

Activity 2

The Signature of the Stars

Rainbows reveal that white light is a combination of all the colours. In 1666, Isaac Newton showed that white light could be separated into its component colours using glass prisms. Soon scientists were using this new tool to analyze the light coming from several different light sources. Some scientists looked at hot objects and gases; others looked at the stars and planets. They all made observations and detected patterns, but it took about 250 years for scientists to understand the connections.

Part 1: Every Element Has a Unique Signature.

Every element *emits* a unique range of colours called an **emission spectrum**. A similar spectrum is produced when light shines through a gas; however, in this case certain colours, or wavelengths, are *absorbed* by the gas. An **absorption spectrum** is the pattern of colours and dark lines that is produced when light shines through a gas and the gas absorbs certain wavelengths. This is the same pattern that occurs in the emission spectrum for the same medium. [Figure 1](#) shows some simplified absorption spectral lines.

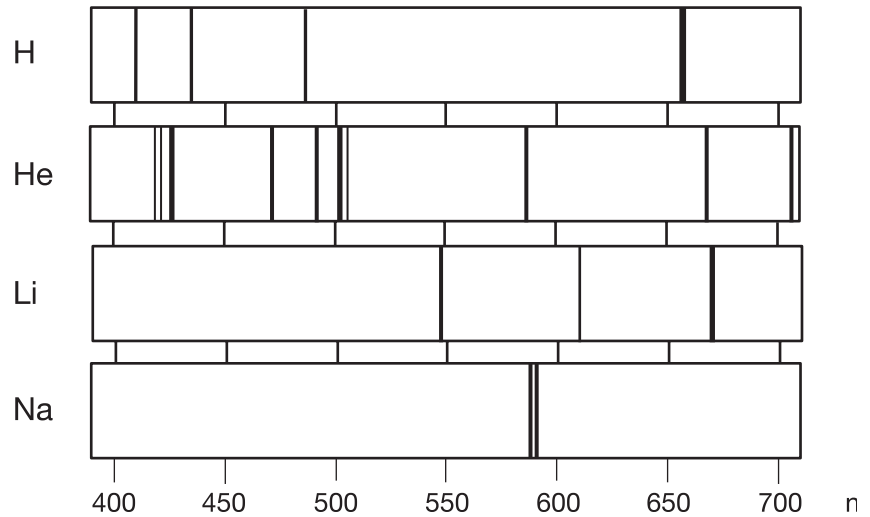


Figure 1 The lines indicate the wavelengths of light that are missing from the light after passing through the sample. The weight (thickness) of the lines indicates the amount of light absorbed at that wavelength. The heavier (or thicker) the line, the more light is absorbed.

1. Scientists can use absorption spectra to analyze unknown substances. Identify the elements present in the sample that produces the spectra in [Figure 2](#).

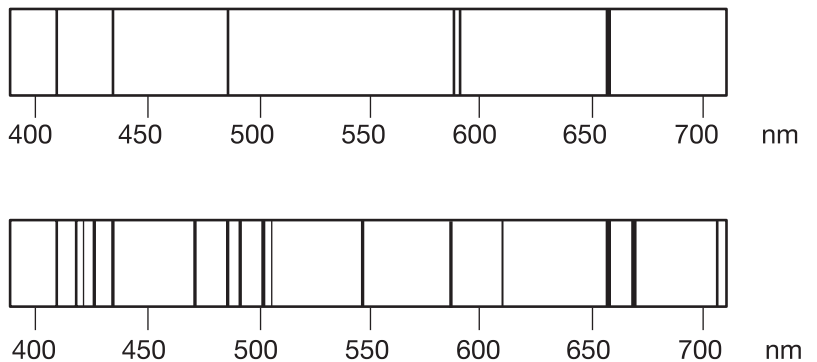


Figure 2 Simplified absorption spectra

The Expanding Universe

Part 2: The Light from Stars Contains Information.

The core of a star is very hot ($\sim 15 \times 10^6$ K), and very hot objects glow. The light produced by a star's core contains all the colours in the spectrum. Astronomers can learn many things about a star's motion, temperature, and composition by analyzing the starlight that reaches Earth. A **spectroscope** is an instrument that separates light into its spectrum. One of the earliest uses of the spectroscope was to analyze light coming from astronomical objects. The light directed from a telescope through a spectroscope produces an image called a **spectrograph**. Figure 3 shows a spectrograph of the Sun.

