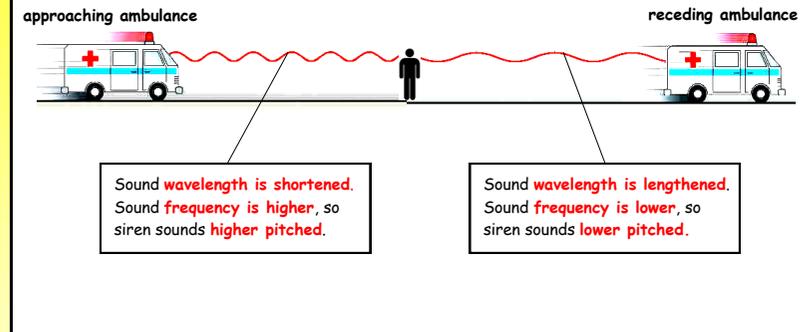


- If a wave source is moving relative to an observer there will be a change in the observed wavelength and frequency. This is known as the Doppler effect.
 - The wave source could be light, sound or microwaves.
 - When the source moves away from the observer, the observed wavelength increases and the frequency decreases.
 - When the source moves towards from the observer, the observed wavelength decreases and the frequency increases.
- There is an observed increase in the wavelength of light from most distant galaxies. The further away the galaxies are, the faster they are moving, and the bigger the observed increase in wavelength. This effect is called red-shift.
- How the observed red-shift provides evidence that the universe is expanding and supports the 'Big Bang' theory (that the universe began from a very small initial point).
- Cosmic microwave background radiation (CMBR) is a form of electromagnetic radiation filling the universe. It comes from radiation that was present shortly after the beginning of the universe.
- The 'Big Bang' theory is currently the only theory that can explain the existence of CMBR.



THE DOPPLER EFFECT

In this effect, the **wavelength or frequency** of a wave changes when there is **relative velocity** between the wave source and an observer.



An example of the **Doppler effect** in sound is illustrated in the diagram shown above. The sound of an ambulance siren changes as it goes past you.

It sounds **higher pitched** as the ambulance moves **towards** you and **lower pitched** as the ambulance moves **away from** you.

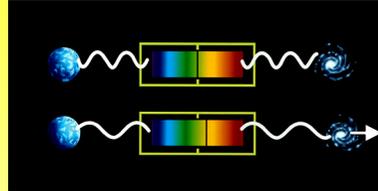
This is because as the ambulance **approaches**, the sound waves are squashed closer together, making the **wavelength shorter** and the **frequency higher**.

As the ambulance **recedes**, the sound waves are stretched out, making the **wavelength longer** and the **frequency lower**.

If the ambulance was stationary, the sound of the siren you would hear would have a constant frequency.

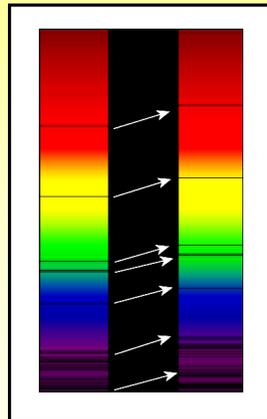
RED-SHIFT

- The Doppler effect also occurs with **light waves**. We can use a prism or a diffraction grating to split the light coming from stars in galaxies into a spectrum. As you already know, the wavelength of light **increases** across the spectrum from **blue** to **red**.
- Analysis of the spectra of light from stars in distant galaxies shows that the wavelengths are **longer** than expected (i.e. they are shifted towards the **red** end of the spectrum ... Hence the name, **red-shift**).



This happens because the star or galaxy is moving **away from** the Earth (i.e. **receding**), causing the light waves to be stretched out.

The **increase** in the **wavelength** means that spectral lines are shifted towards the **red** end of the spectrum.

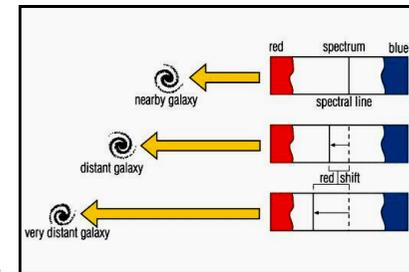


NOTE : The light from some stars and galaxies is shifted towards the **BLUE** end of the spectrum (i.e. **BLUE-SHIFT**). This is because they are moving **towards** the Earth.

The **further away** from Earth a star or galaxy is, the **faster** it is moving.

The **faster** a star or galaxy is moving, the **bigger** is the red-shift.

So the light from the **most distant** galaxies show the **biggest red-shift**.



THE UNIVERSE IS EXPANDING

In 1929, **Edwin Hubble** discovered that :

- The light from **distant** galaxies was **red-shifted**.
- The **further** a galaxy is from Earth, the **bigger its red-shift** is.



From this, he concluded that :

- The **distant** galaxies are moving **away from** the Earth (i.e. receding).
- The **more distant** the galaxy is, the **greater is its recession speed**.
- The whole universe is **expanding**.

THE 'BIG BANG' THEORY

This theory was put forward in order to explain the fact that the universe is expanding and it states that :

- The universe is expanding after exploding suddenly in a **Big Bang** from a very small initial point, some 13.5 billion years ago.
- Space, time and matter were created in the **Big Bang**.



