clearly visible.
- Explain that the camera was able to catch the childrens' image because they reflected the flash of light. The students themselves don't emit any visible light, as a lamp does, for instance. If no light source shines on them, they are too dark to see or take a picture of. At night it is hard to see each other because there is no sunlight.
- Explain that a doctor is actually a photographer when he makes an X-ray image of a broken arm, but he uses an invisible flash! Unlike visible light, X-rays penetrate the human body, thanks to their higher energy. Let the children do exercise 1 from the template and discuss it with the class.
- Show the class image 4 from the appendix. Using this, explain that there are many other kinds of invisible light (see 'General Background Science').

Tip: Tell the children that they emit invisible light themselves, even in the dark! This is called infrared radiation, known as 'heat radiation'. The Sun shines with light because it's very hot. In the same way, humans emit light because of their body heat. Since humans have a different temperature than the Sun – they are much colder – they also emit a different kind of radiation. With an infrared camera you can see people, even in the dark!

Exercise 1

Answer the following questions:

1. If you break a bone in your body, the doctor takes a special photograph of it in the hospital. Has this ever happened to you?

....

2. What did the picture look like?

....

....

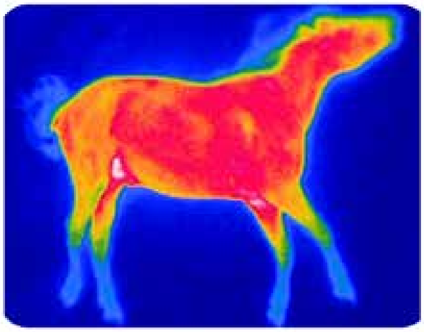
We call these pictures X-ray images.

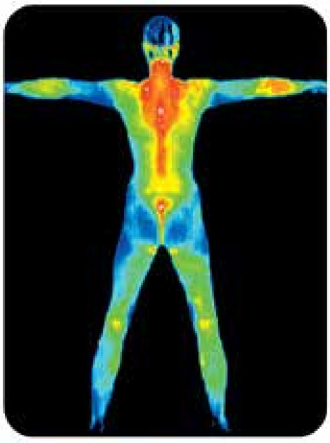
3. What is the difference between an X-ray image and an ordinary photograph?

....

....

4. Circle the photos you think are X-ray images.





8-10

1h30

EU UNIVERSE AWARENESS ACTIVITY

Lesson 4: Build your own Paper Radio Telescope!

Short description

Craft a radio telescope and a string telephone.

Keywords

- Radio telescope
- String telephone
- Sound

Materials

- glue
- scissors
- 26 toilet rolls
- 26 plastic cups
- 13 pieces of rope (about 4 m)
- 26 paperclips
- pencils
- paper
- speaker

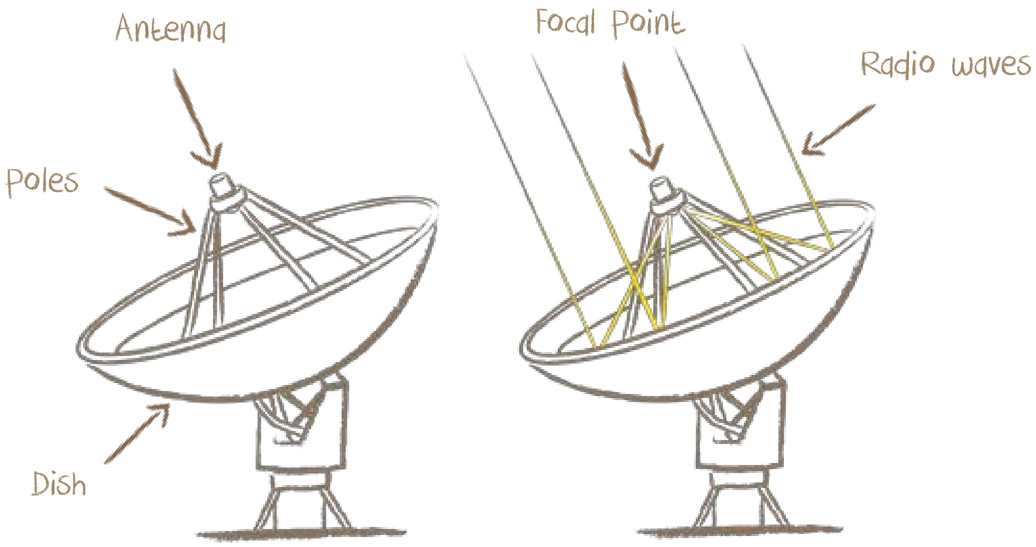
Learning objectives

Become acquainted with the shape of a radio telescope. Learn that, in addition to air, other substances also carry sound.

Background science

A radio telescope is similar to a very large radio. The large size of its dish means it can detect very weak radio radiation. The dish reflects radio waves to the antenna (see illustration). You can compare this to the way an ordinary mirror reflects visible light. In optical telescopes (that detect visible light) there is often a mirror that serves the same purpose as the dish on a radio telescope. The dish is shaped so that only the rays coming from one specific direction are redirected to the antenna. In this way, astronomers can zoom in on a celestial body they want to study and collect much more radiation from it than they would just using a single antenna, without a dish. This means that they can see even the weakest radio objects in space.

A radio telescope can change direction, making it possible to study many different objects across the sky. You can compare this to your ears; the best way to hear something is to turn your head towards the source of the noise. Whereas heavenly bodies emit radiation because they're hot, objects on Earth make sounds because they vibrate. This causes the air to vibrate as well, and we can 'feel' that vibration with our ears. But substances other than air can also carry sound: some carry sound even faster and better than air! Think about how submarines can communicate over large distances – they use sound which travels through water. A tight string can carry sound better than air. Unlike sound, electromagnetic waves can also travel in empty space!



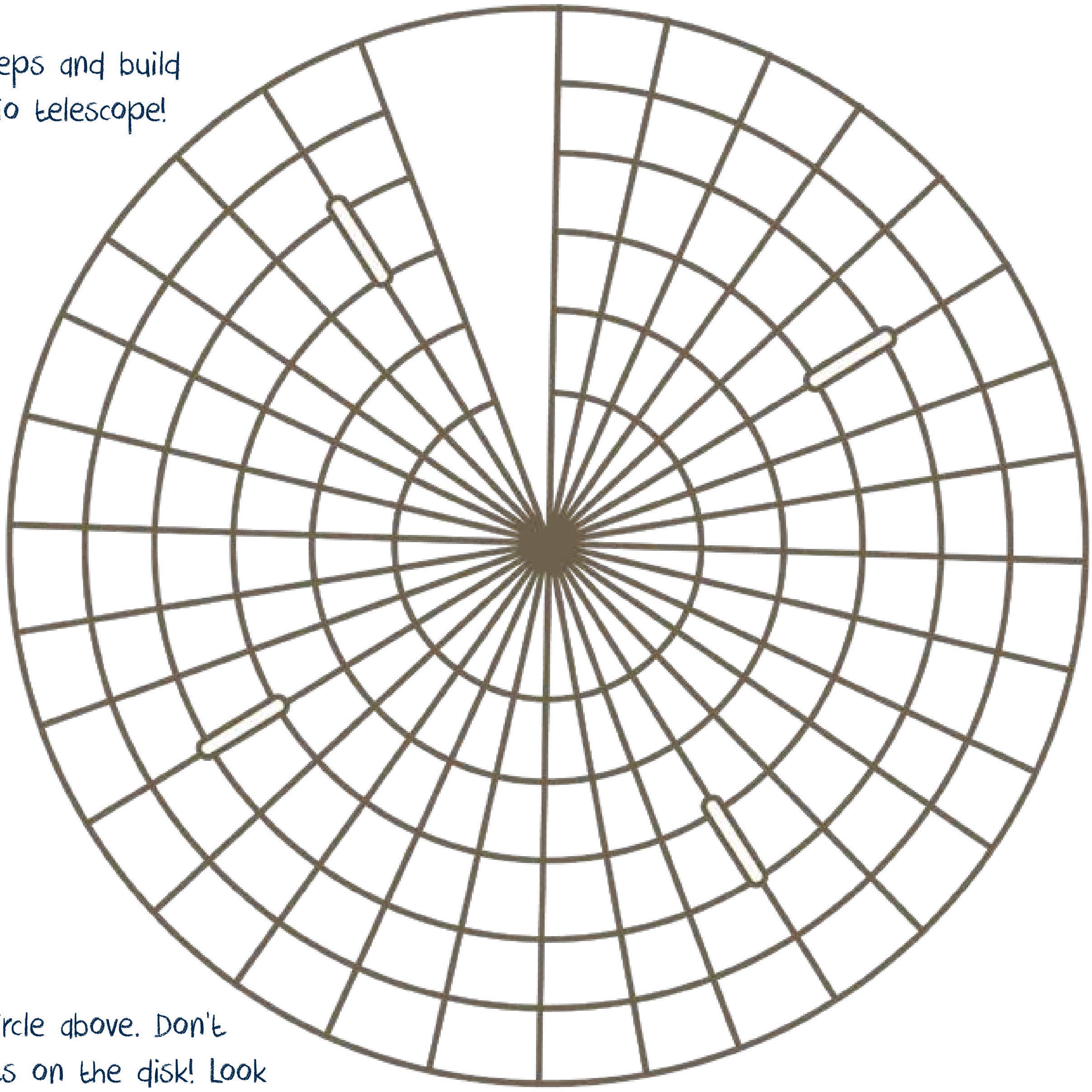
Full description

- Ask the children to do exercise 1 from the template.
- Students who finish early can research how a radio telescope works on the internet while the other children finish.
- When all the children have completed the exercise, ask the class to describe what they made. Help them by asking if they know why there is an antenna sticking out of the dish.
- Sound is actually the vibration of air. Demonstrate this by holding a sheet of paper in front of a speaker. Turn up the volume and ask the children what they see. Just like the paper, the air around the box is vibrating, and this vibration moves towards our ears, which causes us to hear a sound.
- Let the students do exercise 2 from the template.
- Discuss the exercise. Explain that sounds not only travel through air but also through other substances, like water. Some of these substances carry sounds even better than air!