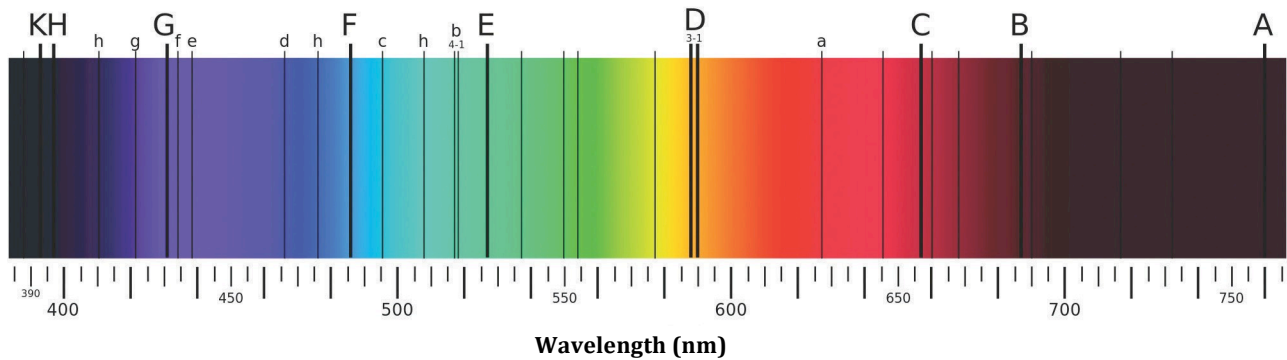


Figure 3 A spectrograph of the Sun. **Note:** The lettered lines represent different elements. Lines A and B are due to terrestrial oxygen and are not due to the Sun.

2. What do the dark lines in Figure 3 indicate?
3. Predict what happens to light as it travels from the core of the Sun to the surface?
4. Where do you think the elements in the outer layers of the Sun come from?

The Expanding Universe

5. Use Figure 3 and the simplified absorption spectra in Figure 4 to identify which elements are in the Sun, that is, which element each letter in Figure 3 represents (except for A and B).

