Acknowledgements

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Discussion to the paper of HUTCHINGS, WALKER and AUMAN

WALKER: Since information tends to become lost these days in the literature, it may be well to remind ourselves that a very good example of a Be star in which material is ejected at irregular intervals, rotates with the star, and than dissipates is HD 217050, whose variations I discussed photoelectrically in 1951. I have always been a little surprised that no one now continued to observe this star, since it provides an excellent object in which to study the mechanism of ejection of material from the equatorial zones of a star rotating close to the limit of stability.

HUTCHINGS: Thank you.

H. J. WOOD: With the Doppler rotational separation of individual blobs as shown in the profiles you may be able to study these variations for periodicities. Have you done any power spectrum analysis of these observations yet?

HUTCHINGS: No, we intend to do this when we have longer trains of observations.

SAHADE: Your third star was 48 Lib, isn't this true? ADELA RINGUELET found several years ago that 48 Lib is probably a spectroscopic binary with a period of a few hours. This was found by measuring the position of the edges of the H_δ absorption. Perhaps one should take into account this fact in interpreting whatever you find in the behaviour of the envelope.

HUTCHINGS: I would suspect periodicities of hours in these stars to be either a pulsation or a rotational phenomenon of the stars themselves, since any companion with this period would be in contact with if not inside the B star itself.

Models for Contact Binaries

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The well-known problem one has in constructing zero age contact binaries stems from the fact that given two mass values, the ratio of the radii for zero age stellar models differs from that derived from the Roche model (KUIPER 1941). Therefore one cannot achieve contact by adjusting just the distance of the two stars, since if for instance the distance would be such that the critical equipotential surface is of the right volume for the primary to fill it completely, then the secondary would be smaller than its critical equipotential surface and one would end up with a semidetached system. LUCY (1968) has shown that this argument does not hold if both stars are surrounded by a common convective envelope, since then an energy exchange is possible in the convective zone which will increase the stars radius if it receives additional energy which has to be radiated away and will decrease the radius if some of the energy is lost to the companion. It follows that in transferrring energy from the primary to the secondary we can change the ratio of the radii in the right sense. Given the masses of the two components the geometry of the Roche equipotential surface, which contains the inner Lagrangian point will determine the distance of the two components and the energy exchanged between them. But there is another boundary condition to fulfill, that is in order to avoid too large energy fluxes in the common convective envelope the adiabatic constants of the two single stars put together have to be almost equal. LUCY computed models assuming exact equality of the two adiabatic constants, which means that one can get solutions for certain mass ratios only. Since we did not know in advance the accuracy down to which the two adiabatic constants had to be equal, in our model computations we allowed for any difference in these constants our stellar models would come up with. To prove whether this is justified or not, let us try to estimate the amount of energy flux which would occur in our models. We will demonstrate this with some numbers taken from a model of 1.4 $M_\odot$ and 0.7 $M_\odot$. The temperature difference is of the order 10^4 °K, so by exchanging two mass elements at constant pressure there will be an energy exchange of $2c_P \Delta T \approx 5 \cdot 10^{12}$ erg/g. The mass flow in the convective currents (no net flow) will be $A = \varrho\ l^2 v$, where for v we take the velocity of sound $v_s = \sqrt{5/3\ P/\varrho}$ and $l = d/100$, d being the distance of the two stars, so $A = 10^{-4}\ d^2\ \sqrt{5/3\ P\varrho}$. With $P = 3 \cdot 10^7$, $\varrho = 5 \cdot 10^{-6}$, and $d = 2 \cdot 10^{11}$ we get $A = 6 \cdot 10^{19}$ g/sec for a point in the convective zone, where the temperature gradient is nearly adiabatic. This value will change by several orders of magnitude if the points down to which luminosity is exchanged are assumed to be deeper in the convective zone or closer to the surface. The energy lost by the primary and gained by the secondary is therefore $\Delta L \approx 0.1\ L_\odot$. The energy exchange required for contact amounts to 0.65 $L_\odot$. These two numbers can easily be made equal by placing these points slightly deeper in the convective zones. Hence we conclude that it is not necessary to assume the adiabatic constants of the two convective zones to be equal but that the „degree of contact" is another free parameter which will reduce the energy flux between the two components to the value required for contact. The following argument shows how the system will adjust to the proper degree of contact. Let us assume that the energy transport mechanism is too effective so that the secondary will have too large a radius. It therefore will lose some mass to the primary. Synchronization of this mass will cause the system to increase the distance between the two components. This reduces the degree of contact and therefore the energy flux from the primary to the secondary until that value is reached which is required for contact. To actually calculate the degree of contact a better understanding of the energy transport is necessary which should also take into account deviations from hydrostatic equilibrium. The estimate given above does not depend strongly on the driving forces, since the velocity was assumed to be the velocity of sound.

We now want to present some of our results. We have calculated model sequences for two different primary masses, 1.4 $M_\odot$ and 1 $M_\odot$, by varying the mass of the secondary. In a third sequence the mass ratio was fixed as 2 : 1, while the total mass of the system changed from 1.5 $M_\odot$ to 2.4 $M_\odot$. The chemical composition was taken as 73.9 % by mass of hydrogen and 24 % by mass of helium, the rest being a mixture of heavier elements. In Fig. 1 a diagram similar to the period-colour diagram is shown, namely mean effective temperature during maximum as a function of period. The two sequences with fixed primary mass are drawn as filled triangles, the line connects the systems with mass ratio 2 : 1 (filled squares, numbers give the mass of the primary). Crosses indicate the W UMa-systems observed by EGGEN (1967), which are candidates for being contact binaries. Most of our systems fall well into the region populated by the observed systems, although they seem to reproduce mainly the systems with the lowest periods for a given effective temperature. In contrast LUCY's sequence A is not in such a good agreement with the observations; his sequence B is based on fiftyfold enhanced CNO reaction rates and the systems computed by MOSS and WHELAN (1970) with LUCY's assumptions (open squares) are based on a very helium rich composition.

