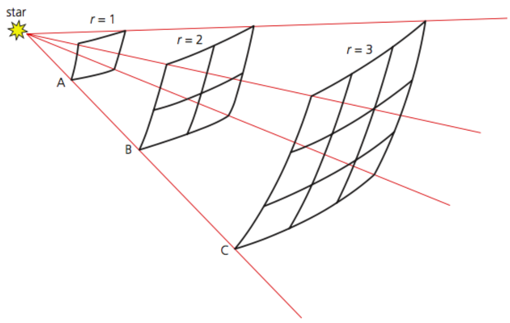
Luminosity, intensity and distance measurement

Use the equation for the intensity of a star, I
Determine astronomical distances using parallax
Measure astronomical distances using standard candles



Stellar Luminosity

As it spreads out from distant objects, light obeys an inverse square law. The **luminosity** *L* of a star is the amount of energy in Joules it actually radiates per second (that is, its power) and is measured in watts, W.
The intensity of the radiation is defined as the **intensity**, *I*, of a star:

$$I = \frac{L}{4\pi r^2}$$

The unit of brightness is Wm−2.

The intensity of the radiation is a measure of the radiation that arrives at a particular distance

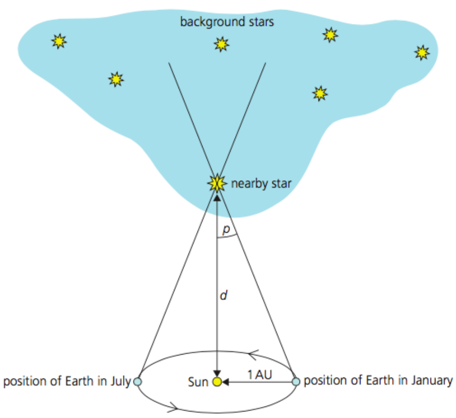
Example: The luminosity of Betelgeuse is 5.4 x10^{30}W. Its radiant energy intensity at the Earth is 1.1x10^{-8}Wm^{-2}. How far away is Betelgeuse? Find r using the equation above.

$r^2 = L / 4\pi I \quad = 5.4 \times 10^{30} / 4\pi\ (1.1\times10^{-8})$

r = 6.2 x 10^{18}m

Astronomical Distances

The mean distance from the Earth to the Sun is called the **astronomical unit** (**AU**) and 1 AU is equal to 1.50 × 10^{11} m.
For interstellar distances, astronomers use a unit called the **parsec**.
The effect of parallax can be used to measure how far stars are from Earth. The parallax angle of a star is **half the angle that a star moves in six months**, against a background of very distant stars. P**arallax angle p** (measured in



radians) is related to the **distance d** of the star by: $d = \frac{1AU}{\tan p} = \frac{\mathbf{1AU}}{\boldsymbol{P}}$ using the fact that, for small angles, tan $p = p$. One radian = 57° 17′ 45″ radians to arcsecond (″): 1 rad = (57 × 3600)″ + (17 × 60)″ + 45 = 206 265″

So: $d = \frac{206265}{p(arcsecond)}$ (1 parsec (1 pc) = 206 265 AU) so: $\boldsymbol{d = \frac{1}{p}}$

1 parsec is the distance at which the observed parallax angle of the star is equal to 1 arcsecond (1 second of arc).
1 kiloparsec (1 kpc) = 10^3 pc
1 megaparsec (1 Mpc) = 10^6 pc

$$\tan a \approx a = \frac{1\text{ AU}}{d}$$

$$\Leftrightarrow d = \frac{1\text{ AU}}{a} = \frac{1.5\times10^{11}\text{ m}}{\frac{1}{3600}^{\circ}\left(\frac{\pi}{180^{\circ}}\right)} = 3.1\times10^{16}\text{ m}$$

One **light year (ly)** is the distance that a photon of light travels through space in one year (3 × 10^8 m s^{-1}).
1 light minute = 3.00 × 10^8 m s^{-1} × 60 s =1.80 × 10^{10} m

1 light second = 3.00 × 10^8 m s^{-1} × 1 s = 3.00 × 10^8 m
Also: 1 pc = 3.26 ly

Standard Candles

Some stars known as variable stars have properties which mean their luminosity can be determined quite separately from other measurements, These are known as standard candles. If we have a value for luminosity and measure the intensity (brightness) of a star reaching the Earth, we can then calculate how far away it is by comparing it with a standard candle with the same luminosity.