



4MOST: Build Your Own Spectroscope

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Why do astronomers need spectra?

Almost everything we know about stars and galaxies comes from their light. A photograph tells you where something is and how bright it looks, but a spectrum tells you what it's *made of*, how hot it is, and how fast it's moving towards or away from us.

This is what 4MOST is designed for. The 4-metre Multi-Object Spectroscopic Telescope, operating on ESO's VISTA telescope in Chile, can take spectra of 2,400 objects at the same time. Over its first five years, it will collect spectra of more than 40 million stars and galaxies.

In this activity, you'll build a simple spectroscope from a CD and some paper. It works on the same principle as 4MOST's spectrographs: splitting light into its component colours so we can read the information hidden inside it.

What you'll need

- The spectroscope template (printed from this instruction booklet)
- A sheet of black craft paper or card and glue (optional, but recommended)
- An old CD or DVD
- Scissors
- Tape

A quick primer: how spectroscopes work

White light is a mixture of many colours (wavelengths). To study those colours individually, we need to separate them.

A prism does this through *refraction*, bending different wavelengths by different amounts. A diffraction grating does it through *diffraction*, using a pattern of tiny slits or grooves to spread the wavelengths apart. The surface of a CD is covered in microscopic grooves arranged in a spiral - that's why it produces rainbows when light hits it. Your CD spectroscope uses exactly this effect.

Professional spectrographs work the same way, just with precision-engineered gratings instead of old DVDs. 4MOST uses two types: high-resolution spectrographs that can pick apart very fine details in stellar spectra, and low-resolution spectrographs that cover a broader range of wavelengths, ideal for measuring galaxy redshifts.

How to build your spectroscope

1. Print out the template in this instruction booklet.
2. If you have black craft paper or card, paste the template onto it carefully. This makes the spectroscope sturdier and reduces stray light, giving you cleaner spectra.
3. Cut along the dashed lines. Make sure you cut out *both* windows: the "eye" window and the "towards light" window.
4. Fold along the solid lines as shown in the diagram, gluing where instructed. "Up" means towards the printed side; "down" means towards the black paper side.
5. Stick the base onto the CD/DVD, with the reflective side facing up. You should be able to look through the eye hole onto a reflective part of the CD.



Your finished spectroscope should look something like the picture.

Try these light sources

Point your spectroscope at each of the following and sketch or describe what you see. The CD acts as a diffraction grating to split the light into the colours of the rainbow.

- **A fluorescent lamp** - Look for distinct bright lines separated by dark gaps.
- **An LED bulb** - Compare the pattern to the fluorescent lamp. Is it the same?
- **A candle flame** - You should see a smooth, continuous rainbow with no gaps.
- **A TV, computer or phone screen** - is this also a continuous rainbow?
- **The daytime sky** (never point directly at the Sun!) - What does this look like?

Questions to Consider

1. **Why do different light sources produce different spectra?**
2. **What happens when you look at the daytime sky?**
3. **Can a spectrum tell you how fast something is moving?**

The spectroscope you've just built captures light through a single slit and spreads it across a CD. MOST does something similar, but 2,400 times simultaneously. Robotic fibre positioners, each thinner than a human hair, move independently to point at 2,400 different stars or galaxies across a field of view as wide as eight full Moons. The light from each fibre feeds into one of

4MOST's spectrographs, where precision diffraction gratings split it into a spectrum.

To learn more about how astronomers use spectra, see 4MOST Explains: Spectra. To find out about the science surveys 4MOST is conducting, visit 4most.eu.

Answers

1. Why do different light sources produce different spectra?

Every chemical element emits and absorbs light at specific wavelengths. A fluorescent lamp contains mercury vapour for example, which produces a characteristic set of bright lines. An LED produces a smooth, broad spectrum, without the discrete emission lines you would see in a fluorescent lamp.

This is exactly how astronomers determine what stars are made of. 4MOST's 1001MC survey measures the chemical compositions of millions of stars in the Magellanic Clouds to understand how those galaxies formed and evolved. Each element leaves its own fingerprint in the spectrum.

2. What happens when you look at the daytime sky?

You should see a continuous rainbow (from sunlight) with some faint dark lines cutting across it. Those dark lines are *absorption lines*, caused by elements in the Sun's atmosphere absorbing specific wavelengths. This is how we know what the Sun is made of without ever visiting it.

4MOST's Galactic surveys this technique on millions of stars across the Milky Way, measuring their chemical fingerprints to reconstruct the history of our galaxy.

3. Can a spectrum tell you how fast something is moving?

Yes. When an object moves away from us, its light shifts to longer (redder) wavelengths. This is called *redshift*, and it works like the change in pitch of a passing ambulance siren (the Doppler effect). The faster something moves away, the greater the shift.

4MOST's TiDES survey is obtaining spectra for galaxies hosting supernovae (exploding stars that can be used as distance markers across the universe). By measuring the redshifts of these host galaxies, and combining them with supernova brightness measurements, we can trace how the expansion of the universe has changed over time and constrain dark energy. Spectra of the supernovae can also tell us about the kind of star that exploded.

