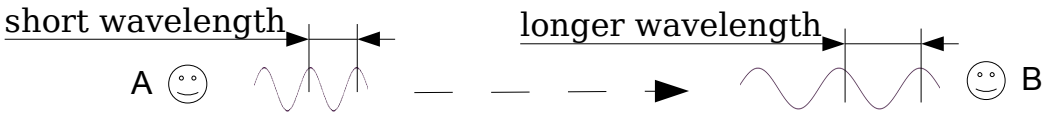
Redshift

Contents:

What is redshift?



A wave travels from emitter A to observer B. If the wave arrives at B with a longer wavelength than when it was emitted, then the relative change in the wavelength is called the

REDSHIFT

The opposite to redshift, when the wave arrives with a shorter wavelength, is called **blueshift**.

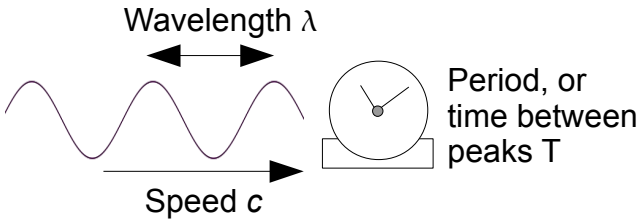
On Earth, the wave can be a sound or a light wave. In space, it's always light (sound does not travel without a medium to travel through, eg. air).

There are two main causes of redshift in astronomy: the Doppler effect, and expansion of the Universe

Redshift cause 1: Doppler Effect

When a wave is emitted by something that is moving through space away from you, or you are moving away from it, then it arrives redshifted due to the Doppler effect. For example, the sound of a racing car's engines drops to a lower pitch as it passes by (switches from moving towards you, blueshifted sound, to moving away from you, redshifted sound). To understand this, it helps to know something about the basic properties of waves.

Properties of waves



Speed *c*	300,000,000 m/s for light 340 m/s for sound in air
Wavelength λ (Greek lambda)	distance between peaks (unit: m)
Period T	time between peaks (unit: s)
Frequency f = 1/T	pitch for sound, or colour for light (unit: 1/s or Hertz)

The properties are related by the equations $c = f\lambda$ or $c = \lambda/T$

long wavelength = long period = low frequency = low pitch or redder light
short wavelength = short period = high frequency = high pitch or bluer light

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Redshift cause 1: Doppler Effect (continued...)

Redshift due to DOPPLER EFFECT: Peak 2 travels further and arrives late

Imagine that A sends a wave to B. If A is not moving, then B will measure the same time between peaks of the wave as A. If A moves away from B, then the later peaks have further to travel in order to reach B, and arrive late. B measures a longer time between peaks, or period, than A.

A longer time period is equivalent to a longer wavelength, so the wave is redshifted. This redshift is due to the fact that A is moving away from you, and it is called the

DOPPLER EFFECT

The Doppler effect is a prediction of Einstein's S*pecial Theory of Relativity*.

Redshift cause 2: Expansion of the Universe

Imagine that galaxy A emits a light wave which has a distance of 1 metre between peaks. It takes millions of years to reach galaxy B, during which time the universe has expanded, and the wave itself stretches with it. When it arrives at B, it has a longer wavelength than when it left A. This is

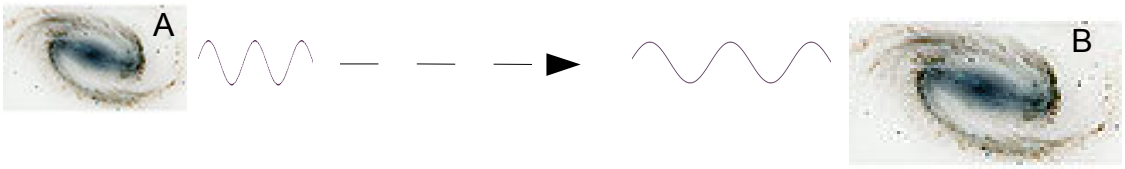
COSMOLOGICAL REDSHIFT

It is a prediction of Einstein's general theory of relativity.

Edwin Hubble (1929) found that almost all galaxies are redshifted. He combined his measurements of galaxy distances (measured using Cepheid variables) with Vesto Slipher's data on galaxy redshifts. What is more, he found that the greater the distance, the greater the redshift.

This result fitted in with Friedmann and Lemaitre's model of an expanding universe based on Einstein's theory of *General Relativity*, and was taken as the first evidence that the universe is expanding.

A long time ago in a galaxy far, far away



Us, now

Redshift due to EXPANSION OF UNIVERSE: wave is stretched as spacetime expands

The current rate of expansion of the universe is given by the **Hubble constant**
Ho = 73 km/s per megaparsec

"Space is big. You just won't believe how vastly, hugely, mind- bogglingly big it is. I mean, you may think it's a long way down the road to the chemist's, but that's just peanuts to space."

Douglas Adams, The Hitchhiker's Guide to the Galaxy

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