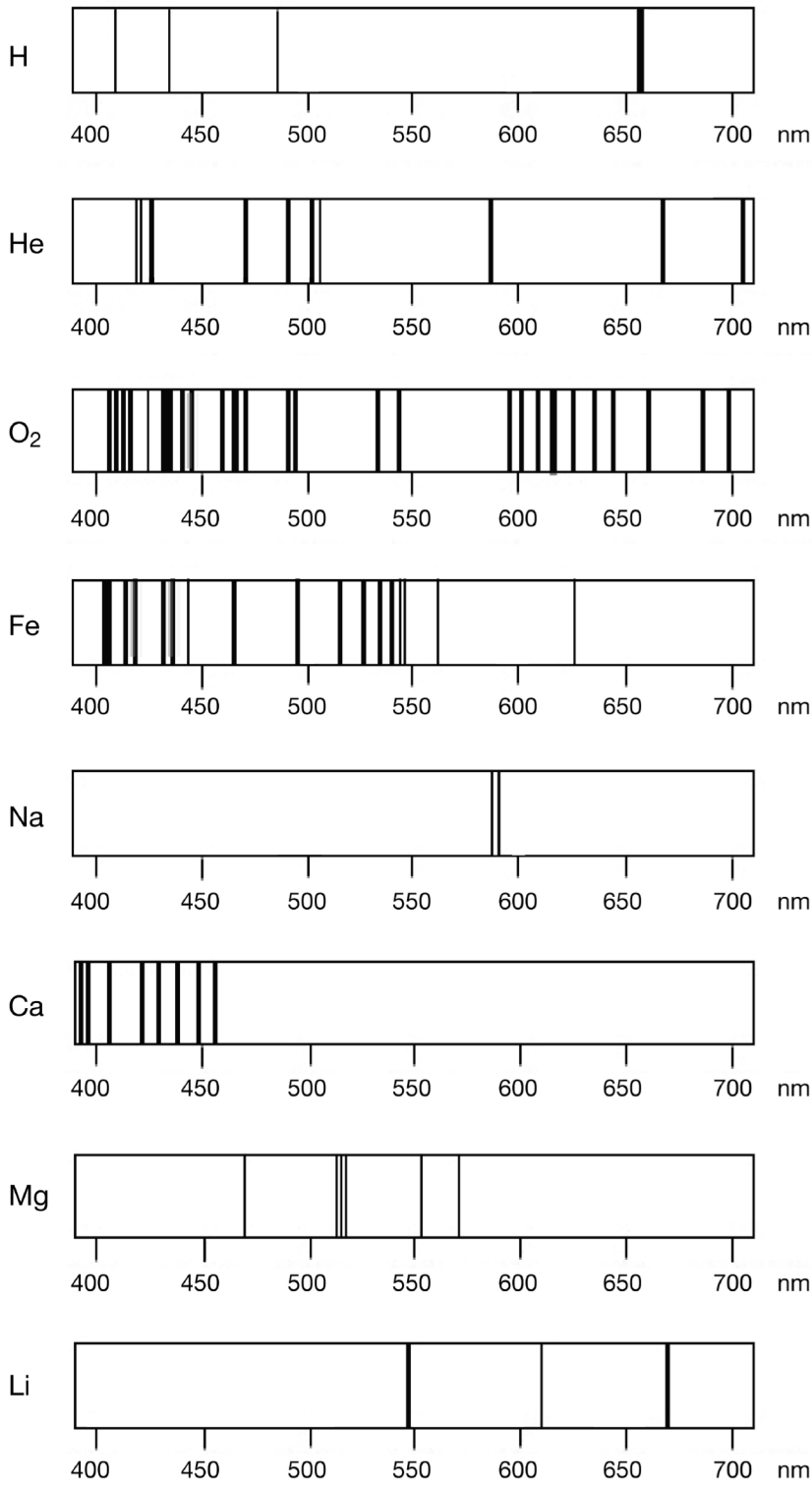


Figure 4 Simplified absorption spectra

The Expanding Universe

Part 3: The Spectra from Galaxies Are Redshifted.

In 1912, American astronomer Vesto Slipher began to observe more distant objects using a spectrometer, and he noticed that most of them had a distinct shift toward the red end of the spectrum. He recognized this as a Doppler shift caused by the motion of the objects. A redshift means that the source of light is moving away from the observer.

Figure 5 shows an emission spectrum from the quasar called 3C 273. We see that the emission lines due to hydrogen are shifted to the red end of the spectrum. The larger the redshift is, the greater the relative motion.

