ASTROEDU

Peer-reviewed Astronomy Education Activities

SKAO and the mysteries of invisible light

Discover the invisible light with SKAO, the largest radio telescope in the world!

Author: ['Jamie Sloan (Jodrell Bank Centre for Engagement)', 'Naomi Smith (Jodrell Bank Centre for Engagement)']

KEYWORDS

fibre optics, light, telescope, spectrum, infrared, technology, radio wave, SKAO

CATEGORY

<QuerySet [<SciCategory: Physics>, <SciCategory: Scientific instrumentation>, <SciCategory: Technology and Robotics>]>

AGE

12 - 16

LEVEL

<QuerySet [<Level: Informal>, <Level: Middle School>, <Level: Secondary>]>

TIME

multiple days

GROUP

Group

SUPERVISED

Yes

COST

High Cost

SKILLS

<QuerySet [<Skills: Asking questions>, <Skills: Constructing explanations>]>

TYPE OF LEARNING

<QuerySet [<Learning: Guided-discovery learning>, <Learning: Observation based>, <Learning: Technology-based>]>

MATERIALS

For Activity 1

- Infrared camera, see object 1 in the image below. Many different models can be purchased, from adapters that clip onto smartphones, to professional models.
- Black plastic bag.

For Activity 2

- Radio Frequency (RF) detector, see object 2 in the image below.
- OPTIONAL: Spectrum analyser (a WiPry-Pro model attached to an iPad), see object 3 in the image below.

For Activity 3

- Parabolic microphone, see object 4 in the image below. The microphone collects and amplifies sound, which can be heard through a set of headphones. It allows the user to hear someone speaking quietly on the other side of a room.

For Activity 4

- Laser pointer, see object 5 in the image below.
- Optical fibre, see object 5 in the image below.

For Activity 5

- A sound system that accepts two input signals, see object 6 in the image below.
- Two mp3 players, see object 6 in the image below.

Figure 1: equipment that can be used in the activity

GOALS

To discover the existence of invisible types of light and that special types of telescopes observe them to study the Universe.

LEARNING OBJECTIVES

- To learn about the existence of infrared and radio waves
- To discover the SKAO, one of the major upcoming astronomical endeavours
- To understand why antennas often use parabolic dishes
- To comprehend the function of optical fibers in data transmission.

BACKGROUND

The electromagnetic spectrum

Astronomers do not only use the light we can see with our eyes to observe the Universe. In fact, they use different types of telescopes around the world or in space, each sensitive to a particular range of wavelengths within the electromagnetic spectrum: gamma rays, x-rays, ultraviolet, visible light (the type we see with our eyes), infrared, microwaves, and radio waves. These types of light are identical to each other apart from their wavelength (gamma rays are the shortest, and radio waves are the longest – around 100,000 times longer than visible light).

Each type of light unveils different phenomena to astronomers, giving them a more comprehensive view of the Universe.