An alternative idea for the creation of the universe, called the **steady state** theory, proposed that the movement of the galaxies was caused by matter entering the universe through 'white holes'.

This theory was favoured by most scientists until 1965, when the presence of **cosmic microwave background radiation** in the universe, swung the argument in favour of the **Big Bang** theory.

Scientists knew that the creation of the universe from a sudden Big Bang would have produced enormous amounts of **short wavelength (high energy) electromagnetic radiation (i.e. gamma rays)**.

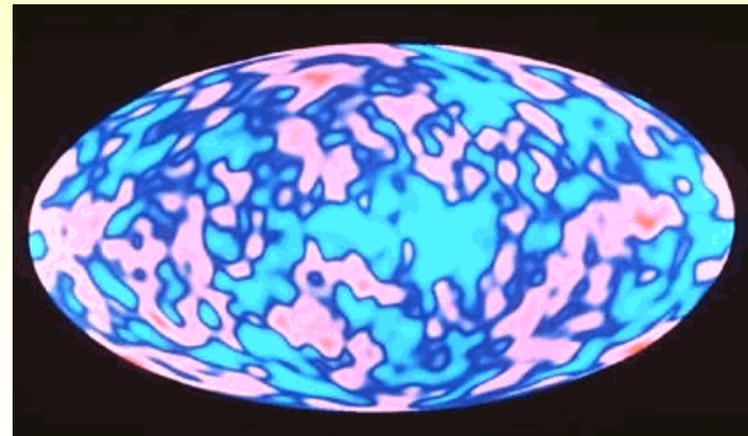
Then, as the universe expanded, the gamma radiation would have been 'stretched' to become **longer wavelength, microwave radiation**.

It was in 1965 that two scientists, **Penzias** and **Wilson**, detected microwaves coming from every direction in space and the existence of this cosmic microwave background radiation is only explicable in terms of the Big Bang theory.

COSMIC MICROWAVE BACKGROUND RADIATION (CMBR)

The basic facts about cosmic microwave background radiation are that :

- It was created as high-energy gamma radiation just after the Big Bang which produced our universe.
- It has been travelling through space since that time.
- As the universe expanded, it stretched out longer and longer wavelengths and it is now microwave radiation.
- It has been mapped out using microwave detectors on Earth as well as on orbiting satellites.



A microwave image of the universe from the Cosmic Background Explorer satellite.

UNIT 1	GCSE PHYSICS	1.5.4	Red-shift	81
<p>• PRACTICE QUESTIONS</p>				
1	<p>Complete the sentences below using the following words :</p> <p>receding orbiting approaching expanding</p> <p>(a) The Earth is The Sun.</p> <p>(b) The distant galaxies are</p> <p>(c) A blue-shift in the light from a star would indicate that it is the Earth.</p> <p>(d) The universe is</p>			<p>5 Complete the sentences below using the following words :</p> <p>stretched expanded created detected</p> <p>(a) The universe was in a massive explosion called the Big Bang.</p> <p>(b) The universe in and after the Big Bang.</p> <p>(c) Microwave radiation from space can be from all directions.</p> <p>(d) Radiation created just after the Big-Bang has become by the expansion of the universe and is now microwave radiation.</p>
2	<p>Evidence for the origin of the universe has been obtained by analysing light reaching us from bodies in the universe.</p> <p>(a) Name the bodies whose light has provided evidence for the origin of the universe.</p> <p>(b) What is the name given to the change in wavelength of the light coming from the bodies you have named in (a)?</p> <p>(c) What does the shift in wavelength which you have named in (b) tell us about the motion of distant galaxies?</p>			<p>6 In 1929, Edwin Hubble made two discoveries concerning the light coming from distant galaxies.</p> <p>(a) State the two things he discovered.</p> <p>(b) State the three conclusions which Hubble drew from his discoveries.</p>
3	<p>(a) What is the Doppler effect?</p> <p>(b) Explain why a person standing on the platform at a railway station hears a change in the pitch of a train's whistle as it goes past him.</p>			<p>7 Until 1965, the majority of scientists believed in the Steady State theory to explain the creation of the universe. Then, following a discovery made in 1965, the Big-Bang theory was favoured.</p> <p>(a) What is the Steady State theory?</p> <p>(b) What are the main ideas of the Big-Bang theory?</p> <p>(c) What was the momentous discovery which caused scientists to change their thinking?</p>
4	<p>Galaxy A is 1500 million light years away from Earth and galaxy B is 5000 million light years away.</p> <p>(a) Which galaxy will give the bigger red-shift when its light is studied?</p> <p>(b) Explain why the galaxy you have chosen gives the bigger red-shift.</p>			<p>8 (a) What is the position of microwave radiation in the electromagnetic spectrum?</p> <p>(b) What type of radiation was the cosmic microwave background radiation (CMBR) when it was created just after the Big-Bang?</p> <p>(c) Why did the type of radiation which was created just after the Big-Bang change into the CMBR which permeates the present universe?</p> <p>(d) What do you think will happen to the CMBR as the universe continues to expand in the future?</p>