Related lessons: lesson 2, lesson 10, lesson 12

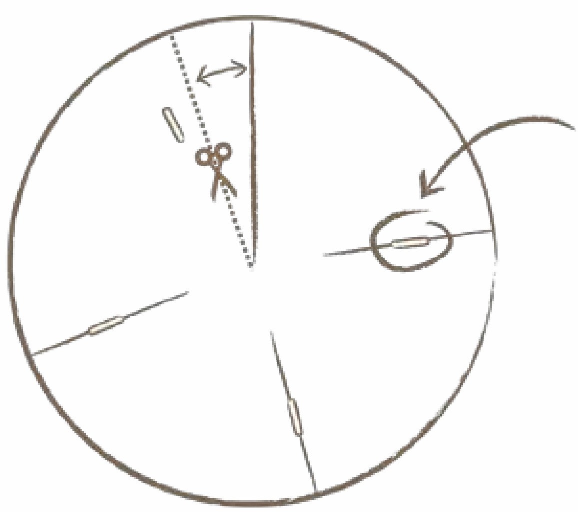
Exercise 1

Follow the steps and build your own radio telescope!



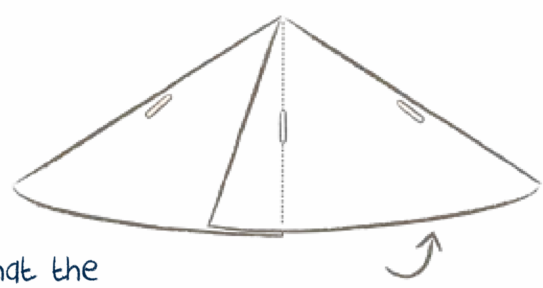
Step 1

Cut out the circle above. Don't forget the slits on the disk! Look at the example on the left



Step 2

Cut along the line with the scissors depicted in the illustration below. Put glue on the white patch and fold the sides on top of each other.



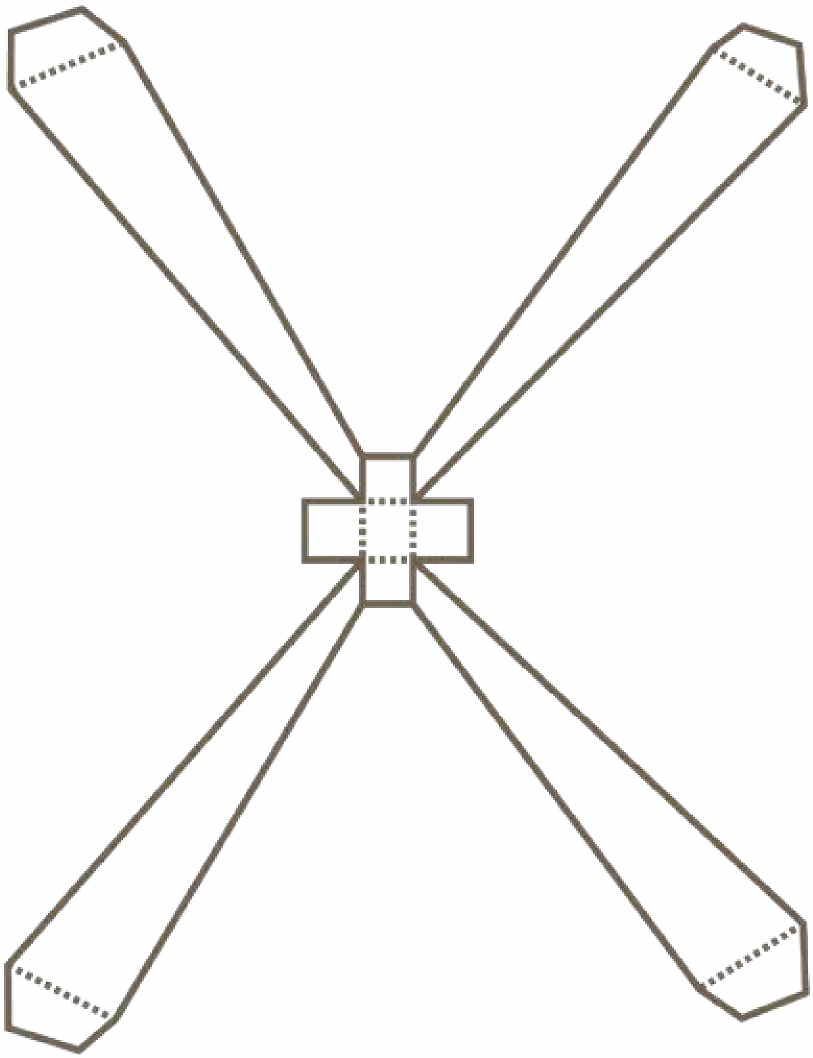
NOTE:
Make sure that the lines are on the inside of the hat.

Step 3

Now you're going to build the antenna! Cut out the figure below.

Step 4

The dotted lines are folding lines. Fold everything backwards.

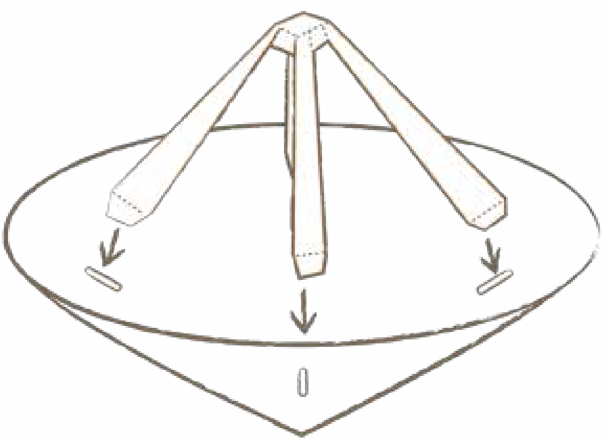


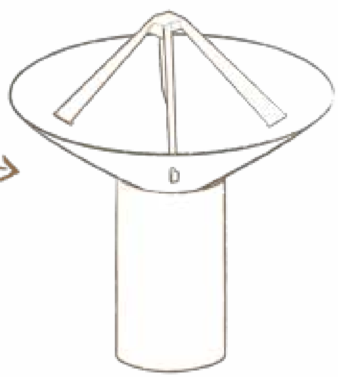
Step 5

Put glue on the feet of the antenna.

Step 6

Slide the antenna feet between the dish's slits and glue them onto the other side of the dish.





Step 7

Glue the dish onto a toilet paper roll, and you're done! You just built your own radio telescope!

Exercise 2

You will now perform an experiment in pairs and build a string telephone. You will need the following materials.

- a piece of string
- two plastic cups
- a sharp pencil

Instructions:

- Puncture a small hole in the bottom of both cups.
- Pull the string through the holes. Tie a knot at both ends of the string such that it won't slip out.
- Use the cups as a telephone to talk to your partner. Make sure the string is pulled tight.

What do you think will happen?

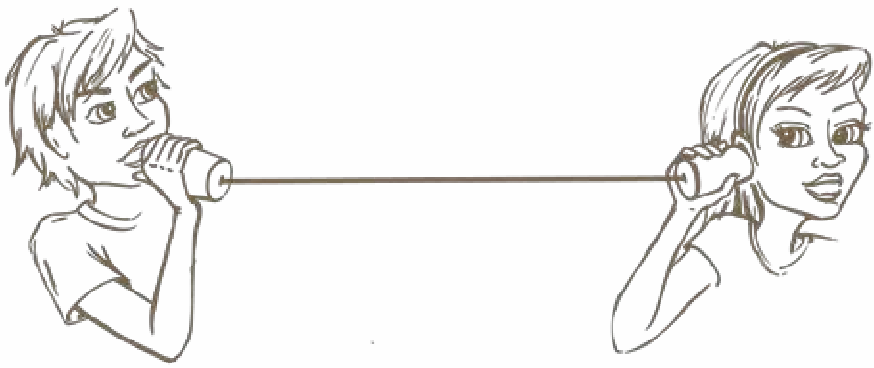
....

....

If you whisper softly, does your partner still hear you?
How do you think this is possible?

....

....



8-10

45 mn

EU UNIVERSE AWARENESS ACTIVITY

Lesson 5: Create your own Radio Image!

Short description

Colour a sketch of a radio image. Link radio images to the corresponding optical image.