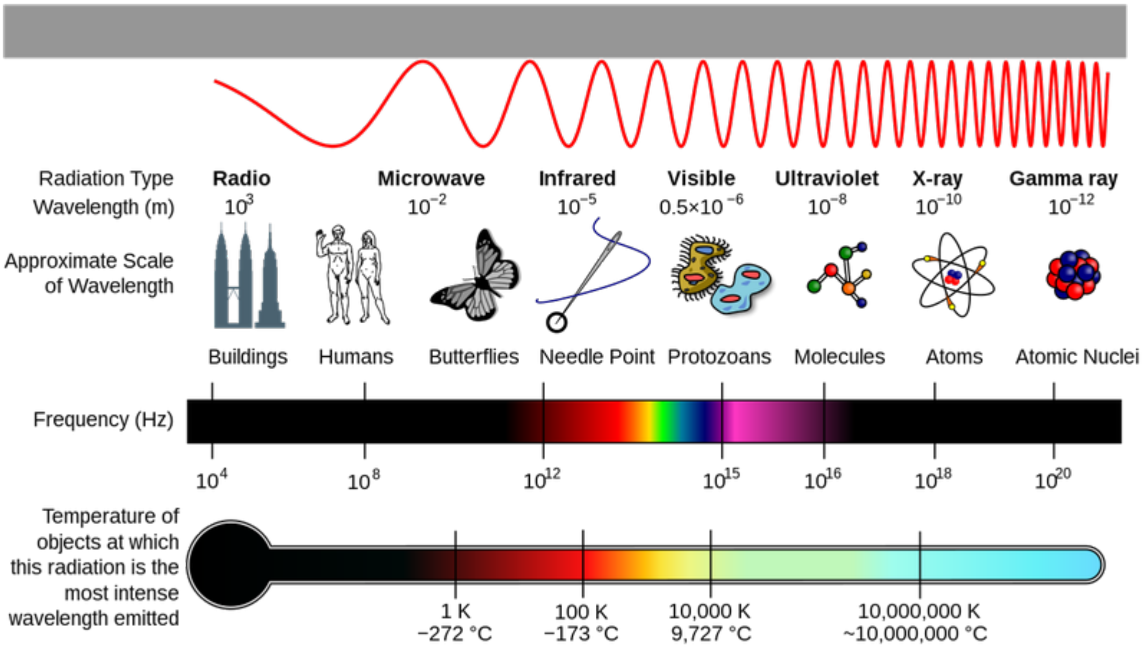

Figure 2: An overview of the electromagnetic spectrum. Adapted from the original image. Source: Wikimedia Commons. This file is licensed under the ***Creative Commons Attribution-Share Alike 3.0 Unported*** *license.*

What is SKAO?

The Square Kilometre Array Observatory (SKAO) is the next generation of radio telescopes, currently under construction. It will detect radio waves from objects in space. After the first phase of construction, it will already be the largest radio telescope in the world; however, SKAO is expected to expand even further in the future.

SKAO will be tens of times more sensitive and hundreds of times faster at mapping the sky than today's best radio telescopes. It will be made up of two separate instruments; a mid-frequency telescope in South Africa and a low-frequency telescope in Australia. Each of these in turn is made up of many telescopes (an array), which are linked together to work as one powerful telescope.

The mid-frequency South African instrument will consist of around 200 moveable dishes. Each will be about 15 metres across and they will be spread out over a distance of 150 kilometres.

The low-frequency instrument in Australia will be made up of around 130,000 antennas. These will not physically move, though they can be pointed at objects in space by picking out specific directions in the sky.

Figure 3: Composite image of the SKAO telescopes, combining real hardware already on site with artist's impressions. Left: an artist's impression of the future SKA-Mid dishes blends into the existing ones in South Africa. On the right: an artist's impression of the future SKA-Low stations blends into the existing prototype in Western Australia. Credits: Artist's impression by SKAO.

The telescopes are positioned in remote areas of South Africa and Australia to distance them from human-made sources of radio interference (e.g. mobile phones).

They will be linked by huge fibre-optic networks, which will transfer the raw data to the central computers at each site.

It is a colossal engineering endeavour, with many technical challenges still to be overcome. Twenty countries are involved around the world. The international Headquarters is located at the Jodrell Bank Observatory in Cheshire, UK

SKAO will be used to answer fundamental questions of science and about the laws of nature, such as: how did the Universe form and evolve? Is Einstein's theory of General Relativity correct? What is 'dark matter' and 'dark energy'? What is the origin of cosmic magnetism? Is there life somewhere else in the Universe?

However, perhaps the most significant discoveries to be made by the SKAO are those we cannot predict.

FULL DESCRIPTION

Activity 1: Let's discover Infrared light

Using an infrared camera, you will show that there is electromagnetic radiation invisible to our eyes and that it is possible to build devices to observe it, just like SKAO will do.

An excellent demonstration of the existence of light that our eyes cannot see is based on an infrared camera and an ordinary black bin bag.

Ask students to put an arm inside the plastic bag and observe it. They will not be able to see the arm, as visible light cannot travel through the bag, which appears opaque to our eyes.

Then ask them to look at the plastic bag with an infrared camera. They will now see the arm inside the bag, thanks to the infrared waves that can pass through the bag, making it appear transparent on the camera.

Figure 4: Hands in a plastic bag, seen in visible light (left) and with an infrared camera (right). Credits: NASA/JPL-Caltech/R. Hurt (SSC)

After showing the existence of infrared light, explain to students that this is analogous to how SKAO's radio telescopes will create radio pictures of the Universe. Just like infrared radiation, radio waves are undetectable to the human eye, but they unveil hidden objects and phenomena in the Universe. Radio waves pass through clouds of gas and dust in space, whereas visible light is blocked, allowing astronomers to peer through these clouds and see the objects within or behind them (an impossible feat for an optical telescope, which observes visible light).

Activity 2: The existence of radio waves

You will use a RF (radio frequency) detector to pick up radio waves, just as the SKAO's telescopes will do to observe the Universe.

