MASS LOSS AND SHELL MASSES OF CLOSE BINARY STARS

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ABSTRACT. From the values of period changes for 6 close binary stars the mass transfer rate was calculated. Comparing these values M_t with the values of shell masses M_{sh}, the expression

$$\lg \dot{M}_t = \underset{\pm 24}{4.24} + \underset{\pm 6}{0.63} \lg M_{sh}$$

was derived. The analysis of this expression points out the initial character of the outflow of matter, and one may determine the time interval of the substitution of the shell matter. So one may conclude that for a certain mass transfer rate, a certain amount of matter accumulates in the nearby regions of the system.

The study of orbital period changes of close binary stellar systems led to the idea that these secular and irregular changes are due to the mass loss and to the redistribution of masses in a close binary. Secular changes of orbital periods are known for approximately 400 eclipsing binary stars. For many stars, including cataclysmic binaries, irregular period changes are known. Thus, the mass loss and the matter redistribution in close binaries are often observed phenomena.

Using the value of the parabolic number q from the expression for the moments of minima, and the values of masses M_1 and M_2 ($M_1 \geq M_2$) as well, one may determine the mass transfer rate, for instance, from a formula derived by Kreiner and Ziółkowski (1978):

$$\dot{M}_t = 243.5 \frac{q}{P^2} \frac{M_1 M_2}{M_1 - M_2} \quad (M_\odot/\mathrm{yr}) \qquad (1)$$

Paper presented at the IAU Colloquium No. 93 on 'Cataclysmic Variables. Recent Multi-Frequency Observations and Theoretical Developments', held at Dr. Remeis-Sternwarte Bamberg, F.R.G., 16–19 June, 1986.

Astrophysics and Space Science **131** (1987) 675–679.

The value of $\dot{M}_t$ is known for many eclipsing binary stars. But for the separation between the ejected and transferring plasma, one may use the expression derived by Huang (1963):

$$\frac{\delta P}{P} = (1+3\gamma)\,\frac{\delta(M_1+M_2)}{M_1+M_2} - 3\left(\frac{\delta M_1}{M_1} + \frac{\delta M_2}{M_2}\right), \qquad (2)$$

where $\delta P/P$ is the value of the period's arbitrary change, $\gamma = (M_1+M_2)^2/M_1 \cdot M_2$.

However, the correct determination of the values of ejected and transferred plasma cannot be made without taking into account the plasma ejected in stellar wind. This value may be derived, for example, using the expression of Vilkovisky and Tambovtseva (1984):

$$\mathrm{Mrad} = 10^{-9.48}\left(\frac{R}{R_\odot}\right)^2\left(\frac{\mathrm{Tef}}{10^4}\right)^4 \quad (M_\odot/\mathrm{yr}) \qquad (3)$$

where R and T_{ef} are the radius and the effective temperature of a star. Naturally, in determining the value of $\dot{M}_{rad}$ for a close binary system, one must take into account the contributions of both components. However, their mutual influence on this process and the contribution of circumstellar formations are so far difficult to estimate, so the estimates of $\dot{M}_{rad}$ are approximate.

Comparison of the value of the mass transfer rate, derived from dynamical consideration, $\dot{M}_t$ and the mass loss rate due to 'stellar wind' $\dot{M}_{rad}$ shows that they are similar, but the values of $\dot{M}_t$ are always greater than $\dot{M}_{rad}$. Thus, neglecting the flow through the second Lagrangian point, one may estimate the accretion rate and so the rate of stellar evolution in a close binary.

For example, we will take data on 6 eclipsing binaries which have powerful circumstellar envelopes, emission components of spectral lines, period changes and well determined values of absolute parameters of stars. They are all in the stage of mass ejection and mass transfer. The parameters of these objects and references are given in Table I.

