

## ECLIPSING BINARY STARS

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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  $90^\circ$  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. Fig. 1 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  $\alpha$  we get

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

Therefore the minimum inclination angle is given by

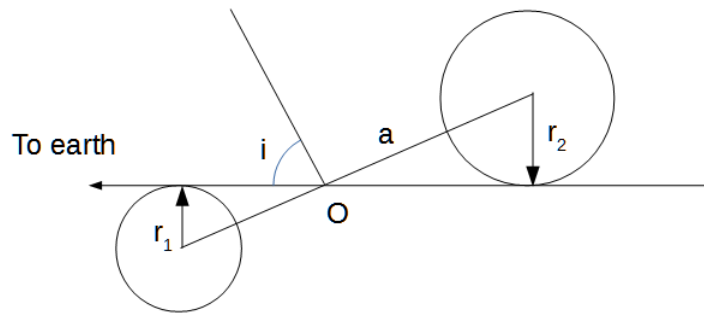


FIGURE 1. Eclipsing binary stars.

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

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

[We can also see this a bit more directly. 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  $r_1 = 10R_\odot$ ,  $r_2 = R_\odot$  ( $R_\odot$  is the radius of the Sun) and  $a = 2$  AU. Then the minimum angle at which an eclipse occurs is

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

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

$$= 0.0256 \quad (7)$$

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

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

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