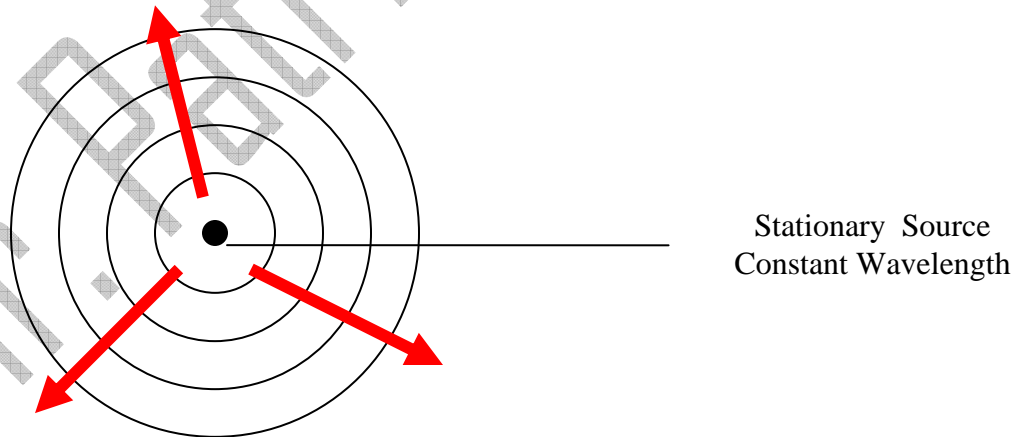
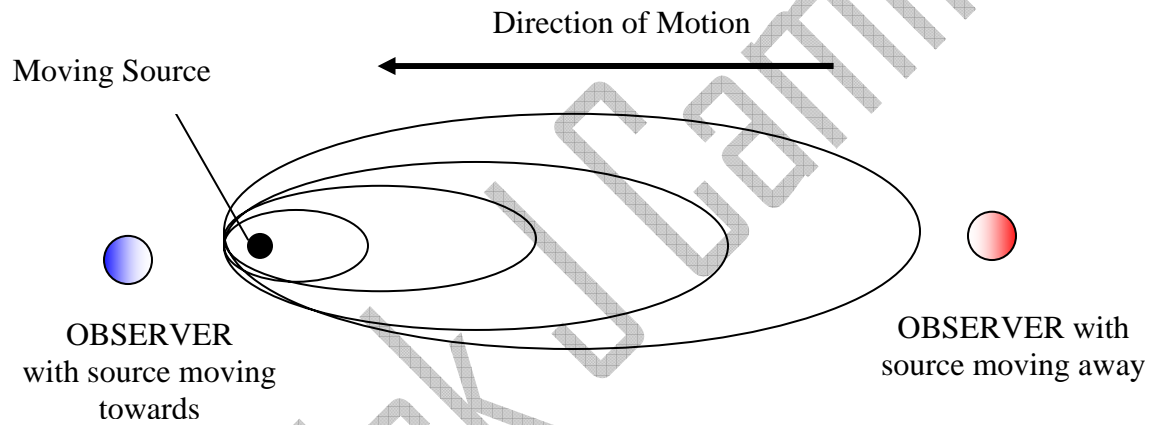


# The Expanding Universe

## The Doppler Effect

When a sound source is moving relative to the observer it is noted that there is a difference in the frequency when compared to the same source when it is at rest. This is observed as a change in pitch.



When the source is moving towards the reference point the wave is squashed or compressed causing an increase in the pitch. On the other hand if the source is receding there would be an increase in the wavelength manifested by a decrease in the pitch.

The Doppler Effect occurs not only with sound but also with light.

When the spectrum of light from a star is compared with those of the same elements in the lab it is observed that there is always a shift in the corresponding wave positions.

This has been proven to be invaluable in Astronomy.

With some stars the spectral lines are longer while with other stars the spectral lines are shorter. The shifts in these wavelengths are considered as being attributable to the Doppler shift.

- If the lines are at a **longer wavelength** that is **red shifted** then the star would be moving **AWAY** from the earth.
- If on the other hand the lines are of a **shorter wavelength** that is blue shifted then the star would be moving **TOWARDS** the earth.

The extent of the shift in the wavelength depends on the speed with which the star is moving relative to the earth. Measurements of the galactic red shifts reveal that the speed with which a galaxy is receding is proportional to the distance from us (HUBBLE'S LAW).

#### HUBBLE'S LAW

The recession velocity  $v$  of a distant galaxy is proportional to its distance  $d$ .

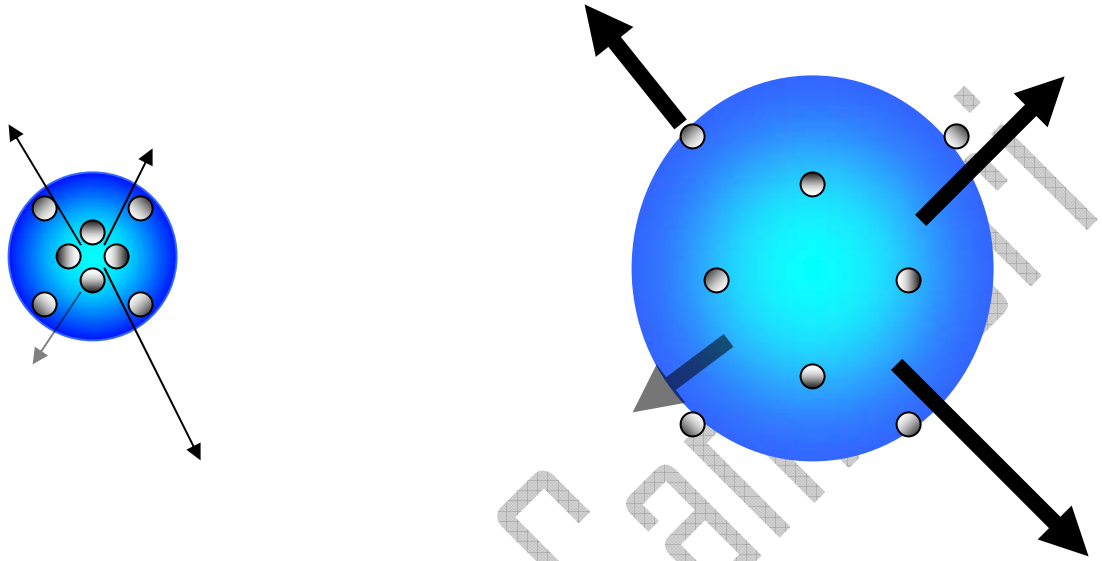
$$v \propto d$$

$$\text{Or } v = H_0 d$$

Where  $H_0$  is the Hubble constant.

$H_0$  is measured in  $\text{km s}^{-1} \text{Mpc}^{-1}$  or  $\text{s}^{-1}$  estimated between  $60\text{s}^{-1}$  &  $80\text{s}^{-1}$

Hubble's law provides the notion of an expanding universe, referred to as the **Hubble's expansion**.



If the rate of expansion is increasing, projecting the rate backwards would give rise to a time when space and time were created in the so-called big bang.

$$\text{If: } v = H_0 d \text{ so } t \approx d/v = 1/H_0$$

This time period is referred to as the **HUBBLE PERIOD** and is equivalent to 12 to 16 billion years.