Keywords

- Radio image
- Radio telescope

Materials

- Coloured pencils

Learning objectives

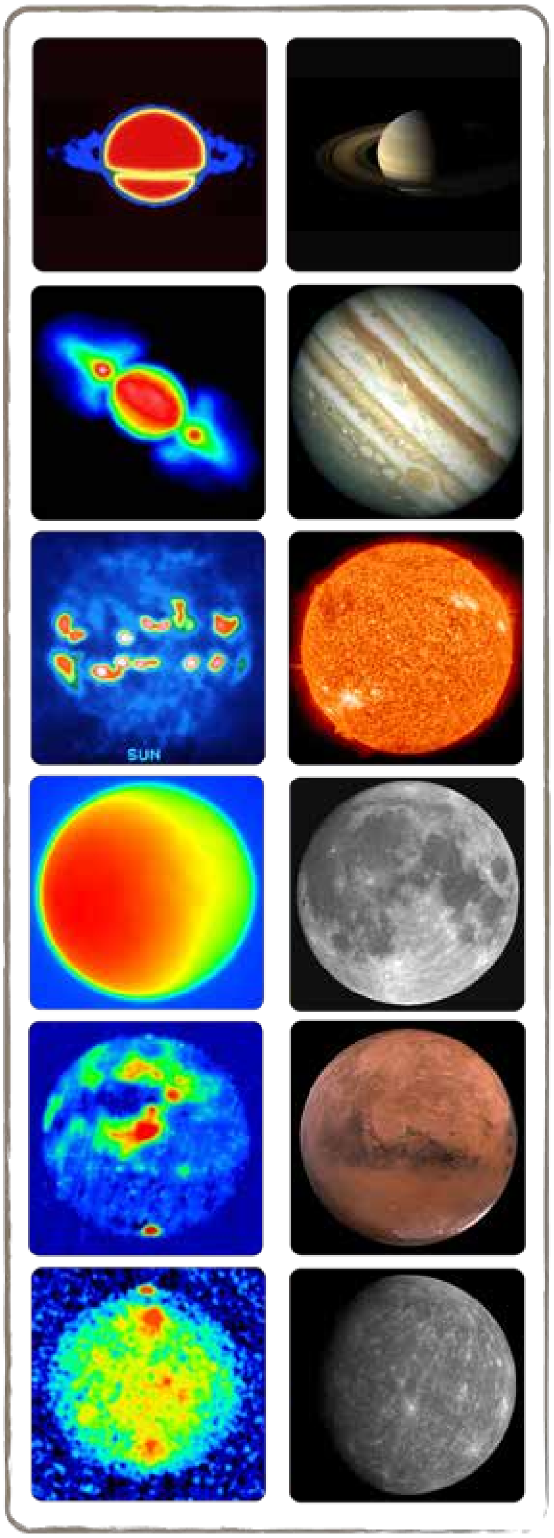
Become familiar with radio images, which look different to optical images.

Background science

If we look around us, we see our environment thanks to visible light from the Sun. If we look at the Universe at night, we see the visible light of other heavenly bodies: the stars. When astronomers observe the sky with a radio telescope, they see the Universe in a completely different light than they do through an optical telescope. Instead of looking at visible light, they detect radio waves – which are simply a different kind of light.

In reality, it is impossible to depict a photograph that was taken with a radio telescope, since radio waves are invisible. That is why astronomers colour their radio images with 'visible' colours. This way, they make properties of objects visible that would otherwise go unnoticed. Different heavenly bodies emit different sorts of electromagnetic radiation, and each kind gives us different information. In some cases, a space object isn't visible at all in optical light, for example, if it is hidden behind a cloud of dust. To see such an object, you have to make use of radiation that can pierce through the cloud. Certain kinds of radiation can do this!

In the images below, you will find different space objects that were photographed with both visible and invisible light. In each picture, different properties are visible. On the Moon, for example, you can see dark spots in visible light, which are invisible if looked at using radio waves. By means of invisible light, you can see Jupiter's magnetic field, which doesn't show in the picture on the right. On the other hand, Saturn's rings are visible in both the optical and radio pictures.



Saturn

Jupiter

Sun

Moon

Mars

Mercury

Full description

- Tell the students that both visible and invisible light exists (see 'General Background Science').
- Explain why astronomers look at the sky through radio telescopes.
- Ask them to do exercise 1 from the template.
- When the children are finished, discuss the exercise. Explain that they have drawn a radio image. Tell them that radio telescopes see the Universe in different light than we do, resulting in different pictures.
- Show the class image 5 from the appendix and tell the students that this is a radio image.
- Explain why astronomers take pictures with a radio telescope instead of with an optical telescope.
- Let the children do exercise 2 from the template. Above, you can find the correct combinations.
- Discuss the exercise. Do the students notice any differences between the two pictures of the same objects? Do they see any similarities?

Exercise 1

Colour the boxes:

1 = purple
2 = light blue
3 = dark blue
4 = green
5 = yellow
6 = red

3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	1	1	2	2	2	2	2	2	2	2	1	1	3	3	3	3
3	3	3	1	1	2	2	4	4	4	4	4	4	2	2	1	1	3	3	3
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3	2	2	4	4	5	5	6	6	6	6	6	6	5	5	5	4	4	2	3
3	2	2	4	1	4	5	5	6	6	6	6	6	5	5	4	1	4	2	3
3	2	2	4	4	1	4	5	6	6	6	6	5	5	4	1	4	4	2	3
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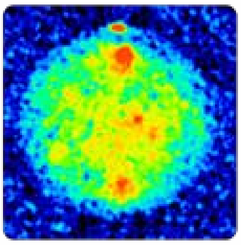
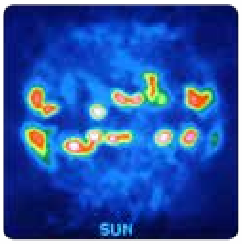
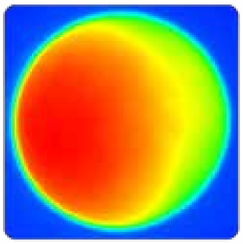
3	3	3	1	2	2	2	4	4	4	4	4	2	2	2	1	1	3	3	3
3	3	3	3	1	1	2	2	2	2	2	2	2	2	1	1	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

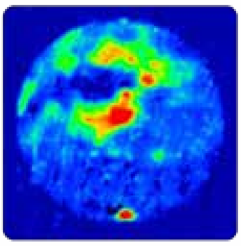
Exercise 2

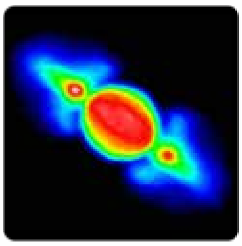
Below, you will find images of the Sun, the Moon and some planets. On the left are images taken with invisible light, and on the right we see the heavenly bodies as we know them in visible light. Draw a line connecting the pictures of the same object. Do you know their names?

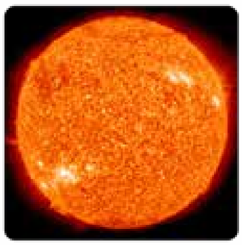


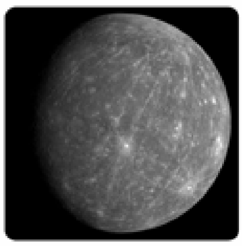












8-10

45mn

EU UNIVERSE AWARENESS ACTIVITY

Lesson 6: Looking with Different Eyes!

Short description

Craft red and blue glasses and look through them.

Keywords

- Glasses
- Colours
- Red
- Blue

Materials

- Sunglasses
- Glue
- Scissors
- 7 sheets of red tracing paper
- 7 sheets of blue tracing paper

Learning objectives

Learn that what you see depends on the 'glasses' you look through.

Background science

On sunny days we put on sunglasses to protect our eyes against the bright sunlight. When we do this, we see everything darker than we're used to. How you perceive the world around you depends on the glasses you wear. If you look through coloured glasses, you see your surroundings in a different way. When astronomers look into space with a radio telescope, they look at the world through 'radio glasses'. These 'radio glasses' are much harder to make than blue and red ones that the children will make during this lesson. Our eyes are not sensitive to radio waves, so in order to see them we have to build a completely new device that can detect them: a radio telescope.

With a radio telescope, astronomers see other properties of an object in space than those seen with an optical telescope. With other kinds of 'invisible' radiation, you can even see entirely different objects and phenomena. We also make use of invisible radiation to look at things in a different way in everyday life. For example, in the hospital a doctor uses X-rays to check for broken bones!

