University of Glasgow
Dept of Physics and Astronomy

Measuring Astronomical Distances: Parallax

Trigonometric Parallax

We have seen that the **flux** F and **luminosity** L of a star (or any other light source) are related via the equation:

$$L = 4\pi D^2 F \qquad (1)$$

Hence, to determine the luminosity of a star from its flux, we also need to know its distance, D.

At least for the nearest stars, we can measure their distance accurately using trigonometry. Figure 1 shows the effect of **trigonometric parallax**: when we look at an object along different lines of sight its position against the background shifts. (Try this out for yourself by looking at some nearby object and covering first your left and then right eye – note how its position shifts against the distant background)

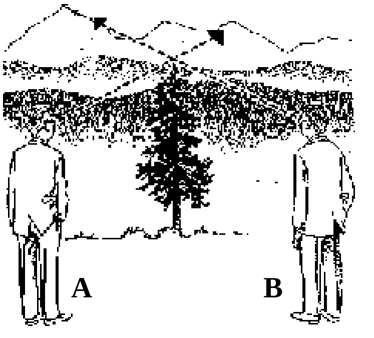
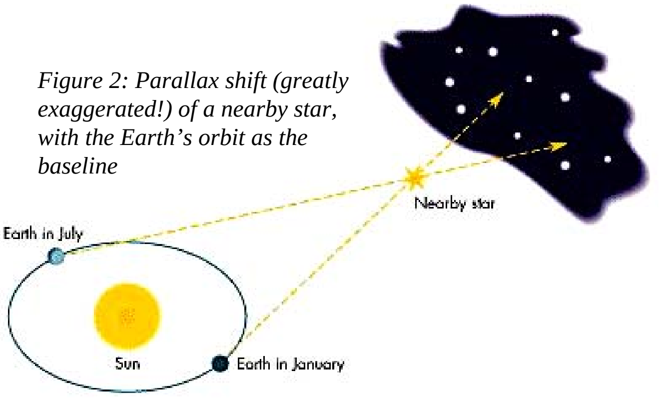


Figure 1: The effect of parallax. A *and* B *line up the tree with different mountains because they are seeing it along different lines of sight*

We can see this **parallax shift** when we compare the positions on the sky of a nearby star observed six months apart. As the Earth orbits the Sun, its line of sight towards the star changes, which makes the star's position shift against the (more distant) background stars (see Figure 2). Because the stars are so far away, this shift is tiny – even the nearest star, Proxima Centauri, shifts by about 1/2000th the width of the Full Moon! However, with very careful observations, the angular shift can be measured.

Figure 2: Parallax shift (greatly exaggerated!) of a nearby star, with the Earth's orbit as the baseline



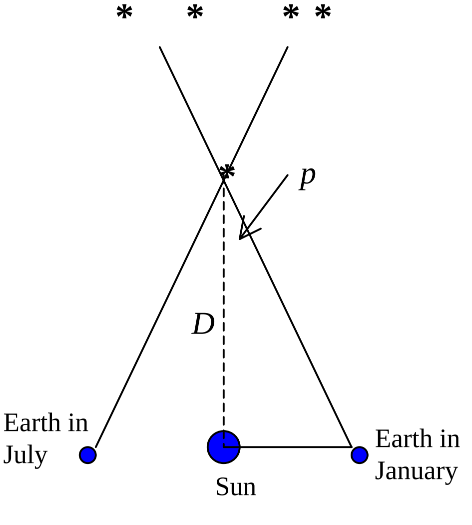


Figure 3: Parallax angle, p, of a nearby star, distance D from the Solar System

We can use similar triangles to deduce the distance of a star from its parallax shift. Figure 3 shows the **parallax angle** p (defined as one half of the shift in angular position six months apart), in the right angled triangle with base equal to the Earth-Sun distance and height equal to the distance, D, of the star. If D is measured in Astronomical Units (see A1X), then

$$D = \frac{1}{\tan p} \cong \frac{1}{p} \ \text{A.U.} \qquad (2)$$

where we have used the **small angle approximation** for the angle p, which is valid if p is measured in **radians**. Converting p into **seconds of arc**, using:

$$1 \text{ radian } = \frac{180}{\pi} \text{ degrees}$$

$$= \frac{180}{\pi} \times 3600 \text{ arc seconds}$$

gives the equation:

$$D = \frac{206265}{p''} \ \text{A.U.} \qquad (3)$$

This leads us to define a new unit of distance: the **parsec** (usually abbreviated as pc). **A star at a distance of one parsec shows a parallax angle of one second of arc**

From Equation (3), it follows that:

$$\begin{aligned} 1 \text{ pc} &= 206265 \text{ A.U.} \\ &= 3.086 \times 10^{16} \text{ m} \qquad (4) \\ &= 3.262 \text{ light years} \end{aligned}$$