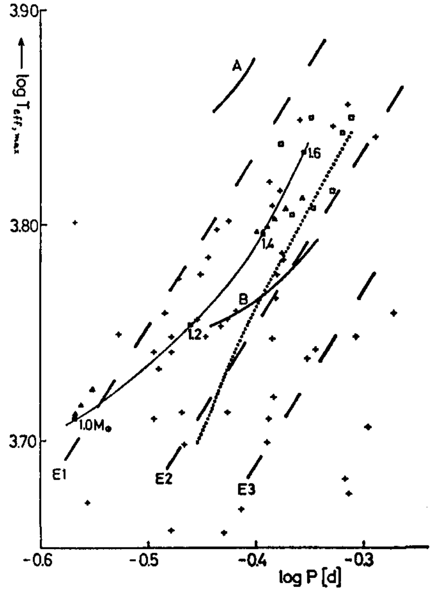

Fig. 1

In Fig. 2 the mass ratio is plotted against the period. Theoretical systems are indicated as in Fig. 1, while the crosses represent W UMa-systems observed by MAUDER (1971). As one can see, the strict equality of the adiabatic constants places those systems in the upper right of the diagram, while our models as well as the observed ones populate the rest of the diagram too. The energy exchange between the two components causes a deviation from the normal mass-luminosity relation. This is shown in Fig. 3, where the luminosity of the primary in units of the total luminosity is drawn against the mass ratio. Here all our models are indicated by filled circles, while crosses denote MAUDER's observed systems. Lines for different mass-luminosity relations $L \sim M^{\alpha}$ are drawn to show the deviations from the normal mass-luminosity relation with $\alpha \approx 4$. The deviation of our models from this relation is the minimum required for the explanation of observed systems, but we feel that taking into account the proper degree of contact will increase the energy exchange between the two components necessary for contact. We also calculated luminosity and mean effective temperature of our systems at maximum and primary and secondary minimum. The most striking effect of the light curves of W UMa-systems is the near equality of the depth of the two minima. We cannot reproduce this with our models. The mean effective temperatures would give a ratio of the depths of 0.56, taking into account gravity darkening with LUCY's (1967) law for convective envelopes ($T_e \sim g^{0.08}$) increases the ratio to 0.71. Shifting the layers, where energy is exchanged, closer to the surface will bring this number to 1, but until we have some better understanding of the process of energy exchange, the question of the light curves must remain open.

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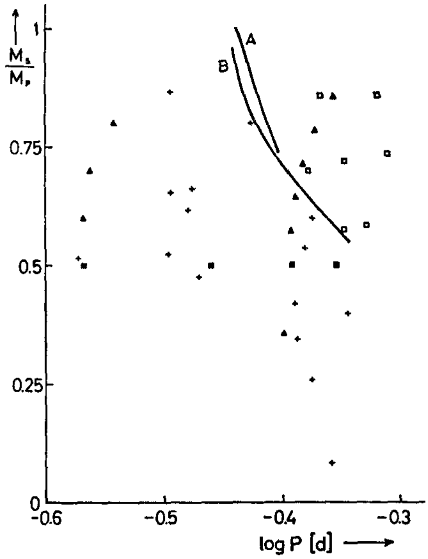

Fig. 2

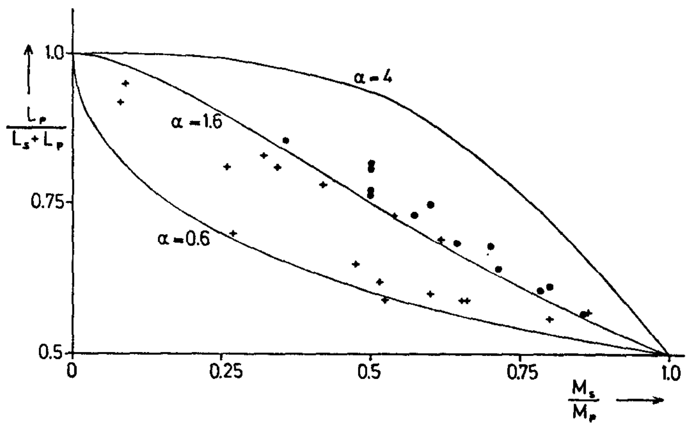

Fig. 3

Discussion to the paper of BIERMANN *and* THOMAS

SMAK: What is the influence of the „degree of contact“ on your results?

THOMAS: The degree of contact will determine the energy transferred. Since from the models we can determine the amount of energy transfer necessary for contact to occur, the degree of contact can be estimated from the formula given above.

SCHUMANN: I cannot understand, why a blowing up the secondary over its Roche limit should not fill a hantle-like envelope.

THOMAS: To construct zero age contact systems, we can treat the distance of the two components as a free parameter. So while blowing up to the secondary we also increase the distance to get both components filling their respective Roche lobes.

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