ECLIPSING BINARY STARS

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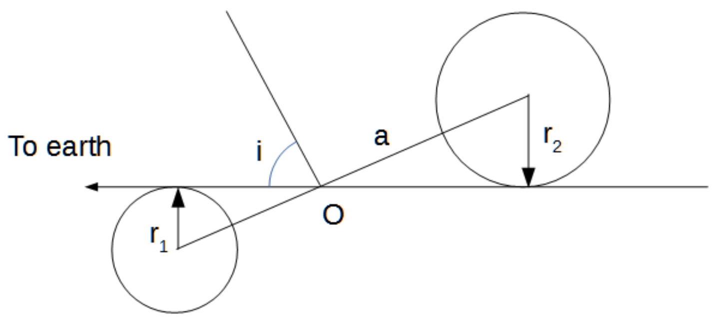
Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 7, Problem 7.3.

In attempting to determine the masses of the two stars in a binary system, one of the main problems is that we don't know the angle of inclination i between the orbital plane of the stars and the plane of the sky. A special case where a constraint can be put on this angle is when i is close enough to 90°that the stars either partially or totally eclipse each other.

We can find the smallest angle at which the two stars just eclipse each other. The diagram shows the situation:



The stars have radii r_1 and r_2 and their centres are separated by a distance a, with the plane of the orbit at angle i. Suppose the distance from O to the centre of star 1 is $\frac{a}{2}-\alpha$, so that the distance from O to the centre of star 2 is $\frac{a}{2}+\alpha$. Then because the two triangles are similar

$$\frac{r_1}{\frac{a}{2}-\alpha}=\frac{r_2}{\frac{a}{2}+\alpha}=\sin\left(\frac{\pi}{2}-i\right)=\cos i \tag{0.1}$$

Solving the first equation for α we get

$$\alpha=\frac{a(r_2-r_1)}{2(r_1+r_2)} \tag{0.2}$$

Therefore the minimum inclination angle is given by

$$\cos i = \frac{r_2(r_1+r_2)}{\frac{a}{2}(r_1+r_2)+\frac{a}{2}(r_2-r_1)} \tag{0.3}$$

$$= \frac{r_1+r_2}{a} \tag{0.4}$$

[Actually, I suppose this result is a bit more obvious than this derivation shows, since if we move r_1 over so that it's in line with r_2, we get a right triangle with the side opposite the angle $\frac{\pi}{2}-i$ of length r_1+r_2 and hypotenuse a.]

Example. Suppose the two stars have $r_1 = 10R_S$, $r_2 = R_S$ (R_S is the radius of the Sun) and $a = 2$ AU. Then the minimum angle at which an eclipse occurs is

$$\cos i = \frac{11R_S}{2\text{ AU}} \tag{0.5}$$

$$= \frac{11\times 696300\text{ km}}{2\times 149597871\text{ km}} \tag{0.6}$$

$$= 0.0256 \tag{0.7}$$

$$i = 88.53^\circ \tag{0.8}$$

If this system is an eclipsing binary, we know i to within 1.5° so an accurate mass determination should be possible.

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