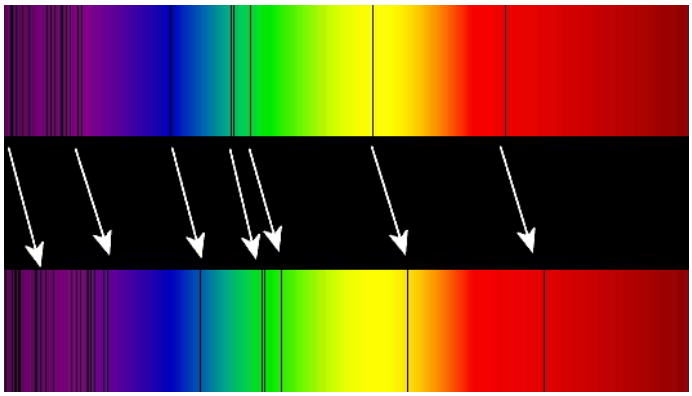
8.4 Red-shift

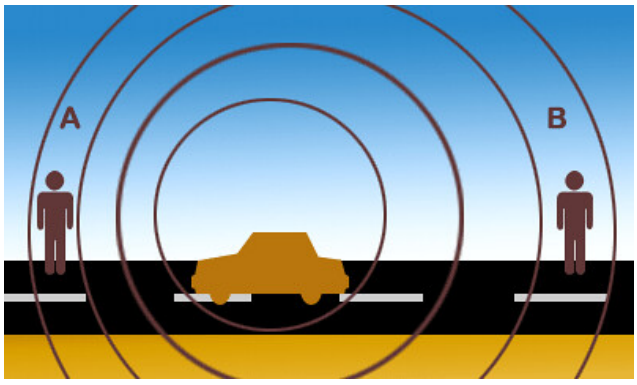
We can analyse visible light coming from luminous objects in space by passing it through a type of prism, which splits the light according to its wavelength. We obtain a spectrum. We find that the spectrum is not continuous, but contains dark lines where wavelengths of light seem to be missing. These wavelengths of light are 'missing' because they have been absorbed by elements in the outer layers of the stars emitting the light. Different elements absorb different wavelengths, so they are like a fingerprint of the elements which make up the star.



light from our Sun

light from distant star

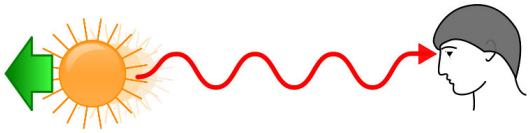
When light from our Sun is compared to light from stars in distant galaxies, we find the same dark lines, showing us that the stars are made of the same elements everywhere in the Universe. However, the dark lines are shifted to longer wavelengths. This is called "red-shift". The reason for this shift is that distant galaxies are moving away from us, and any light they emit gets stretched to longer wavelengths. This is similar to the Doppler Shift for sound waves.

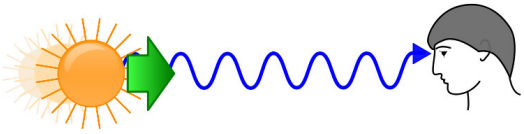


Consider the diagram left. Two people are listening to the sound produced by a car. The car is travelling from right to left. Person A hears a higher frequency (shorter wavelength sound) than person B because the waves produced by the car get compressed in front of the car and stretched out behind.

This same affect occurs for objects emitting light (e.g. stars). Stars which are moving away from us have their light stretched to longer wavelengths. Stars which are moving towards us have their light compressed to shorter wavelengths.

(1) Which has the longer wavelength, red or blue light?



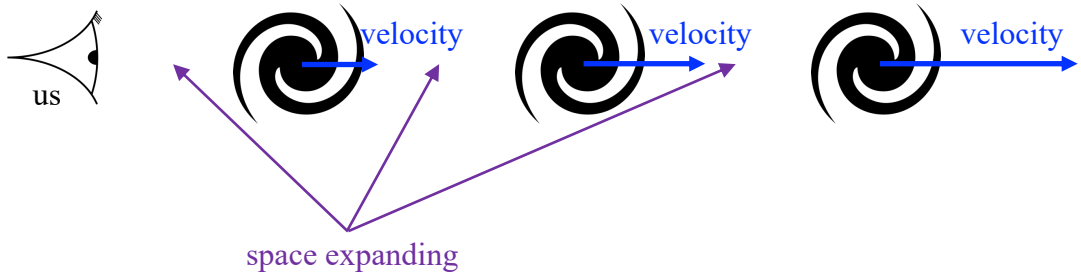


(2) It is found that light from distant galaxies is always red-shifted. What does this tell us about the motion of distant galaxies relative to us?

The amount that the light has been stretched to longer wavelengths (red-shift) depends on how fast the galaxy is moving. The faster it is moving away ('recessing'), the more the light is stretched and the greater the red-shift.

(3) It is found that the further a galaxy is away, the greater its light is red-shifted. What does this tell us about how the recession speed changes as distance increases?

Imagine that you are inside a giant scrunched-up sponge that is allowed to expand. You will observe the sponge moving away from you in all directions. In addition, parts of the sponge that are further from you will be moving away from you faster. This is what is observed for distant galaxies. The further a galaxy is away from us, the faster it is moving (recessing) away from us. This is because the space in between galaxies is expanding.



The red-shift data we have on distant galaxies is evidence for a universe that is expanding. One theory for an expanding universe is called the 'Big Bang' theory. This theory proposes that the universe began as a very hot, dense state around 13.7 billion year ago, and has been expanding ever since.

(4) How can we conclude, from the red-shift data, that the Universe was denser in the past?

Extra support for the Big Bang theory comes from Cosmic Microwave Background Radiation (CMBR). This is the remnant of high energy (short wavelength) electromagnetic radiation that existed shortly after the formation of the universe (according to the Big Bang theory). As space expanded, this electromagnetic radiation was stretched into the microwave part of the spectrum. This radiation was discovered by chance by American scientists in 1964.

(5) With an ever-expanding universe, what part of the electromagnetic spectrum will the CMBR ultimately be stretched into?