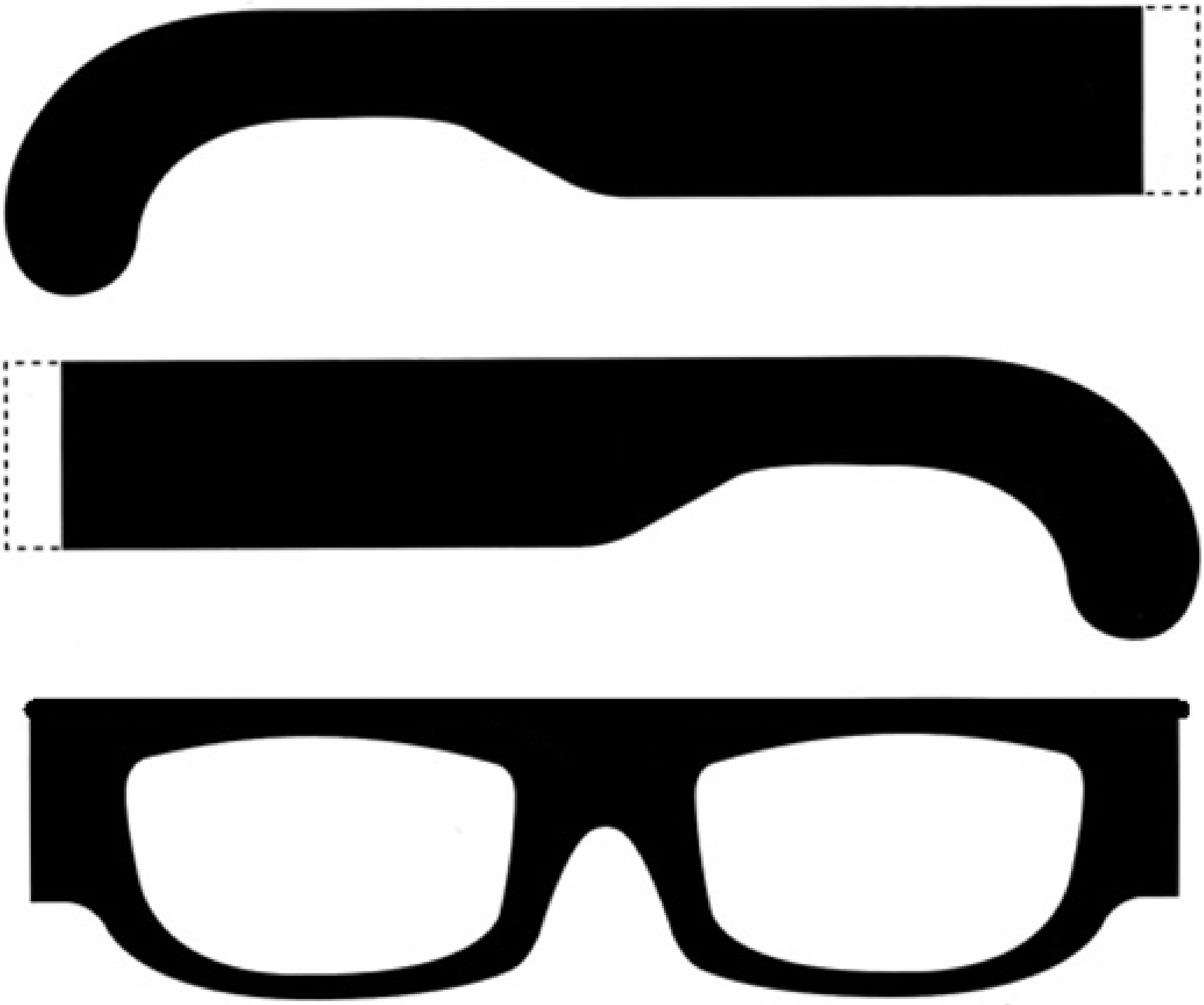
Full description

- Ask the children why we put on sunglasses on a sunny day.
- Let them do exercise 1 from the template and discuss it. Emphasise that how you perceive the world around you depends on the glasses you look through. With a radio telescope, you see the Universe in a different way than when you look through a normal, optical telescope.
- Tell the students that both visible and invisible light exist (see 'General Background Science').
- Ask them to do exercise 2 from the template. Explain that they can sort the pictures in different ways. For starters, they could categorise them by type of radiation: radio, X-ray or visible. Alternatively, they could categorise the pictures by item.

Related lessons: lesson 7

Exercise 1

You are going to make your own glasses! Cut out the shapes below and glue the edges of the two arms to the lens frames. Next, glue the red paper on to the left lens frame, and the blue paper onto the right.



Put on the glasses and close one eye. What do you see when you look around?

....

....

....

Now close the other eye. Again, what do you see?

....

....

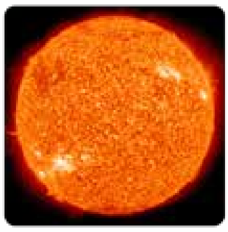
What do you see if you open both eyes?

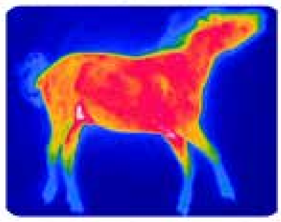
....

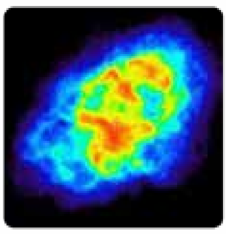
....

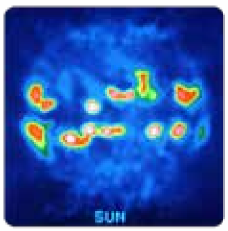
Exercise 2

Check out the photographs below. They were taken in visible light, radio waves and X-rays. Which images belong together?









Lesson 7: Happy Families!

Short description

Play 'Happy Families' with six kinds of electromagnetic radiation.

Keywords

- Happy Families
- Electromagnetic spectrum

Materials

- Scissors
- Glue
- Cardboard

Learning objectives

Learn about the different kinds of electromagnetic radiation that exist, in addition to optical light.

Background science

In addition to visible light, there are other kinds of electromagnetic waves, as described in the 'General Background Science'. If a picture is taken with a special device that can detect 'invisible' radiation, it needs to be printed in visible colours so that human eyes can see it. Each kind of radiation results in a characteristic picture.

The Happy Families game from this lesson consists of a number of characteristic radio, infrared, microwave and X-ray images. The radio images show space objects that emit radio waves. You could also take infrared pictures of heavenly bodies, but it is easier to simply photograph people and animals in infrared: we emit infrared radiation ourselves, because our body is warm enough to give off this kind of light. Infrared images often have a 'red glow' when astronomers depict them in visible colours.

We see X-ray images when we might have broken a bone. When this happens, the doctor makes an X-ray image to peek through your skin and study the bone beneath. X-ray images are always depicted in black and white.

Some space objects also emit X-rays.

One card shows a very famous image taken using microwave radiation: a shot of the cosmic background radiation that is coming at us from outer space in every direction! Ultraviolet radiation is often depicted in blue. And of course, all normal pictures are made in visible light!

Full description

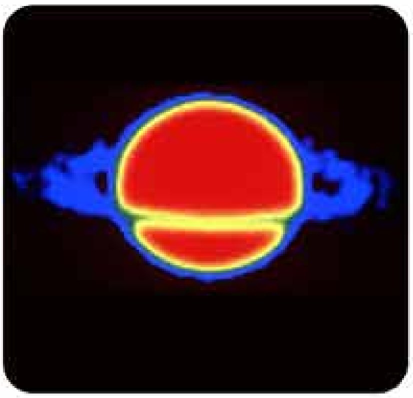
- Show image 4 from the appendix (electromagnetic spectrum) and ask the children what they know about it.
- Explain that we are only able to see a small amount of all the different kinds of light. Introduce the students to the other forms of electromagnetic radiation (see 'General Background Science').
- Show image 5 from the appendix. Explain that this is a characteristic radio image. Astronomers took this photograph with a radio telescope and coloured it with visible colours. It is just one example of a picture that was taken with invisible radiation and transformed into a visible picture. There are also X-ray, microwave and infrared images.
- Let the students do exercise 1 from the template. This Happy Families game consists of six kinds of electromagnetic radiation: radio, microwave, infrared, visible, ultraviolet and X-ray.
- When they are finished, they can play Happy Families. Explain that some pictures were taken with the corresponding radiation (for example, the radio image of the planet with rings is taken with radio waves), while other photographs are 'normal' pictures of devices that use the corresponding radiation (for example the photograph of the microwave oven is taken in visible light, while the microwave oven uses microwaves).

Related lessons: lesson 6

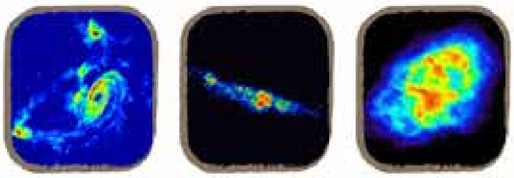
Exercise 1

You are going to make your own Happy Families game. Cut out the cards and glue them on to pieces of cardboard. When you are finished, you can play Happy Families!

