YOUNG W UMa BINARIES AND THE INTERACTION WITH THEIR ENVIRONMENT

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Summary

It is argued that late type W UMa binaries undergo mass ejection, mainly through the second Lagragian point, which causes a steady decrease of their mass ratio m_2/m_1. This makes it reasonable to believe that the W UMa stage is a state of transition between T Tau and normal main sequence stars.

W UMa stars are eclipsing contact binaries which may be considered as irregular variables. However before entering more deeply into this subject we have to make a distinction between two groups of contact binaries. According to the spectral type we may distinguish the group of unstable late type contact binaries (F-G-K), containing about 80% of these objets, and the early type contacts, which seem to exhibit less disturbed lightcurves. The evolution of both types is probably different, and we shall consider here only the important group of late type objects, which show unambiguous evidence of interaction with their environment.

Their variability becomes evident when we compare lightcurves of the same star for the same colour but for different nights. In at least 25% of the cases we find intrinsic changes of $0^{m}.03$ or more which may cover time intervals ranging from several percent to half the cycle of revolution. This statistical result becomes evident from an analysis of 35 of the best observed W UMa stars published up to now, and poses a real problem to the parameter analysis by means of the synthetic lightcurve method. In principle such an analysis may only be applied to stable systems which normally fill their Roche aequipotentials, and possess a homogeneous temperature distribution defined by gravity and limb darkening. The absence of such a stability makes it difficult to believe that the latter conditions are effectively fulfilled, and we are even inclined to believe that at most times both the geometrical and the physical conditions at the surface are greatly disturbed.

For example, a systematic analysis of the photometric observations available for the probably best observed W UMa star VW Cep by the method of synthetic lightcurve analysis, has revealed to us that even night to night changes in the lightcurve may be due to variations in the mean temperature of the locally disturbed visible surface of the system. The occurence of short lived flares is now clearly established, while the surfaces are also periodically covered by areas of different luminosity as is shown by the slower intrinsic variations. It is difficult to decide observationnaly if these areas are due to the impact of material falling back to the surface or dark magnetic starspots as proposed by Mullan (1975), but

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probably both sorts of activity are present. In these cases, we are confronted with gas streams leaving the system and partly falling back on it, as in the first case, or ejected from the neighbourhood of the megnetic spots, as in the second case.

We may indeed suppose that magnetic spots will be accompanied by enhanced prominence activity with particle velocities exceeding the velocities of escape, especially in the neighbourhood of the external Lagrangian points, where the escape is easy even in the case of a moderate activity.

The spectroscopic observations of this type of star provide us with the important radial velocity curves which until some years ago were the only source of information concerning the mass ratio of these binaries. Good radial velocity curves are difficult to obtain for contact binaries because of their faintness and rapid orbital revolution. The only example for which more than two reasonably good curves have been secured is the prototype W UMa itself, for which 5 radial velocity curves have been published (see : Binnendijk, 1970; Whelan, 1973). The derived values of the spectroscopic mass ratio, $q = {}^{m_2}/m_1 < 1$ vary from 0.47 to 0.71 and are significantly higher than the photometrically determined value 0.41 (Whelan, 1973; Hutchings and Hill, 1973). It is not possible to explain these differences, which are also observed for other contact binaries, as an effect of eclipse and tidal distortion on the line profiles. This effect is quantitatively insufficient.

We believe that the higher spectroscopic mass ratios are a direct consequence of absorbing gas streams between the binary star and the observer. These gas streams, which manifest themselves as weak absorption features at the short wavelength side of the lines, will systematically displace the center of gravity of the line profile, produced by the approaching component, to shorter wavelengths. This effect can be easily seen from the following simplified reasoning. We suppose that the velocities of the components at quadrature necessary for the final derivation of the mass ratio are both increased by an equal value Δv, due to the influence of the projected gas stream. We then find for the apparent mass ratio q' :