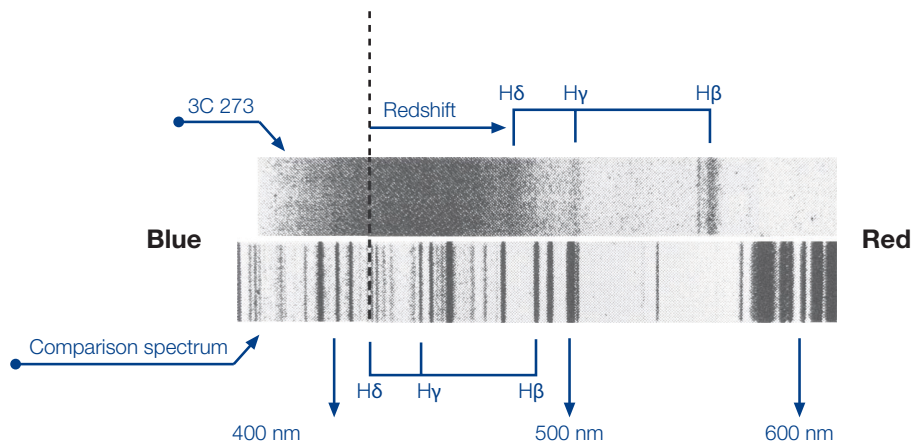


Figure 5 Redshifted spectrum from quasar 3C 273

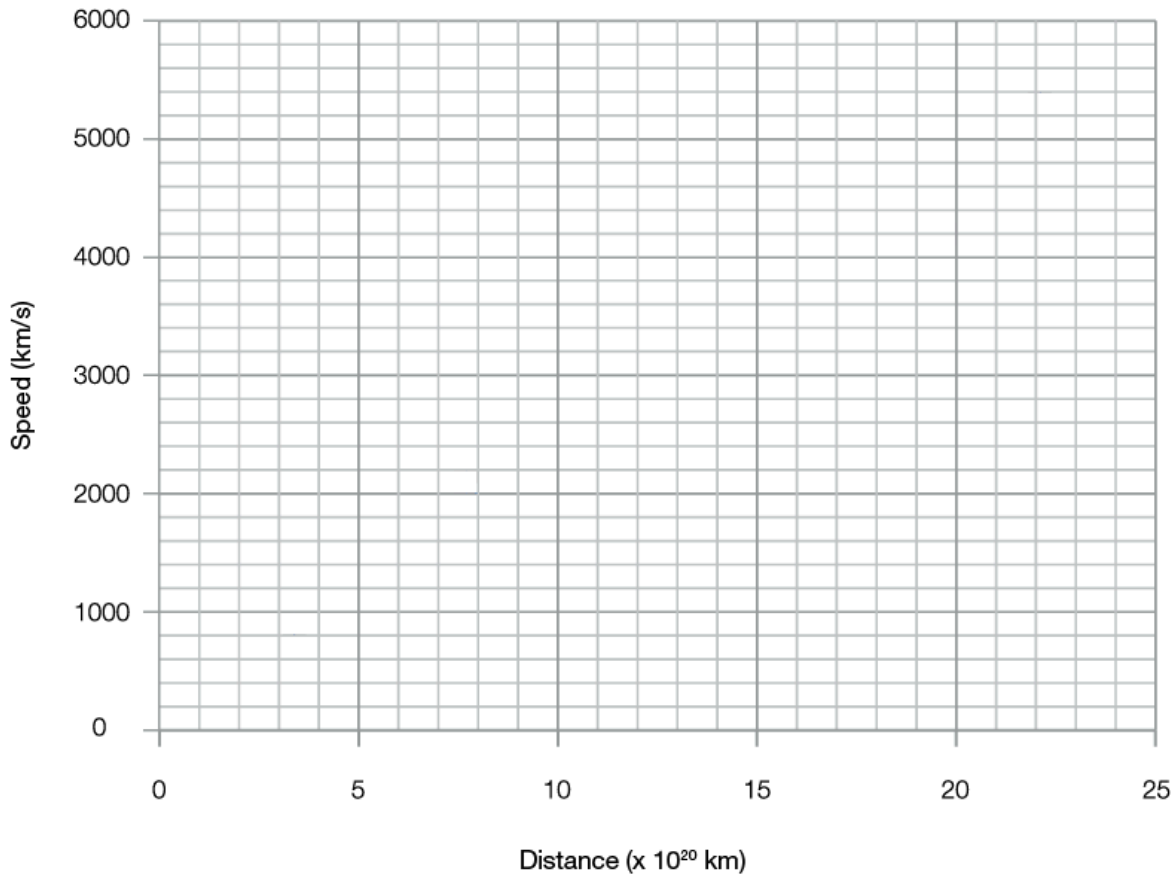
- Edwin Hubble extended this observation to more objects, and for several objects plotted the redshift versus the distance to the object. Try it for yourself. In Table 1, use the redshift of the spectral lines to determine the speed of each galaxy. To do this, use a ruler to align the leftmost spectral line provided with each galaxy with the speed scale at the bottom of the table.

Table 1

Galaxy	Distance (x 10 ²⁰ km)	Calcium Reference Lines		Speed (km/s)
		395 nm	405 nm	
NGC 1357	7.7			2100
NGC 1832	8.2			
NGC 2276	11.4			
NGC 3147	13.6			
NGC 3368	3.4			
NGC 3627	3.1			
NGC 4775	8.2			
NGC 5548	22.1			
NGC 6764	10.0			
NGC 6745	19.7			
Speed scale (km/s)				

The Expanding Universe

7. Plot the speed of each galaxy in Table 1 on the y-axis and the distance to the galaxy on the x-axis. Draw a line of best fit.



8. Calculate the slope of the line. What is the unit for the slope?

9. The slope of this line is called the **Hubble constant**, H_0 . Write the equation for this line using H_0 as your slope. What does it tell you about the relationship between the speed of galaxies and their distance? This relationship is called **Hubble's law**.