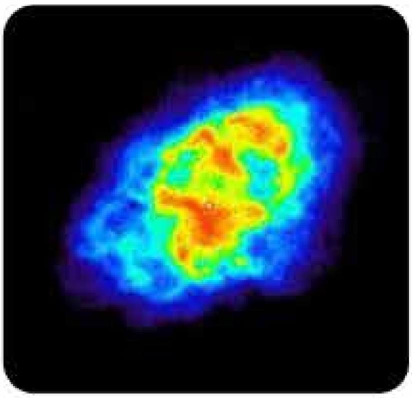
ELECTROMAGNETIC SPECTRUM



Radio Waves

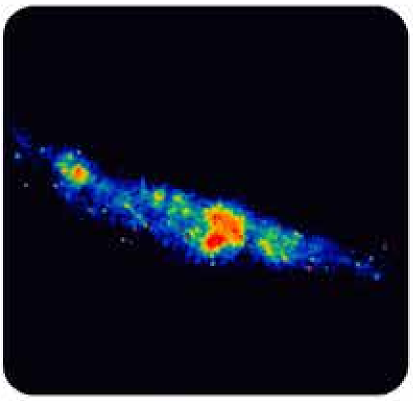


ELECTROMAGNETIC SPECTRUM



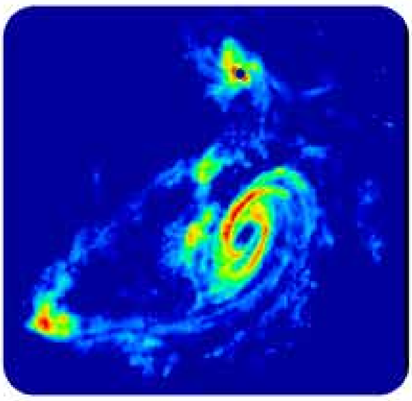
Radio Waves

ELECTROMAGNETIC SPECTRUM

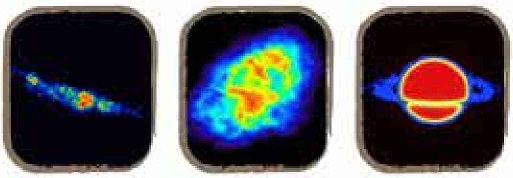


Radio Waves

ELECTROMAGNETIC SPECTRUM

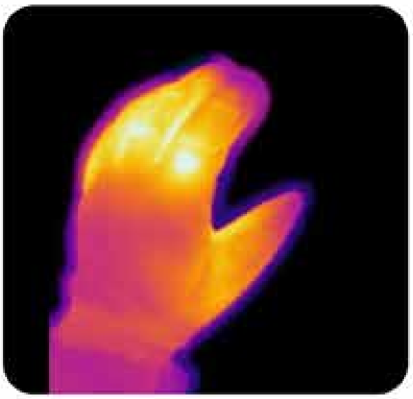


Radio Waves



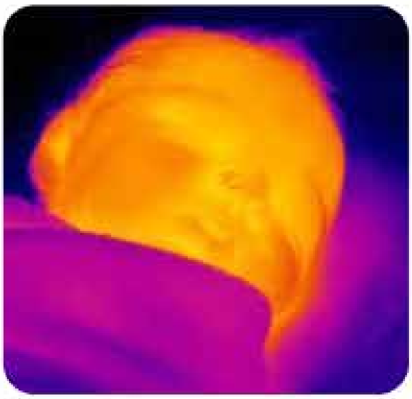
Exercise 1

ELECTROMAGNETIC
SPECTRUM



Infrared

ELECTROMAGNETIC
SPECTRUM



Infrared

ELECTROMAGNETIC
SPECTRUM

Infrared

ELECTROMAGNETIC
SPECTRUM

Infrared

Exercise 1

ELECTROMAGNETIC SPECTRUM

X-ray

ELECTROMAGNETIC SPECTRUM

X-ray

ELECTROMAGNETIC SPECTRUM

X-ray

ELECTROMAGNETIC SPECTRUM

X-ray

Exercise 1

ELECTROMAGNETIC SPECTRUM

Visible

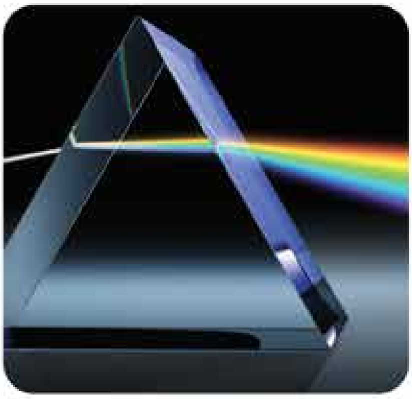
ELECTROMAGNETIC SPECTRUM

Visible

ELECTROMAGNETIC SPECTRUM

Visible

ELECTROMAGNETIC SPECTRUM



Visible

Exercise 1

ELECTROMAGNETIC SPECTRUM

UV radiation

ELECTROMAGNETIC SPECTRUM

UV radiation

ELECTROMAGNETIC SPECTRUM

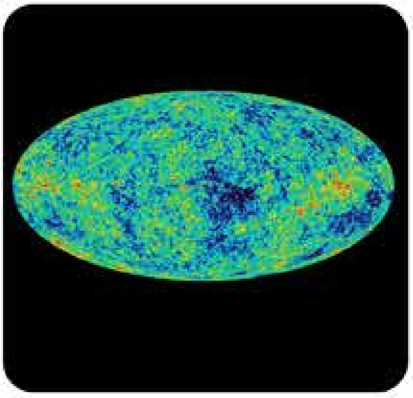
UV radiation

ELECTROMAGNETIC SPECTRUM

UV radiation

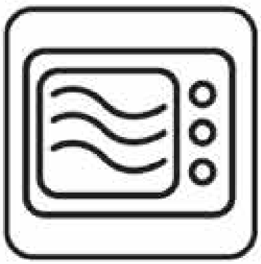
Exercise 1

ELECTROMAGNETIC SPECTRUM



Microwave

ELECTROMAGNETIC SPECTRUM



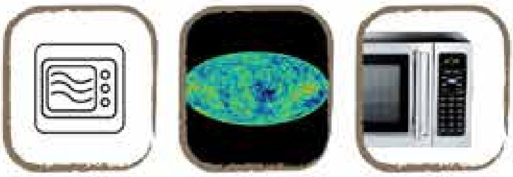
Microwave

ELECTROMAGNETIC SPECTRUM

Microwave

ELECTROMAGNETIC SPECTRUM

Microwave



10-12 | 50mn

EU UNIVERSE AWARENESS ACTIVITY

Lesson 8: Waves!

Short description

Measure drawings of electromagnetic waves and calculate their real length based on the given scales.

Keywords

- Waves
- Wavelength

Materials

- Washing up bowl
- Small stones
- Pens
- Calculators
- Paper

Learning objectives

Learn how scale models work. Get acquainted with wavelengths. Learn that light consists of electromagnetic waves. Learn that radio waves have a longer wavelength than visible light waves.

Background science

As described in the 'General Background Science', light is a form of electromagnetic radiation. This radiation consists of electromagnetic waves that have a specific wavelength. If you draw a wave (see template), you can determine its wavelength by measuring the distance between two peaks. All forms of electromagnetic radiation have a distinct range of wavelengths. The difference in wavelength is what distinguishes them from each other. Radio waves are actually just like light, but their wavelength is too long for our eyes to detect. You could compare this with extremely low-pitched sounds: their wavelength is too long for our ears to detect. In image 4 of the appendix, you see an overview of all forms of electromagnetic radiation with their corresponding wavelength. While visible light consists of waves that are smaller than a bacteria (less than a millionth of a metre), radio waves can be longer than a human being (more than a metre)!

Full description

- Tell the children that radio waves are everywhere around us, but they are not visible to our eyes. Of course, radio stations emit this kind of radiation, but we also receive radio signals from space. Explain that radio waves are actually a kind of light, a kind that humans cannot see.
- Take the students to a lake or a pond. If the weather is bad, or if there is no lake or pond close by, then put a large washing up bowl in the classroom and let a student throw a small stone into the water. Tell the children they should pay close attention to what happens. Ask them to do exercise 1 from the template.
- Discuss the fact that light consists of electromagnetic waves, which have a particular wavelength. Make the analogy with the ripples on water caused by a falling stone.
- Explain what wavelength is. Draw a wave on the blackboard, like the waves from the template. Tell the children that the distance between two peaks is called the wavelength. Now let them do exercise 2 from the template.
- Tell them that the wavelength of radio waves can be very long, even longer than a metre.
- Ask them if they know what ‘drawing to scale’ means.
- Explain that a scale of 1 : 50 means that 1 cm in a drawing is 50 cm in reality. Ask what happens if you have a scale of 1 : 300.
- Discuss some other examples of scale drawings and let them do exercise 3 from the template.
- Discuss the exercise with individual students or together with the class. Show the children image 4 of the appendix and discuss the wavelength of each kind of radiation. Emphasise that radio waves are very long compared to visible light!

Exercise 1

Write down what you saw. You can also make a drawing.

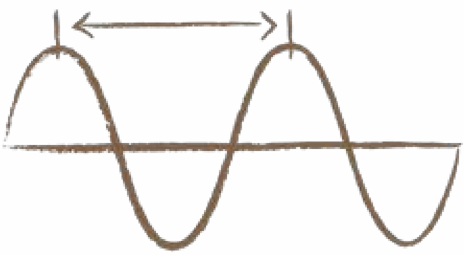
....

....

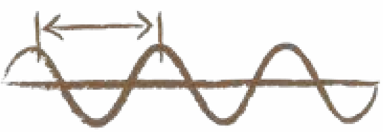
....

Exercise 2

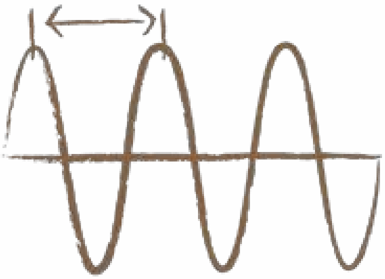
Below are some drawings of waves. Measure the length of the arrows and you'll know their wavelength. Fill in your answer on the dotted line.



The wavelength is ....centimetres



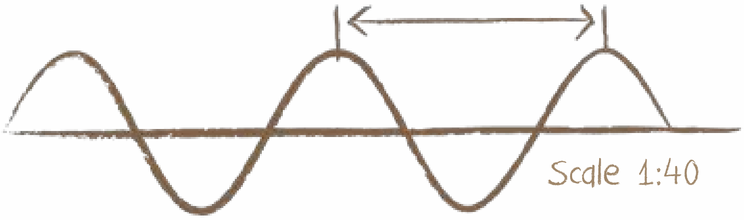
The wavelength is ....centimetres



The wavelength is ....centimetres

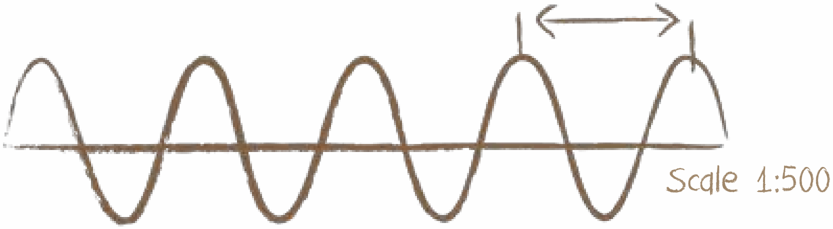
Exercise 3

Below are some drawings of waves. Measure the length of the arrows, but do not forget that the waves are drawn to scale! The scale is noted under each wave. Fill in your answer on the dotted line.



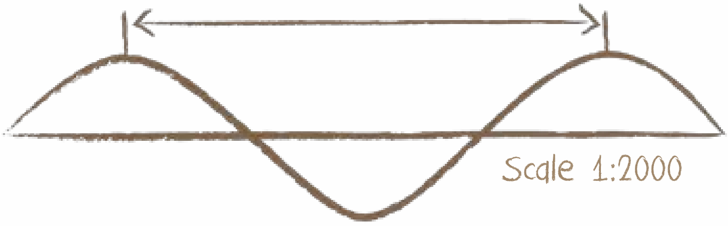
a) The wavelength is .... centimetres

b) So, in reality the wavelength is (answer for a) x 40 = ... centimetres



a) The wavelength is .... centimetres

b) So, in reality the wavelength is (answer for a) x 500= .... centimetres
= .... metres



a) The wavelength is .... centimetres

b) So, in reality the wavelength is (answer for a) x 2000 = ... centimetres
= .... metres

10-12

30 mn

EU UNIVERSE AWARENESS ACTIVITY

Lesson 9: Message from Space!