Radio waves can be an abstract concept, since they are undetectable by the human body. So, we will use an RF detector to detect radio waves.

First, demonstrate how the RF detector works. Bring the antenna close to a source of radio waves (e.g. an active mobile phone, a walkie-talkie, or a radio mic). The antenna will emit a sound or flash a light when it detects the waves. This demonstrates the existence of radio waves even if we cannot see them with our eyes.

After the demonstration, students could be given RF detectors and asked to explore the environment, in search of areas of high and/or low radio activity.

OPTIONAL: if you have a spectrum analyser, you can use it in a way similar to the RF detector. It picks up local radio waves and displays a real-time map of the radio frequencies in the 2.4 GHz band (frequencies of 2.4 GHz to 2.5 GHz). These frequencies are used for wireless communications, such as Wi-Fi networks, mobile phone signals and Bluetooth. Like the RF detector, this can be used to demonstrate the existence of radio waves, as well as the need to build the SKAO in remote locations, away from 'radio loud' areas. In fact, human activity generates a lot of 'radio noise' through wireless technology, which may cover the (much fainter) radio signals from space that the SKAO will look for.

Activity 3: Why do telescopes have a dish antenna?

Students will use a parabolic microphone to collect and amplify sound, understanding why radio telescopes have dish antennas (even if they DO NOT DETECT SOUND BUT RADIO WAVES!)

Ask students to use the microphone to hear someone speaking quietly on the other side of a room. They will be able to hear the sound through a set of headphones.

Then examine the microphone and explain to them that the shape of the bowl focuses sound waves to the microphone in the centre. This amplifies the sound, allowing the listeners wearing the headphones to hear conversations from quite a distance away. The bowl has the shape of a paraboloid (a 3D parabola). This shape reflects the sound to a point, called the focal point. The focal point is where the microphone sits. This is analogous to the dishes of the SKAO mid-frequency instrument in South Africa, which collect and focus radio waves to a detector at the focal point.

IMPORTANT: Please note, after using this piece of equipment, some participants may be under the misconception that the SKAO detects sound, rather than radio waves (a form of electromagnetic radiation, similar to light). Please ensure that participants are aware that the demonstration in this activity is an analogy.

Health & Safety notice: When the headphones are being worn, the microphone should not be subjected to loud noises, e.g. someone shouting into it. This could cause pain and/or ear damage to the person wearing the headphones.

Activity 4: data transfer

You will use the morse code to explain how telescopes transfer data with optical fibre technology.

Light can be transmitted over large distances and very quickly (at a speed of about 200 million metres per second) using optical fibres. This can be demonstrated by firing a laser pointer down a fibre optic cable and seeing it shine out the other end. Simply insert one end of the fibre optic cable into the recess of the laser pen bulb and turn it on.

Students will then be asked to send a message in Morse code down the cable to a person at the other end, turning the laser on and off (see the Morse code in the image below).

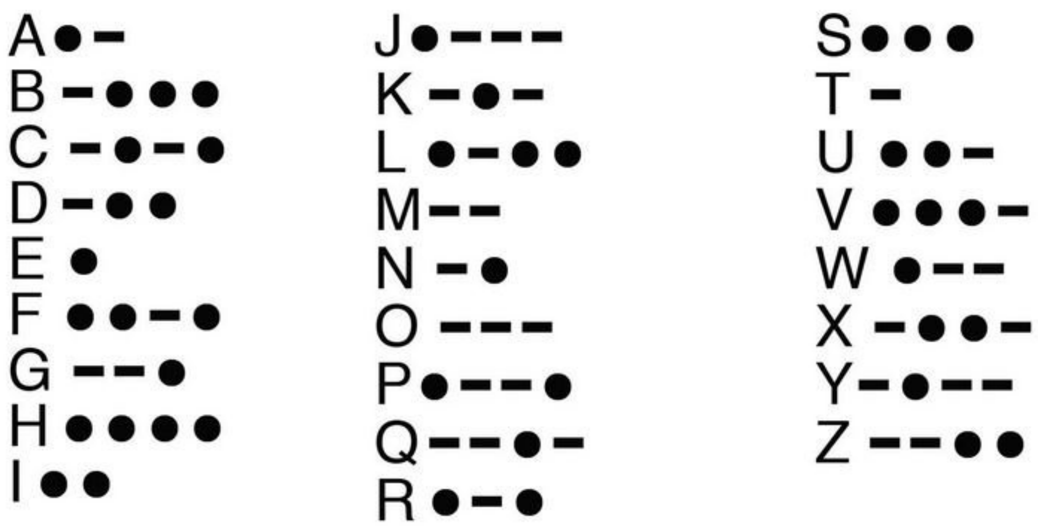

Figure 5: the morse code translates letters to dots • (short signal duration) and dashes — (long signal duration).

