

ECLIPSING BINARY STARS

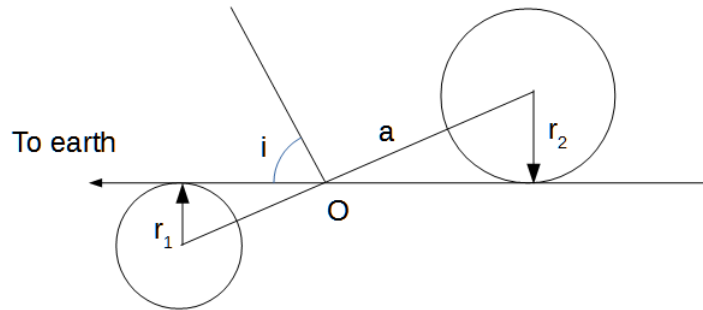
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Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 7, Problem 7.3.

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

$$\frac{r_1}{\frac{a}{2} - \alpha} = \frac{r_2}{\frac{a}{2} + \alpha} = \sin\left(\frac{\pi}{2} - i\right) = \cos i \quad (1)$$

Solving the first equation for α we get

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

Therefore the minimum inclination angle is given by

$$\cos i = \frac{r_2(r_1 + r_2)}{\frac{a}{2}(r_1 + r_2) + \frac{a}{2}(r_2 - r_1)} \quad (3)$$

$$= \frac{r_1 + r_2}{a} \quad (4)$$

[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

$$\cos i = \frac{11R_S}{2 \text{ AU}} \quad (5)$$

$$= \frac{11 \times 696300 \text{ km}}{2 \times 149597871 \text{ km}} \quad (6)$$

$$= 0.0256 \quad (7)$$

$$i = 88.53^\circ \quad (8)$$

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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