

WJEC (Eduqas) Physics GCSE

10.2: Red Shift and Universe Expansion Detailed Notes

(Content in **bold** is for higher tier **only**)

This work by [PMT Education](https://www.pmt.education) is licensed under [CC BY-NC-ND 4.0](https://creativecommons.org/licenses/by-nc-nd/4.0/)



Emission & Absorption Spectra

Line spectra are produced to help **identify elements** present in stars. When substances are **very hot**, they **emit light**. This light can be viewed through a **diffraction grating** as a **continuous spectrum** where wavelength and frequency gradually change. Hot gases don't emit a whole spectrum, only **specific** frequencies or wavelengths of light which can help identify the composition of the gas.

Absorption Spectra

These show the specific frequencies **absorbed** by **cooler gases**, which are the same as those emitted when the gas is hot. The absorbed frequencies appear as **dark lines** on a continuous spectrum as they are **'taken in'** by the gas cloud from the light source.



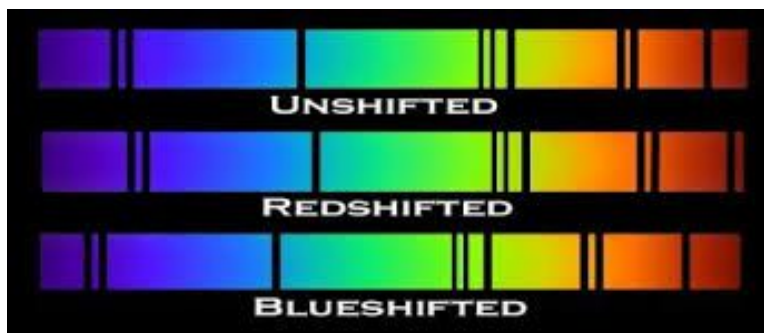
Absorption spectrum showing the absorbed frequencies as thin black lines (adapted from circlingsquares.blog).

Red Shift

If a light source is **moving**, the wavelength of the emission will be **compressed** or **extended** relative to an observer. If the source moves **towards** the observer, the waves will be **squashed** together so wavelength is **reduced**. If the source **moves away** from the observer, the waves will be **stretched** so wavelength is **increased**. This is called **Doppler-Red shift**.

With **light**, the **colour** of the light **varies** for a moving object as the wavelength of the emitted signal is **stretched or compressed**. It is commonly seen with stars as they **oscillate** or for far away planets as they **orbit**.

As the planet **moves away** from the observer, the light wavelength is **stretched** so the light changes to be closer to the **red** end of the spectrum. This is **red shift**. As the planet moves **towards** the observer, the light wavelength is **compressed** so the light changes to be closer to the **blue** end of the spectrum. This is **blue shift**. These shifts can be observed on the line emission or absorption **spectra**.



Shifted absorption spectra (coolcosmos.ipac.caltech.edu).



The Big Bang Theory

The Big Bang theory hypothesises that the Universe began around **13.8 billion years ago** from a **single, very small, hot and dense** region. It then **expanded outwards** from this one point, creating what exists today. The Big Bang theory also suggests the Universe is **still expanding** today. There are several pieces of **evidence** from **observations** of space that appear to support this theory.

Cosmological Red Shift

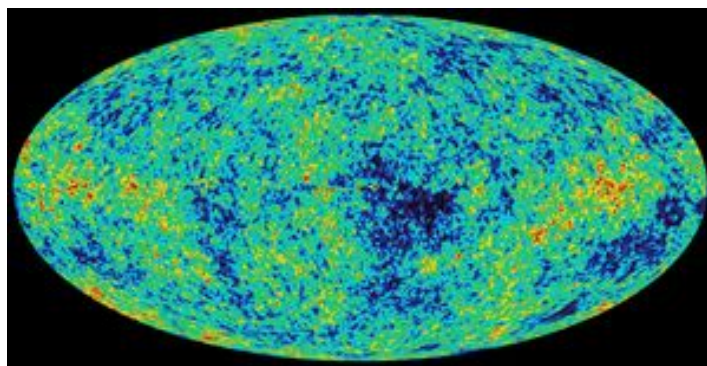
This phenomenon was first hypothesised and observed by **Edward Hubble** in the 20th century. Hubble observed the **absorption spectra** of many different galaxies and saw that they displayed the **same relative pattern** as that for our sun. However, the absorbed lines appeared to be **red shifted**.

This means these galaxies must be **moving away** from the Milky Way (our galaxy) and so Hubble concluded that this cosmological red shift was caused by an **increasing distance** between galaxies. It also provides evidence for an **expanding universe**.

Cosmic Microwave Background Radiation (CMBR)

In the 20th century, it was proposed that the universe came from a **single point** that **exploded** out in the Big Bang. The analysis of **red shifted signals** from far away galaxies by Hubble provided good evidence for this and also suggested the universe is **still expanding**.

If the universe began with an explosion, it would be expected that **radiation** from this explosion would **still exist** and be **detectable**. This radiation was detected for the first time in 1964 as **microwave radiation**, part of the CMBR.



The CMBR detected from Earth (keystagewiki.com).

The CMBR also provides good evidence for a **continually expanding universe**. Initially in the explosion, **high energy, short wavelength gamma radiation** would have been released. However, **lower energy, longer wavelength microwave radiation** is now detected. It is suggested that as the universe expands, the gamma waves have to **travel further** so have become **red shifted** (stretched) into microwaves detectable today.