The activity shows that, by switching the laser on and off, you can now transmit digital information down the fibre at a very high speed. This can be used to transmit information in a binary format: when the light is off, that is a 0, and when the light is on, that is a 1 (note, though, that the light through real fibre optic cables flashes on and off thousands of times a second).

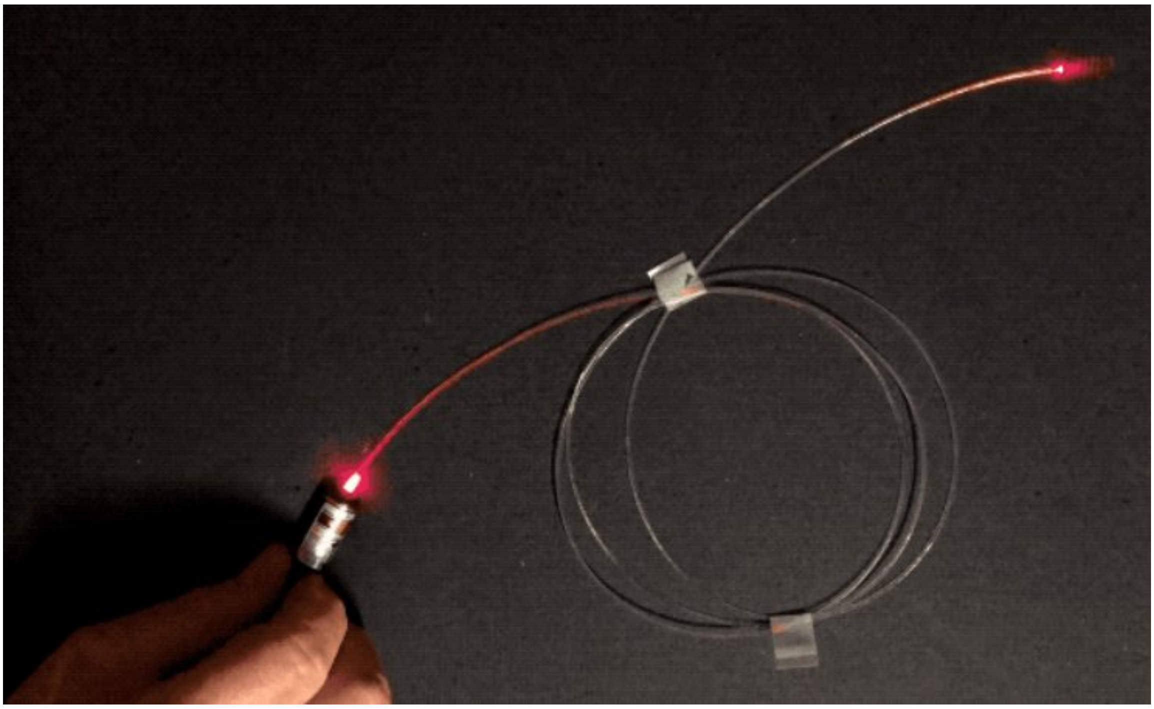

Figure 6: Laser light through an optical fibre. Credits: https://www.thefoa.org/tech/sciproj.htm

Discuss with students about how the SKAO dishes and antennae will be connected by a vast network of fibre optic cables to transfer data from the individual detectors to a central processing unit, where it is combined. This will make the SKAO work as a single instrument with better sharpness and a higher ability to detect faint signals than the individual antennas it consists of. The amount of data the SKAO network will have to carry is truly staggering. In the first phase alone, SKAO will produce 159 Terabytes of raw data per second, with information being transported down fibre optic cables as visible light. SKAO will use enough optical fibre to wrap around the Earth twice!

Health & Safety notice: use a class II (or weaker) laser pointer. Class II laser means the blink reflex is quick enough to protect the eye against damage from accidental exposure. However, eye damage could still occur from prolonged exposure, due to misuse of the equipment. You may wish the laser to remain permanently in the possession of a member of staff, or place it in a clamp stand pointing in a safe direction (and the fibre brought to the laser pen, rather than the other way around). You might also use signs warning people not to shine lasers in their eyes.

Activity 5: The importance of synchronisation

Students will try to play two identical sounds at exactly the same time, understanding how difficult this task is.

