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.**

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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.


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

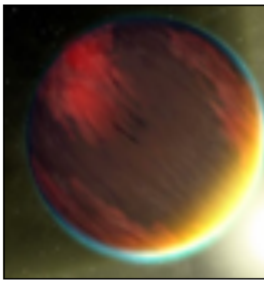
Appendix

## Lesson 3
### Activity Sheet 3a

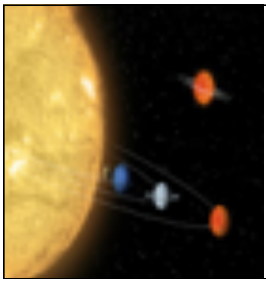
| | |
|---|---|
|  | Spectrum for white light |

| Spectra | Ingredients |
|---|---|
|  | Sodium |
|  | Iron |
|  | Helium |

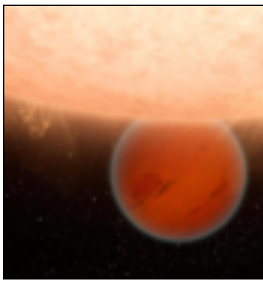
| | |
|---|---|
| **Name** | HD 189733b |
| **Type** | Gas Giant |
| **Mass** | 1.162 |
| **Orbit** | 2.2 days |
| **Atmosphere** | Iron |



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



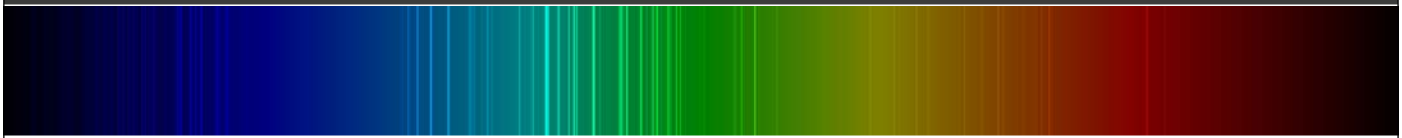
| | |
|---|---|
| **Name** | 55 Cancri e |
| **Type** | Super Earth |
| **Mass** | 8.63 x Earth |
| **Orbit** | 0.7 days |
| **Atmosphere** | Helium |



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

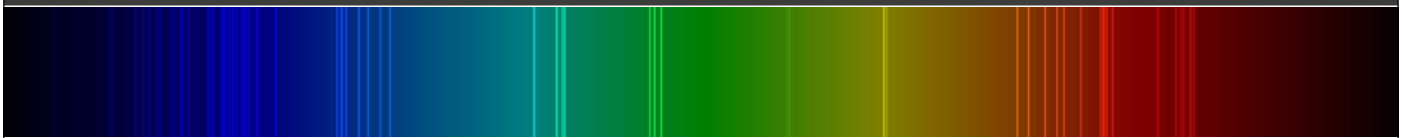
# Lesson 3
## Activity Sheet 3b

**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?