$$q' = q \frac{v_1}{v_1 + \Delta v} + \frac{\Delta v}{v_1 + \Delta v} \cong q + \frac{\Delta v}{v_1} (1 - q)$$

where q is the true mass ratio and v_1 is the velocity of the primary component ($\Delta v < v_1$). So the resulting effect is an apparent increase of q depending on the superimposed velocity Δv and the mass ratio q itself. A graphic representation of this effect is given in figure 1, which shows for a certain number of well studied systems the measured ratio q_{spec}/ q_{phot}, compared to the influence of a gas stream giving rise to a displacement of $\Delta v = 0.25\ v_1$ of the measured velocities of the approaching components. The resemblance of these two rather approximative curves is sufficiently good for us to consider gas streams as promising for the explanation of abnormal spectroscopic mass ratios.

The wellknown property of W UMa systems that they show erratic changes of the period completes the dynamical picture given above. It is generally accepted

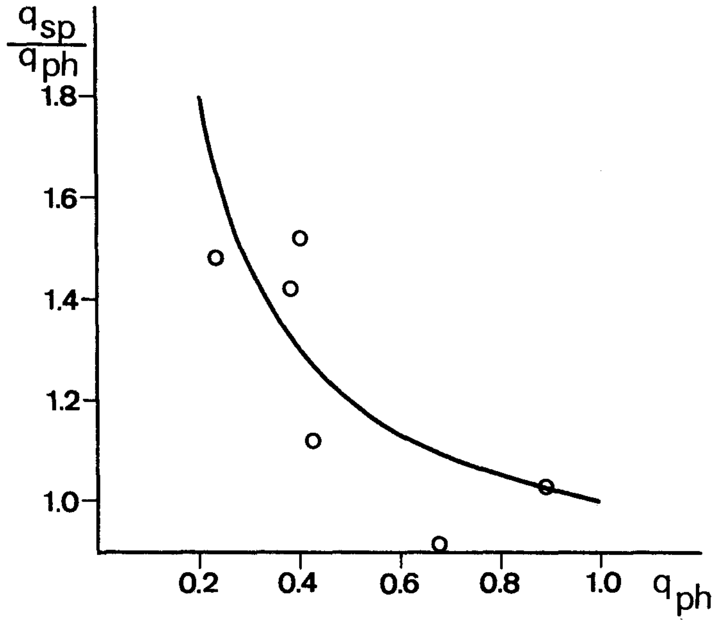

Fig. 1 - Spectroscopic and photometric mass ratios. Determined values and expected values corected for gas streams.

that these period changes are due to transport of material physically connected with the system. If we assume half of the mass transported as definitely lost from the system, we may estimate from the measured values of dP/P, a mass loss of $0.4 - 1.0 \times 10^{-7}$ m_0 per year. This means that these systems can loose one solar mass in 10^7 years. Their total mass is not more than 3 to 4 solar masses, so we may wonder with some anxiety what contact binaries will become after, say, 10^8 years.

In order to find an acceptable scenario of contact binary life, we shall finally consider the statistical behaviour of the mass ratio. Figure 2 shows the frequency of contact binaries for different mass ratios as determined from reliable observations. In case where both spectroscopic and photometric values were available the latter were prefered for the reasons explained above. The most obvious characteristics of the frequency curve are the relative absence of high mass ratios, already noted by other people and the rapid decrease in the interval $q < 0.2$. However this latter effect is, at least partly, due to observational selection, and we shall now try to see if it is possible to correct for it. In order to do so we first calculate the amplitudes of the lightcurves of a great number of model contact systems with various mass ratios, orbital inclinations, and mean temperature conditions.