Short description

Code and decode an alien message by colouring in boxes based on zeros and ones.

Keywords

- Code
- Mathematics
- Message
- Alien
- Decode

Materials

- Pencils
- Graph paper

Learning objectives

Learn how a mathematical code can contain an image.

Background science

Ever since ancient times, humans have been asking themselves whether it's possible for life to exist on other planets. Thus far, Earth is the only place in the Universe that we are certain is capable of sustaining life. However, the Universe is so immensely vast that you'd expect some form of alien life to have developed somewhere else. Astronomers estimate that in our Galaxy alone – one of hundreds of billions in the Universe – there are 200 billion stars. Billions of planets are probably orbiting these stars. Unlike stars, planets are difficult to spot because they don't emit radiation themselves. That's why astronomers haven't discovered many planets outside our Solar System yet. But, due to ever-improving equipment, they are able to detect more and more so-called exo-planets – planets outside our Solar System. When a planet crosses in front of its host star, it blocks a little bit of starlight, and in doing so gives away its presence. Currently, astronomers have discovered close to two thousand exo-planets – and counting.

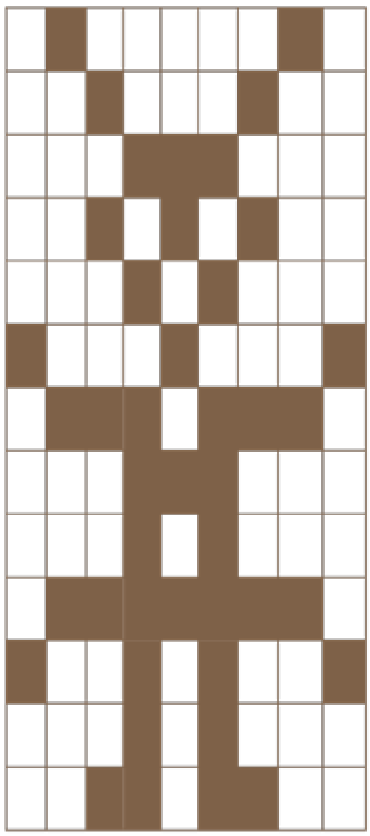
With radio telescopes we can search the sky for alien signals. We unintentionally send radio waves into outer space when we communicate using radios or mobile phones. Perhaps aliens have also invented these technologies! In that case there would be artificial radiation coming from their planet. With a radio telescope we could detect it. Maybe they're even trying to send us a message!

It is highly unlikely that this message would be in English, Spanish or any other earthly language. Perhaps aliens are sending a message in their own language, which would be a shame, because nobody on Earth would understand it. However, it might be possible to decipher their message anyway, because aliens could send it in mathematical language. Mathematics is considered to be a universal language. It is not made up by humans, but based on facts from nature. For example, the value of the number π (pronounce: pi) is the same anywhere in the Universe: it is the ratio between the circumference and the diametre of a circle, about 3.14. Aliens will probably have a different word for a star, but they definitely use the same value for the ratio between its circumference and its diametre!

Other sources: The American Search for Extraterrestrial Intelligence project (SETI) actively searches for alien signals: http://www.seti.org/

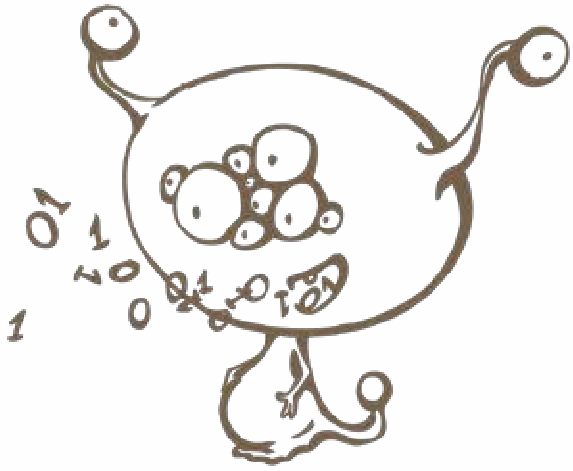
Full description

- Ask the students if they think alien life exists. How would aliens communicate?
- Tell them that if there are aliens somewhere out there, they would probably speak totally different languages than we do on Earth. That would make it very difficult for us to understand them! But they may be sending us mathematical messages. Mathematics is considered the universal language, so aliens would also be familiar with maths. Such a mathematical message might still be hard to decode, but in theory we are capable of doing so. Alien maths should be the same as ours!
- Let the children do exercise 1 from the template. If they fill in the right code, they will get the image on the right.



- Now tell the students they can make a message of their own! Ask them to do exercise 2 from the template.

Exercise 1



You are going to decode a message! Draw a grid on a paper sheet, 9 boxes across and 13 boxes down.

Ready? Starting from the top left corner, colour a box black for every 1 and leave a box blank for every 0 (see below). When you see a '/' in the message, move on to the next row.

The message from space:

010000010/001000100/000111000/001010100/000101000/100010001/011101110/000111000/000101000/011111110/100101001/000101000/001101100

If you filled in the message correctly, you will have an image. What do you see?

....

....

....

Exercise 2

Now you are going to create your own message to send into space! Get a new paper sheet and, just like in exercise 1, draw a grid that is 9 boxes across and 13 boxes down. Create your own image by colouring some boxes black. When you're finished, get a new paper sheet and draw the same grid again. For every box you coloured black in the previous grid, write a 1 in this grid. In every box you left blank, write a 0.

Write your message down in 1s and 0s, like the code in exercise 1. Give your message to your neighbour and see if they can decode it!

10-12

50 mn

EU UNIVERSE AWARENESS ACTIVITY

Lesson 10: Reflection!

Short description

Find the words 'radio telescope' in a word search. Heat up marshmallows over a bowl that has been warmed using aluminium foil and the Sun.

Keywords

- Reflection
- Focal point
- Radio telescope

Materials

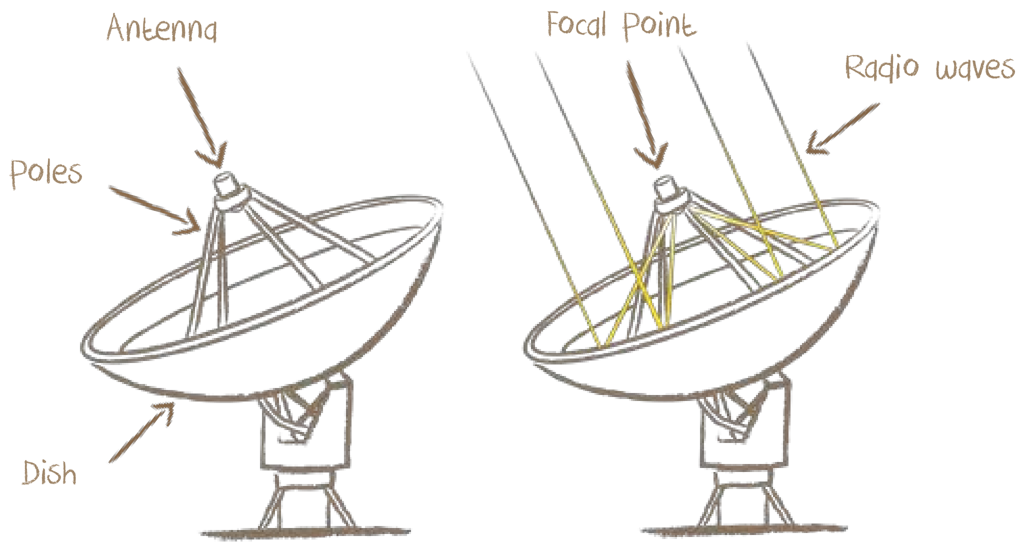
- 13 pocket mirrors
- 13 pieces of cardboard
- 13 flash lights
- 13 bowls
- 13 marshmallows
- 13 cocktail picks
- aluminium foil

Learning objectives

Learn about the use of the dish on a radio telescope. Learn that electromagnetic waves come together at a focal point if they are reflected the right way.

Background science

A radio telescope is similar to a very large radio. The large size of its dish means it can detect very weak radio signals. The dish reflects radio waves to the antenna (see illustration). You can compare this to the way an ordinary mirror reflects visible light. In optical telescopes that detect visible light, there is often a mirror that serves the same purpose as the dish on a radio telescope. The dish is shaped such that just the rays coming from one specific direction are redirected to the antenna, which is the called the focal point. In this way, astronomers can 'zoom in' on heavenly bodies they want to study and collect much more radiation than they would with just a single antenna and no dish. This means they can detect even the weakest radio sources in space.



