STELLAR PARALLAX AND THE PARSEC

Link to: physicspages home page.

To leave a comment or report an error, please use the auxiliary blog.

Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 3, Problem 3.5.

Although parallax measurements using the Earth's diameter are suitable for determining distances to the planets, the parallax angles for anything outside the solar system are far too small to be useful. The largest baseline that Earth-bound observers can use is the diameter of Earth's orbit, and this is indeed used for measuring the parallax of stars.

An object with a parallax angle p of 1 arc-second has a distance in AU of

$$d = \frac{1}{p}\text{ AU} \tag{1}$$

where p is expressed in radians. (Remember that p is actually *half* the difference in angular position of the object as measured between the two ends of the base line) 1 arc-second is $\pi/(60 \times 60 \times 180)$ so with p given in arc-seconds

$$d = \frac{206264.8}{p}\text{ AU} \tag{2}$$

If $p = 1''$ the object is 206264.8 AU away, and this distance is defined to be 1 *parsec* (*par*allax-*sec*ond). One parsec is 3.2615638 light years. With p in arc-seconds and d in parsecs, the formula becomes

$$d = \frac{1}{p}\text{ parsecs} \tag{3}$$

To get an idea of how small parallax angles are, the closest known object outside the solar system is the red dwarf star Proxima Centauri, which is 4.24 light years, or 1.3 parsecs away. Proxima Centauri's parallax is therefore $1/1.3 = 0.769''$. Given that the resolution of most amateur telescopes is several arc-seconds, parallax measurements are not possible from your backyard!

As with everything else in astronomy, better results are obtained if we can make observations from above Earth's atmosphere. Between 1989 and

1993, the European Space Agency (ESA) ran a spacecraft called Hipparcos, which measured the parallax of over 118,000 stars with a precision of around 0.001” (one milli-arc-second). To get an idea of how small an angle this is, suppose we observe a coin such as the Canadian or American dime (10-cent piece) or the British 5 pence piece, all of which are around 1.9 cm in diameter. To subtend an angle of 0.001”, the coin must be at a distance of

$$d=\frac{0.019\text{ m}}{0.001\times\left[\pi/\left(60\times60\times180\right)\right]}=3.92\times10^{6}\text{ m} \tag{4}$$

This is about 60% of Earth’s radius, or 1% of the distance to the moon.

NASA had planned a mission called the Space Interferometry Mission (SIM) which would have been able to measure parallaxes down to $4\times10^{-6}\,''$ but unfortunately, SIM was cancelled in 2010 so the mission was never launched. To get an idea of how small this angle is, the test coin would now be at a distance of

$$d=\frac{.001}{4\times10^{-6}}\left(3.92\times10^{6}\text{ m}\right)=9.8\times10^{8}\text{ m} \tag{5}$$

which is about 2.5 times the distance to the moon.

An even more extreme example is as follows. Suppose grass grows at 5 cm per week. This amounts to a growth rate of

$$g=\frac{0.05}{7\times24\times60\times60}=8.27\times10^{-8}\text{ m s}^{-1} \tag{6}$$

In order for this growth rate to subtend an angle of $4\times10^{-6}\,''$, we need to observe the grass from a distance

$$d=\frac{8.27\times10^{-8}\text{ m}}{\left(4\times10^{-6}\right)\times\left[\pi/\left(60\times60\times180\right)\right]}=4263\text{ m} \tag{7}$$

That is, SIM could have detected grass growing on a 1-second timescale from a distance of more than 4 km!

PINGBACKS

Pingback: Shaula (Lambda Scorpii)
Pingback: Barnard’s star: distance and velocity
Pingback: Optical interferometry: the SIM PlanetQuest project
Pingback: Binary stars: determining masses and the mass function
Pingback: Sirius binary star system