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IS EPSILON AURIGAE A SEMI-DETACHED SYSTEM WITH AN ACCRETION DISK?

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The strange binary system ϵ Aur has been of interest to astronomers ever since its discovery by Fritsch in 1851. The basic facts concerning it are well known and are as follows (for further details see Handbury and Williams[1]). The system has a very long period of 9886 days (about 27·1 years), during which interval only one light reduction is observed. The maximum reduction is at a very constant level $0^{m}\!\cdot\!82$ below the normal value of $2^{m}\!\cdot\!96$ (which corresponds to light loss of 53 per cent) and lasts for 330 days, while the duration of the whole eclipse is 714 days. The visible primary component shows the spectral characteristics of an F2 star with an effective temperature of 7400 °K while the secondary, which causes this obscuration, has never been detected even though extensive searches have been carried out for it. From the observations, all astronomers (*e.g.* Morris[2]) agree that

$$M_2^3\,(M_1+M_2)^{-2} = 3{\cdot}12\;M_\odot \qquad (1)$$

is a good approximation to the mass function, where M_1 and M_2 represent the masses of the primary and secondary components respectively.

Not unnaturally, many models have been proposed to explain this phenomenon. It has been suggested by Paczynski[3] that ϵ Aur could be a system in which the primary fills its inner Roche surface so that mass exchange occurs, resulting in the formation of an accretion disk surrounding and obscuring the secondary star. He proposes that it is the passage of this disk (seen almost edge-on) across the face of the primary which causes the observed eclipse. Both the geometry of the eclipse and the geometry of the Roche surfaces place restrictions on the configuration of the system which must simultaneously be satisfied. It is our intention to suggest that this is not the case and that in consequence all models of this type are inadmissible.

Many investigations have been carried out into the geometry of the Roche surfaces; Kopal[4] gives a good summary of the position. Let the x-axis be along the line of centres of the two stars, the y-axis parallel to the rotation axis and the z-axis forming a right-handed set. It is then conventional to label the points where the various maxima in the x, y and z directions occur on the Roche surfaces $P_1, P_2, \ldots, P_7$. The two that are of immediate interest to us are P_6 and P_7, the maximum values of the limiting surfaces in the z direction.

Since the primary is assumed to fill its Roche lobe, its line-of-sight cross-section changes with time. However, the only important epoch is during an eclipse, when the relevant linear dimension of this cross-section is $2z_6$. If T is the duration of the whole eclipse and t the duration of the maximum-

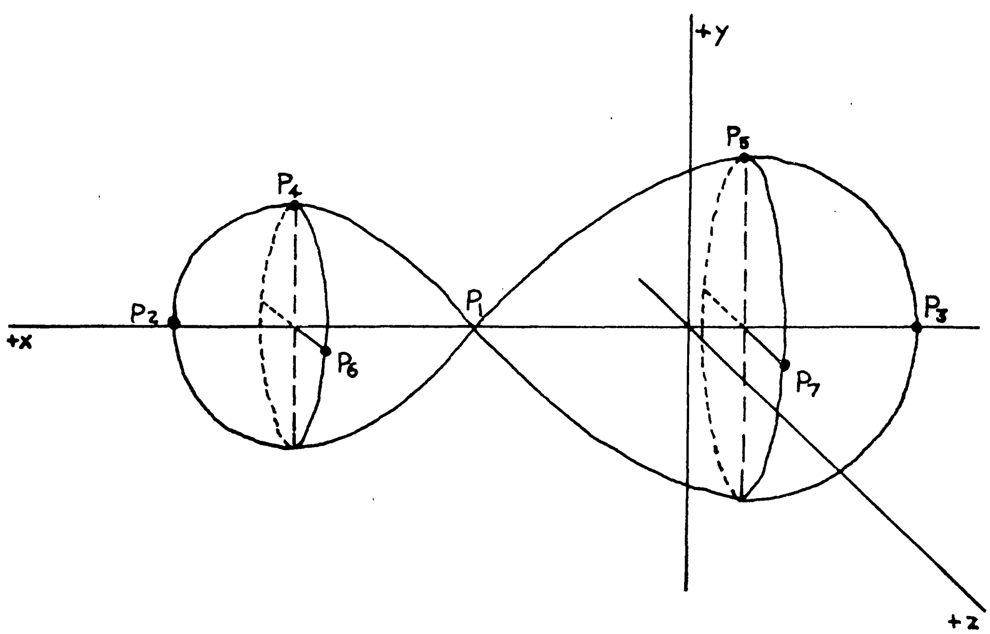

FIG. 1

Side view of Roche Limiting Surface. The small lobe represents the boundary of the observed primary star while the larger one depicts the hypothetical surface containing, and much greater than, the secondary component.

obscuration phase, then the duration of the partial obscuration before the maximum is reached is $(T-t)/2$. This period corresponds to the time taken by the leading edge of the obscuring disk to travel across the face of the primary, so that

$$2z_6/V = (T-t)/2 \, , \tag{2}$$

where V is the relative velocity of the two components during an eclipse. If D is the projected length of the disk during eclipse then

$$D - 2z_6 = tV \tag{3}$$

which on eliminating V using equation (2) gives

$$D/2z_6 = (T+t)/(T-t) \, . \tag{4}$$

(Note that provided the disk covers the equator of the primary, which it must to obtain the correct light loss, these equations are independent of the relative positions of the centre of the disk and the primary equator.)