10. The age of the universe, T , can be approximated by taking the reciprocal, or inverse, of H_0 . Take the reciprocal of your slope. How old is the universe (in years)?

The Expanding Universe

Extension: Type 1a Supernovas

Type 1a supernovas are incredibly bright and almost all identical, two characteristics that make them very useful for studying the universe on the largest (and oldest) scale.

The distances to Type 1a supernovas can be determined using two different methods: brightness and redshift. For nearby Type 1a supernovas both methods give the same result; hence, Hubble's law is a straight line. However, as we look at more distant Type 1a supernovas, the line begins to curve. Figure 6 shows how the brightness of Type 1a supernovas changes with redshift.

DISTANT TYPE 1a SUPERNOVAS

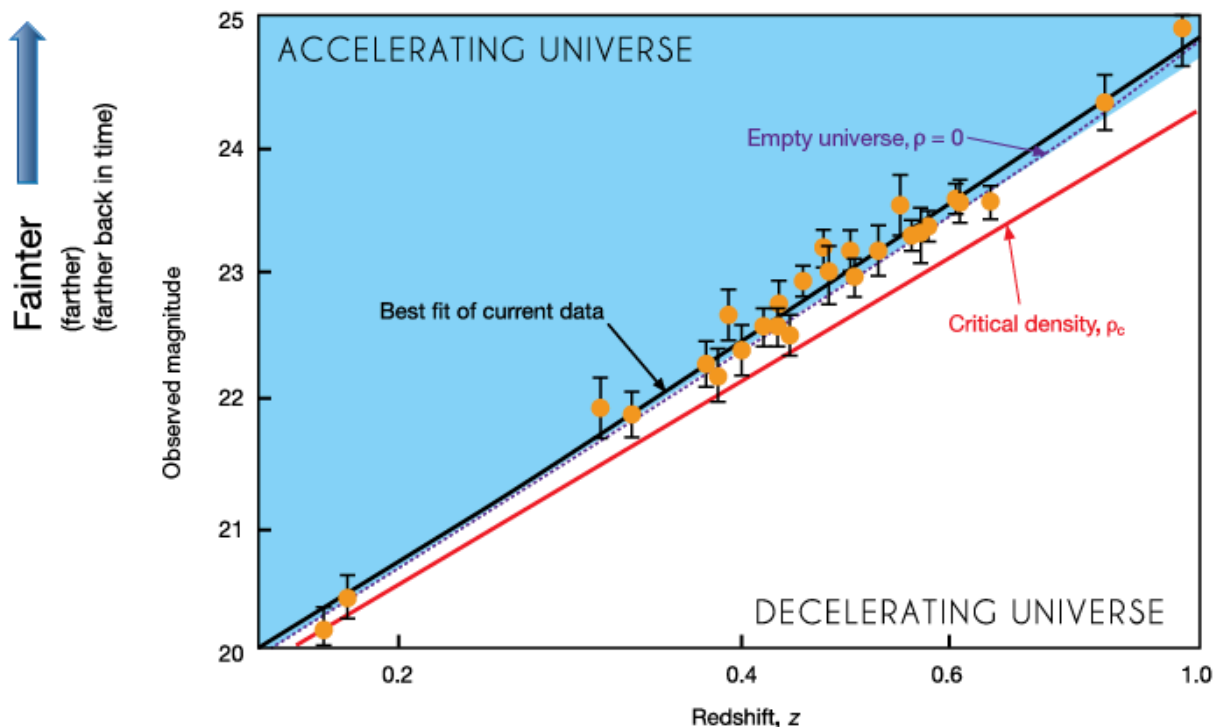


Figure 6 Cosmologists use a parameter called z to indicate redshift. The higher the value of z , the higher the redshift.

11. Predictions based on different models are shown in Figure 6. The bottom line describes a flat universe, which contains only mass and zero vacuum energy. The dotted line describes an empty universe, and the top line is the line of best fit. What kind of universe does the line of best fit describe?
12. Type 1a supernovas look dimmer than expected for a given redshift. This observation suggests an expanding universe in which the expansion is increasing over time, that is, accelerating. The dark energy model proposes that the universe has a vacuum energy that exerts a negative pressure, causing the universe to expand faster as it ages. What does this mean for the future of the universe?