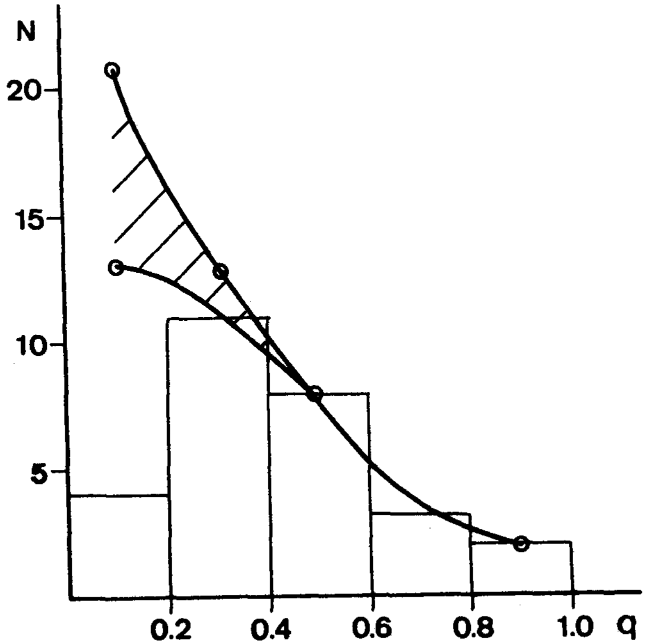

Fig. 2 - The frequency of mass ratios for W UMa type stars. Observed frequencies and expected frequencies corrected for selection effects.

From this grid of models it is possible to now determine the percentage of stars $\alpha(q, \Delta m)$ which would be observed for every combination of q and Δm if :

1 - The frequency distribution as a function of mass ratio were constant, which remains to be tested,

2 - The orbital inclinations were distributed at random, which is probably true,

3 - The probability of detection were the same for systems with small and large amplitudes, which is certainly not true.

The introduction of a frequency distribution $\beta(q)$ and a "probability of detection" function $\gamma(\Delta m)$ makes it possible to compare, for every combination of q and Δm, the observed number of contact binaries with the theoretically expected number $\alpha(q,\Delta m)\ \beta(q)\ \gamma(\Delta m)$. From this comparison we can, at least in principle, determine both $\beta(q)$ and $\gamma(\Delta m)$. The statistical material is somewhat meager and not of uniformly high precision. Nevertheless it is possible to claim that there are at least as many contact binaries in the interval $0 < q < 0{,}2$ as in the interval $0{,}2 < q < 0{,}4$ but probably more, as indicated in figure 2. The explanation of the discrepancy between the observed and the expected number of low mass ratio binaries is

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simple.

Practically all low mass ratio binaries are observed in the low amplitude range 0,2 $< \Delta m < 0.4$, whereas average mass ratio binaries (q = 0,5) may be observed in the amplitude range 0,2 $< \Delta m <$ 0,8. Because of observational selection effects many low amplitude binaries are missed, and hence many low mass ratio binaries exist but remain to be discovered.

It is almost certain that all the late type contact binaries are formed by fission of the contracting pre-main sequence star. Nothing is know about the initial mass ratio of a contact binary just after fission takes place, but it is reasonable to believe that high mass ratios will be preponderant. If this is true a rather rapid evolution must take place from higher to lower mass ratios in order to explain the frequency distribution. Such an evolution may be easily understood if we assume the mass loss figures quoted above, with a preponderance of mass flow from L_2 situated in the neighbourhood of the smaller component,where the velocities of escape are smallest. Thus it is quite natural to suppose that W UMa type systems evolve into binaries with a steadily decreasing mass ratio, and finally become normal main sequence stars. We have already insisted on this possibility, using a different reasoning, elsewhere (Van 't Veer, 1975, 1976) and recent computations made by Nariai (1976, 1977) on the dynamic influence of a gas flow through L_2 confirm this evolutionary scheme.

The different phenomena analysed above lead us to believe that late type contact binaries are rather short lived objects, ($\sim 5 \times 10^7$ y), which are continuously formed from contracting stars near the main sequence and which rapidly evolve into normal main sequence stars by virtue of their high mass loss rate, mainly through L_2. If this evolutionary pattern is true, we may even go further in considering the contact binary state as a transition phase between the T Tauri stage and normal main sequence evolution.

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