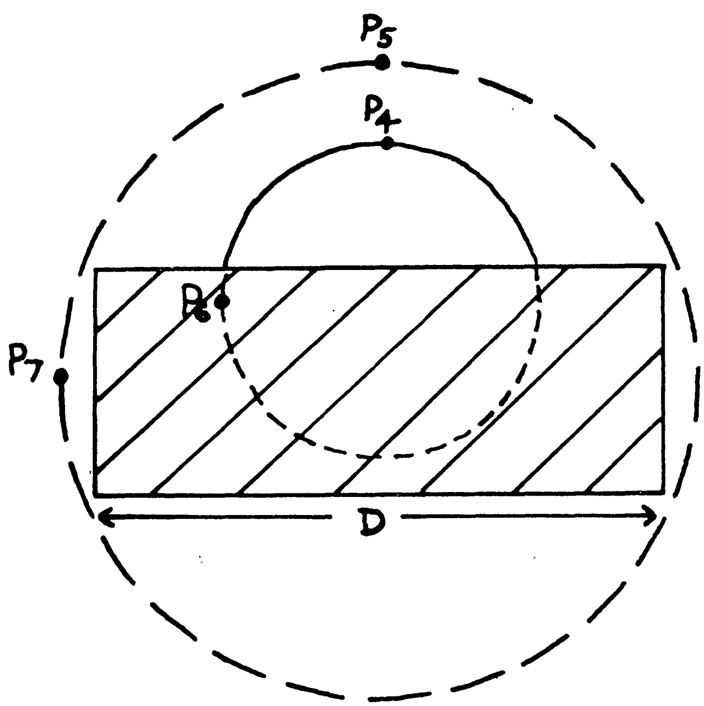

FIG. 2

Relevant configuration during an eclipse. The curve through the points P_5 and P_7 is the theoretical limit of the secondary component. The shaded region represents the accretion disk which surrounds and obscures the secondary star. The curve through P_4 and P_6 is the boundary of the visible primary, the dotted line indicating the region obscured by the accretion disk.

There is the obvious requirement in the model that the disk must fit into the Roche surface of the secondary at all times and in particular at eclipse time. This is equivalent to

$$D \leqslant 2z_7 . \tag{5}$$

Substitution of this inequality into equation (4) yields the condition

$$z_7/z_6 > (T+t)/(T-t) \, . \qquad (6)$$

Since we know that $T = 714$ days and $t = 330$ days this becomes

$$z_7/z_6 > 2{\cdot}72. \qquad (7)$$

Now from investigations of the Roche surfaces (*e.g.* reference (4)) the ratio z_7/z_6 can be deduced in terms of the mass ratio M_1/M_2. From such standard works it follows that inequality (7) is equivalent to

$$M_1/M_2 < 0{\cdot}11 \, . \qquad (8)$$

Combining this with the accepted value for the mass function given in equation (1) yields

$$M_2 \leqslant 3{\cdot}8 \, M_\odot$$

which in consequence implies that

$$M_1 < 0{\cdot}42 \, M_\odot \, .$$

Hence, if ϵ Aur does consist of a primary filling its Roche lobe and a secondary surrounded by an accretion disk, then the mass of the primary must be less than $\frac{1}{2} M_\odot$. It should be noted that this conclusion is independent of most orbit parameters and depends only on the acceptance of the mass function expression. In conclusion we suggest that it is unlikely that a star of spectral type F2 and effective temperature 7400 °K could have a mass as low as this, so that the model is incorrect and some other solution must be found to the puzzle posed by ϵ Aur.

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INFRARED PHOTOMETRY OF CV SERPENTIS WITH A NOTE ON CRL 2120

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Near infrared observations of CV Ser suggest that the infrared "excesses" at 2·2 and 3·8 μm are eclipsed around secondary minimum and that they originate within the system. The identification of CRL 2120 with CV Ser is not supported.

Introduction. CV Serpentis (HD 168206) is a Wolf-Rayet binary[1] system (WC8+B0:) having a separation and orbital inclination such that, while showing eclipses in the λ 4653 Å emission feature[2], it generally does not do so in the continuum[3]. Primary minima occur when the extended envelope, responsible for the line emission, surrounding the WC component is in front