Full description

- Let the children fill in the word search in exercise 1 from the template. If they can't find the answer, tell them the phrase they are looking for is 'radio telescope'.
- Ask them to write down everything they know about radio telescopes. Discuss the answers together with the class.
- Ask the students which features stand out on a radio telescope. Show image 3 from the appendix. Explain that most radio telescopes consist of a large, round surface that we call a dish. Above the centre of the dish there is an antenna that collects the radio waves from space.
- Explain that radio waves are a kind of light and that they reflect, just like 'normal' light (see 'General Background Science').
- Demonstrate the reflection of light on a mirror. Explain that other kinds of radiation, like radio waves, also reflect on certain surfaces. An example is, of course, the dish of a radio telescope!
- Tell the students they are going to perform an experiment in pairs, in which one child will shine a torch at a mirror, while the other child tries to catch the reflected light on a piece of cardboard.
- Let them do exercise 2 from the template. If the Sun isn't shining, they can do the exercise with a lamp. The lamp must have an old fashioned light bulb as Compact Flourenscent Lights (CFLs) don't give off enough heat.
- Discuss exercise 2 and explain that the marshmallow is melting because the light rays are all directed towards the centre of the bowl. The point where it is hottest is called the 'focal point'. You can compare this experiment with a radio telescope. The radio waves are reflected on the dish and come together at the focal point. Explain that the antenna of a radio telescope is always located at the focal point, because all radio waves are reflected towards that specific point.

Related lessons: lesson 2, lesson 4, lesson 12

Exercise 1

Cross out all letters of the words you find in the word search. The letters that remain form a word. Do you know which word? Write down what you know about this word!

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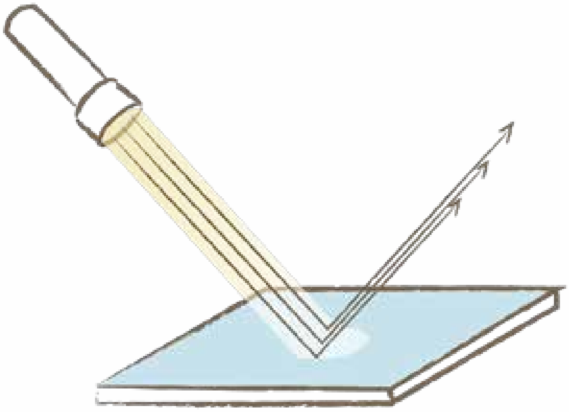
S	P	A	C	E	R	A	T	S	R
E	A	A	N	T	E	N	N	A	D
E	W	E	O	D	T	T	M	L	N
S	P	A	L	C	I	S	O	E	E
E	A	R	N	M	P	U	O	C	S
Y	O	T	E	U	U	N	N	T	L
W	A	H	U	D	J	E	S	I	M
O	I	D	A	R	I	V	G	A	A
S	Y	A	R	C	N	H	R	S	S
O	D	I	S	H	T	S	I	E	S

earth
day
esa
jupiter
light
moon
mars
radio
star
rays
unawe
venus
world
science
send
emit
saturn
dish
antenna
space
mass

Exercise 2

You are going to perform an experiment in pairs! Lay a mirror down on the ground. One of you shines a flashlight on the ground, from an angle (see illustration). The other tries to catch the reflected light with a piece of cardboard.

Swap roles!



When you're finished, you will do another experiment. Take a bowl with aluminium foil. Put this bowl in the sun or under a hot lamp, and hold a marshmallow in the centre of the bowl with a stick. Now hold it like this for a few minutes. After a while, something happens to the marshmallow.

Write down what's happening.

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10-12 | 20mn

EU UNIVERSE AWARENESS ACTIVITY

Lesson 11: Disturbance!

Short description

Create a disturbance in a sound box with a mobile phone.

Keywords

- Devices
- Radio
- Remote control
- Mobile phone

Materials

- Portable radio
- Remote control
- Mobile phone

Learning objectives

Learn that some devices use radio waves. Learn that radio radiation also comes from space. Learn why radio telescopes are located in remote areas.

Background science

A large number of devices use radio waves. Some examples are mobile phones, walkie-talkies, board radios, portable televisions. Because of these devices, radio waves are everywhere around us.

Many radio waves are also coming at us from outer space. However, these are much weaker, because they come from much farther away. Radio telescopes have to be far away from major cities; otherwise, the space signals will be disturbed by human devices. This is because communicating devices use radiation that is the same as some of the radiation coming from space. Therefore, a radio telescope has a hard time distinguishing space objects from local devices.

Full description

- Tell the students that both visible and invisible light exists (see 'General Background Science').
- Ask them to name some devices that use radio waves.
- Tell them that astronomers try to catch radio waves from outer space with radio telescopes. This lesson shows that this is the same kind of radiation that communication devices use.
- Demonstrate that some devices use the same kind of radiation as radios by showing the children that they can disturb a sound box. Do this by turning on a radio and telling the children they should listen carefully to what happens when you press a button on a remote control. Remote controls use infrared radiation – not radio waves – so you won't hear any disturbance.
- Let the students do exercise 1 from the template. Now do the same thing as before, but with a mobile phone. Call someone and make sure that the phone is close to the radio. This time, the class will hear a clear disturbance.
- Ask the children to write down their findings on the template. Discuss the exercise together with the class. Apparently, some devices do use the same waves as a radio! They too affect a sound box with their electromagnetic waves.

Tip: Sometimes you also hear mobile phones interfere with speakers, even though they're not connected to a radio. This is because the speakers themselves pick up the phone signal.

Related lessons: lesson 1

Exercise 1

Write down what you heard when the teacher pressed a button on the remote control.

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Write down what you heard when the teacher called someone.

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Why do you think the sound box was disturbed?

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Explain why radio telescopes are always located far away from cities or towns.

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10-12

40mn

EU UNIVERSE AWARENESS ACTIVITY

Lesson 12: Big, Bigger, Biggest!

Short description

Link pictures to the correct radio telescope.

Keywords

- Radio
- Dish
- Focal point

Materials

- Portable radio

Learning objectives

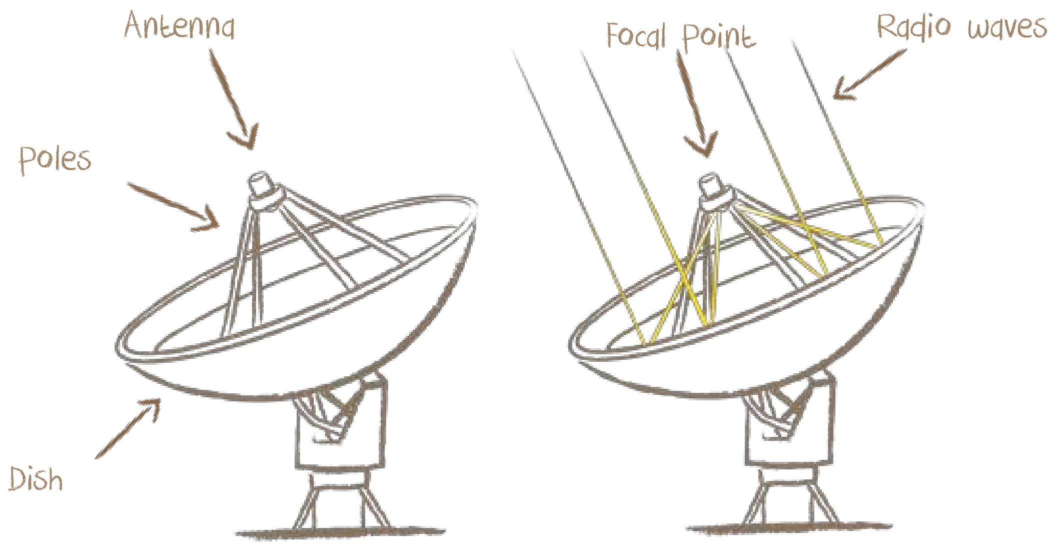
Learn that the larger the dish, the more radio waves it can catch, and therefore, the higher quality images it can make.

Background science

A radio telescope is similar to a very large radio. The dish reflects radio waves to the antenna (see illustration). You can compare this to the way an ordinary mirror reflects visible light. In optical telescopes that detect visible light, there is often a mirror that serves the same purpose as the dish on a radio telescope. The dish is shaped so that only the rays from one specific direction are redirected to the antenna in the so-called focal point. The large dish size means radio telescopes can detect very weak radio signals. In this way, astronomers can point towards celestial bodies they want to study and collect much more radiation than they would with just an antenna and no dish. This means they can detect even the weakest radio sources in space.

The bigger the dish, the more sensitive a radio telescope is to radiation. A larger dish is able to reflect more radiation towards the antenna due to its increased surface area. So, a bigger radio telescope will see fainter objects. This doesn't necessarily mean that a photo has a higher number of pixels if it's taken with a larger dish.

Let's take the example of the two radio telescopes from Exercise 1: One dish has a diameter of 305 metres, and the other has an intersection of 25 metres, but the second is used together with other dishes of the same size. If two of the 25-metre dishes are separated by a distance of 305 metres, they will take pictures with the same number of pixels as the 305-metre dish. The two systems will both photograph an object with the same precision (for example an accuracy of a kilometre). This feature of radio telescopes is called resolution and is different from sensitivity. Sensitivity depends on surface area while resolution depends on the distance between each individual element of the dish.
The 305-metre dish from our example can capture every pixel with a higher sensitivity but two small dishes at a distance of 1 km can capture the image with a larger number of pixels, or higher resolution.



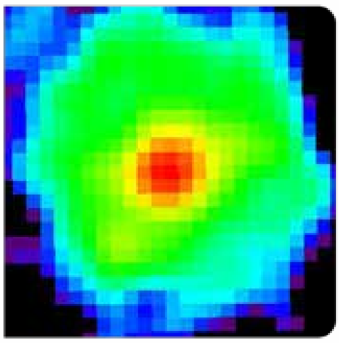
Full description

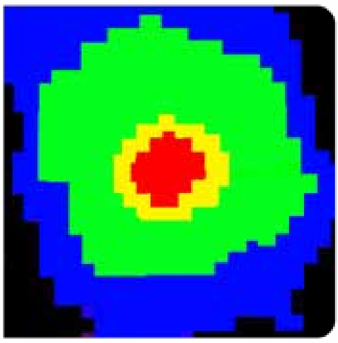
- Tell the students that both visible and invisible light exist (see 'General Background Science').
- Ask them to identify the two main components of a radio telescope.
- Explain that the antenna collects radio waves and passes them on to a computer, which creates an image. The size of the dish is important for the quality of the picture. Let the students do exercise 1 from the template. The photograph with more detail belongs to the 305-metre dish.
- Tell the children that a larger dish can catch more radio waves, resulting in a greater sensitivity and the possibility of photographing fainter objects.

