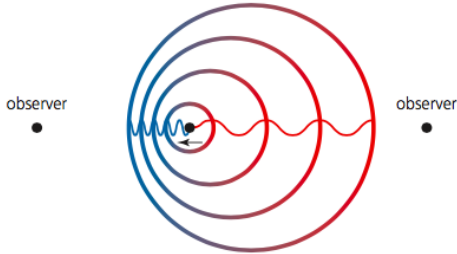


# The Doppler Effect

## *The Doppler Effect and Cosmology*

The study of the structure and development of the Universe as a whole is called **Cosmology**.



- Source moving towards observer
- Wavelength decreased; frequency increased
- Observer sees light blue-shifted
- Source moving away from observer
- Wavelength increased; frequency decreased
- Observer sees light red-shifted

**The Doppler effect** is a change in frequency, or wavelength of a wave for an observer moving relative to its source. The same phenomenon occurs with all other types of waves, including electromagnetic radiation.

Depending on the motion of the object with respect to the observer, the frequency – and hence colour in the case of light – is affected.

the colour of one that is moving away is shifted to the red (longer wavelength), as shown left.

The lines in a star's absorption spectrum are shifted when compared to the same lines as measured in a laboratory. This is due to the motion of the star relative to the Earth. The size of the wavelength shift,  $\Delta\lambda$ , depends on the relative velocity of the star and the observer. The relationship is given by the

**Doppler equation:**

$$z = \frac{\Delta\lambda}{\lambda} = \frac{\lambda_{app} - \lambda}{\lambda} = -\frac{v}{c}$$

The quantity  $\frac{\Delta\lambda}{\lambda}$  is termed the **Doppler shift** and is given the symbol  $z$ .

Here  $\lambda$  is the true wavelength of the absorption line,  $\lambda_{app}$  is the apparent wavelength of the observed absorption line on Earth,  $v$  is the relative velocity of the star and the Earth, and  $c$  is the velocity of light. The relative velocity  $v$  is taken to be the relative velocity of *approach*, so that  $v$  is positive when the two objects are approaching (blue shift) one another and negative if they are receding (red shift).

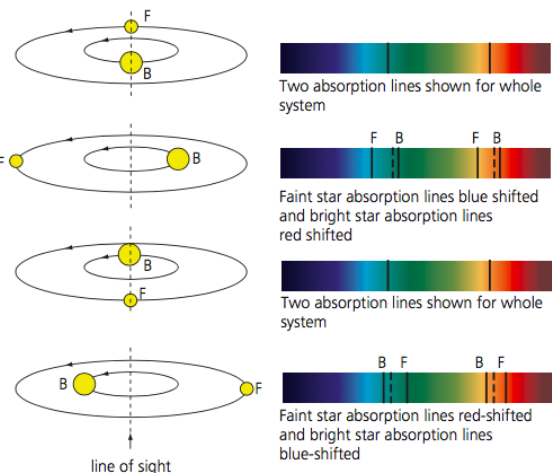
The Doppler equation can also be expressed in terms of the change in frequency:  $\frac{\Delta f}{f} = \frac{v}{c}$

## *Doppler Shift and the Motion of Binary Stars*

The Doppler effect can be used to determine the rotational velocity and the distance between two stars in a **binary star** system.

Here, **eclipsing binaries**, are revealed by the **Doppler shift** of lines in their spectrum. The absorption lines seen from Earth will be Doppler-shifted as the stars rotate about their centre of mass, moving between longer and

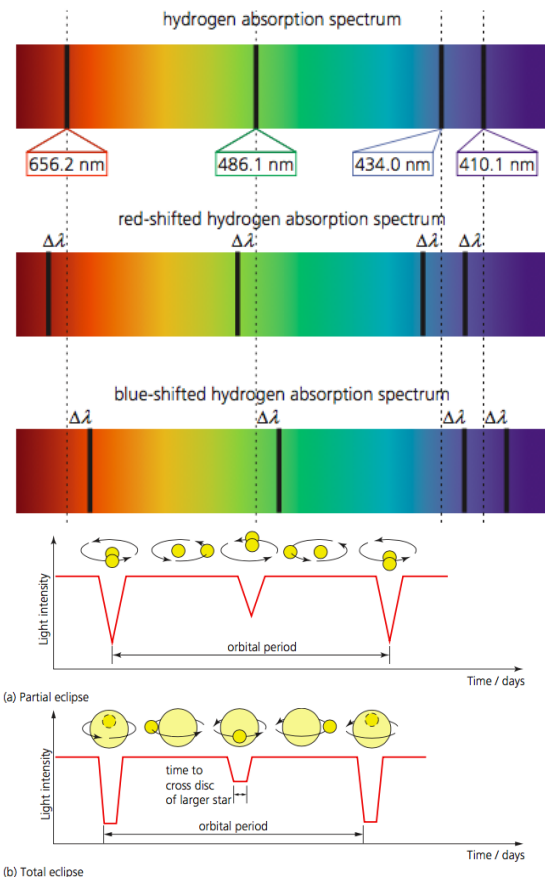
shorter wavelengths in a periodic motion.



There will be a blue-shift in the star's spectral lines when the star is moving towards the Earth, a red-shift in the spectral lines when the star is moving away from the Earth, and no spectral shift in the lines when the star is moving perpendicularly to the line of sight.

Analysis of the spectral motion reveals a cyclic movement of a particular absorption line, shifted one way and then the next with a constant period

It is possible to calculate the linear velocity along the line of sight and the



period, hence the distance between the two stars using the mechanics of circular motion.