Use a sound system accepting two simultaneous inputs, connected to two mp3 players. The two mp3 players are in turn connected to one set of speakers. Each mp3 player should be loaded with the same sound file.

Ask students to try to press "play" on both mp3 players at exactly the same time, so that the sound files are played in sync, showing how difficult this task can be.

Note that there may be other ways of doing this, such as trying to play the same sound file on two different computers at exactly the same time.

In this activity, the mp3 players represent two dishes/antennae in the SKAO array and the speakers represent the central correlator.

In order for the SKAO to function as a single instrument, the signals from all the separate detectors must be synchronised to within 0.000000000001 of a second! Otherwise, the data will not be added up correctly. In practice, to sync the signals from the many hundreds of dishes, or hundreds of thousands of antennae, SKAO will make use of a very accurate time signal.

Health & safety notice: if the volume is too high, long-term exposure to loud sounds may cause discomfort or even hearing damage to participants, or those running the activity. This may be especially dangerous with both sets of this equipment running in a confined space. You may wish to prevent participants from changing the volume levels.

EVALUATION

We propose a series of questions that can be used to assess students' understanding of the activity and its content. The questions can be asked in both oral and written form.

Activity 1
Why are infrared cameras able to see through certain materials, like a black bin bag, while our eyes cannot? Answers: A) Infrared cameras emit a special light that makes all materials transparent. B) Infrared cameras can detect electromagnetic radiation (infrared waves) that can pass through certain materials, unlike visible light. C) Infrared cameras use a higher power source that penetrates through any material. (Correct answer: B)

How does the use of infrared light in the activity relate to SKAO's method of observing the universe? Answers: A) Both rely on visible light to observe and capture images. B) Both use infrared light to see through objects and materials on Earth. C) Both use forms of electromagnetic radiation invisible to the human eye (infrared in the case of the camera, radio waves for SKAO), to reveal objects invisible to our eyes. (Correct answer is C)

Activity 2

What characteristic of radio waves allows them to be detected by RF detectors, despite being invisible to the human eye? A) They are a form of sound that travels through the air. B) They are a type of electromagnetic radiation that specific electronic equipment can interact with and detect. C) They are visible under special lighting conditions. (Correct answer is B)

Why is it important for SKAO's telescopes to be located in remote areas? Answers: A) To avoid light pollution, which reduces the visibility of stars. B) To be closer to astronomical objects for better observation. C) To minimise interference from 'radio noise' produced by modern wireless technology, thus allowing the detection of faint radio signals from space. (Correct answer is C)

Activity 3

How does the parabolic shape of a dish antenna benefit the detection of radio waves? Answers: A) It reflects radio waves to a focal point, hence amplifying the signal and making it easier to detect. B) It disperses radio waves to cover a larger area. C) It converts radio waves into visible light for easier observation. (Correct answer is A)

Activity 4

How does digital information transmission work? Answers: A) By sending information using a wave that changes smoothly. B) By converting information into a series of ones and zeros, which are then sent as signals. C) By using sounds to communicate messages. (Correct answer is B)

Why is fiber optic technology crucial for the data transmission needs of SKAO? Answers: A) It enables the transmission of data using visible light, which is less effective than radio waves. B) It is the only technology that can transmit data in the absence of light. C) It can transmit vast amounts of data at high speeds over long distances, essential for handling the data generated by SKAO. (Correct answer is C)

Activity 5

What is synchronization in the context of transmitting or processing information? Answers: A) The process of mixing different types of information to increase complexity. B) The act of combining information from various sources without timing adjustments. C) The coordination of multiple signals or actions to occur at precisely the same time for accuracy and efficiency. (Correct answer is C)

Why is precise synchronization vital for SKAO? Answers: A) To guarantee that signals from different telescopes can be accurately combined, enabling clear and detailed observations of the Universe. B) To ensure that all telescopes play music at the same time for entertainment purposes. C) To make sure all telescopes are pointed in the same direction at the same time. (Correct answer is A)

FURTHER READING

- More information about SKAO

- SKAO outreach and education site
- FAQ about SKAO

CITATION

Jamie Sloan; Naomi Smith, 2024, *SKAO and the mysteries of invisible light*, astroEDU, 2404

ACKNOWLEDGEMENT

Original Author: Teresa Anderson (The University of Manchester).
Acknowledgement: Project funding provided by: Royal Academy of Engineering.
Thanks to: The University of Oxford, The University of Cambridge, and SKAO Organization.