Related lessons: Lesson 2, lesson 4, lesson 10

Exercise 1

Below, you see two radio images and two radio telescopes.





What is the difference between the two radio images?

Which is, according to you, the best radio image?

Why did you make that choice?

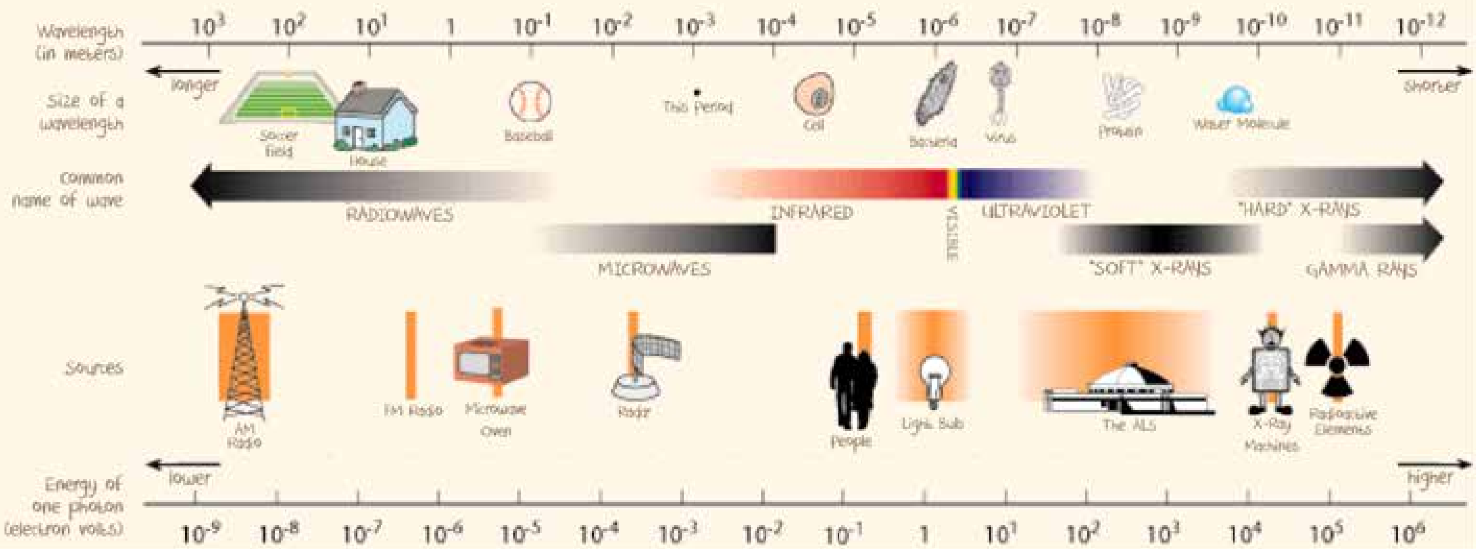
APPENDIX

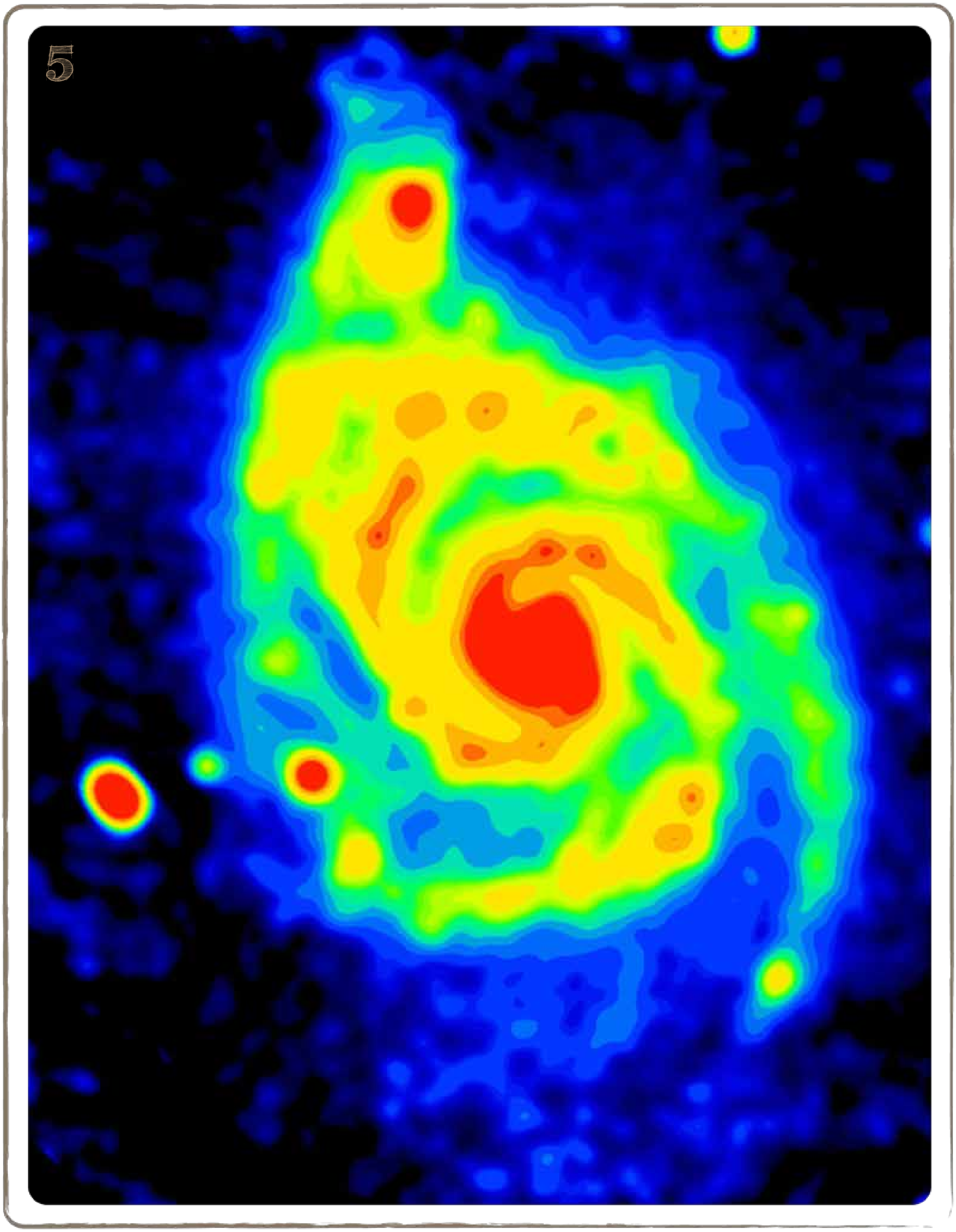
1

3

4

THE ELECTROMAGNETIC SPECTRUM

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Glossary

Focal point

A focal point is the point at which waves meet after reflection. The radio waves coming from a particular space object are reflected by the dish of a radio telescope to the focal point. The antenna is located at the focal point.

Electromagnetic radiation

Visible light – all colours of the rainbow – is just one of many forms of electromagnetic radiation. Other forms include radio, microwave, infrared, ultraviolet and X-rays. Electromagnetic radiation consists of waves. The length of the waves (simply called the wavelength) determines which kind of electromagnetic radiation it is. For example, a wavelength of several hundred nanometres (0.0000001 m) corresponds to visible light; a wavelength of several metres corresponds to radio waves; and a wavelength of 0.000000001 m corresponds to X-ray radiation. For the full electromagnetic spectrum, see image 4 from the appendix.

Frequency

The frequency tells you how often a wave repeats. The frequency of light waves depends on their wavelength. The longer the wavelength, the lower the frequency. With the following formula you can calculate the light's frequency: frequency = speed of light / wavelength.

Wavelength

The wavelength is the distance between two peaks of an electromagnetic wave. It is intertwined with the frequency. The higher the frequency, the shorter the wavelength. With the following formula you can calculate the wavelength: wavelength = speed of light / frequency.

Optical radiation

Optical radiation is the most well-known form of electromagnetic radiation: also known as visible light. All colours of the rainbow are optical radiation.

Radio astronomy

Radio astronomers study the Universe using radio waves, instead of visible light.

Radio telescope

A radio telescope collects radio waves from space. While optical telescopes (for studying visible light) are equipped with lenses or mirrors, radio telescopes have a dish. This dish reflects the radio waves from space and sends them to the antenna, which is in the centre of the dish.

Dish

The dish is the part of a radio telescope that reflects the radio waves from space towards the antenna, which is located in the centre of the dish.

Image Credits

Electromagnetic spectrum, p.6
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Westerbork telescope, p.6
Credit: Wikimedia Commons

Devices, p.10
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Dish, p.12, 20
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X-ray hands, p.17, 37
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Radio image Saturn, p.25, 28, 32, 35
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Radio image Jupiter, p.25, 28
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Radio image Sun, p.25, 28, 32
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Radio image Mercury, p.25, 28
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Optical image Saturn, p.25, 28, 24
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Small dish, p.57
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Appendix 3
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Appendix 4
Credit: NASA

Appendix 5
Credit: NASA / Chandra

Colophon

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