TABLE I

No.	star	lg $\dot{M}_t$	ref.	lg $\dot{M}_{rad}$	ref.	$\dot{M}_t$ (%)	lg $\dot{M}_{sh}$	ref.
1	Z Vul	18.54	6	18.54	15,16	0	23.00	13,14
2	RY Per	18.60	9	18.20	15,16	60	22.89	13,14
3	RZ Sct	19.90	3	19.56	3,16	54	24.78	10
4	TX UMa	20.04	8	18.08	15,16	99	25.00	7
5	β Lyr	20.90	6	19.23	15,16	98	26.78	10,11,12
6	V367 Cyg	21.30	5	20.69	5,16	75	27.18	4

From this table one can see that only in one case (Z Vul) the period change may be explained by mass ejection due to stellar wind. In other systems more than half of the mass ejected by one star is accreted by the other component. An especially large amount of the transferred mass is observed in TX UMa, β Lyr and V 367 Cyg. The fact that β Lyr is in the active stage of mass exchange has been known for a long time, but for two other objects this result is unexpected and deserves attention.

The process of mass loss and redistribution of mass in close binaries is impossible without formation and existence of circumstellar gas structures: shells, discs, flows, Really, the circumstellar gas structures were found and the mass estimates M_{sh} were derived from polarimetrical and spectral data. The comparison of these values with mass loss rates shows the strong logarithmical dependence illustrated in Figure 1 and given by the formula

$$\lg \dot{M}_t = \underset{\pm\,24}{4.24} + \underset{\pm\,6}{0.63} \lg M_{sh}. \qquad (4)$$

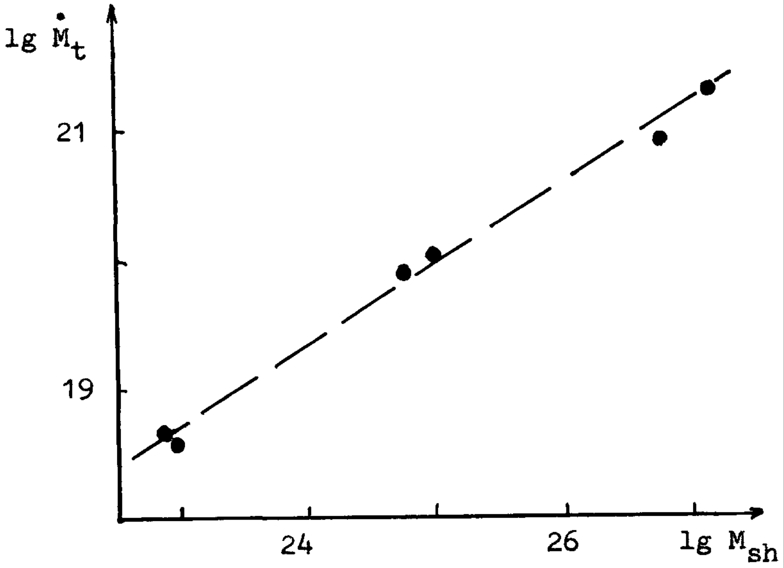

Figure 1. The relation between the transfer rate and the mass of the shell.

The analysis of this expression points out the initial character of the outflow of matter, and one may determine the time interval of the substitution of the shell matter. So one may conclude that for certain mass transfer rates, a certain amount of matter accumulates in the nearby regions of the system.

In the investigated group one must include also close binaries with shells but without period change (RY Sct, (Cherepashchuk, 1985), for example). The absence of a period change during the active stage of mass exchange, is a quite permissible event, which one may explain by a special relation between the ejected and the transferred matter in the binary system. Adopting the following parameters for the system RY Sct: $R_{1,2.}=24R_{\odot}$, $T_{1,2}=3x10^4$ and $2.7x10^4$ K, and using the expression (3), one obtains $M_{rad} = 2 \cdot 10^{20}$g/sec. If the mass of the shell is $M_{sh} = 6x10^{25}$g (Shakhovskoj, 1967), then, according to formula (4) the mass transfer rate is $\dot{M}_t=3x10^{20}$g/sec. Using the values of masses (Cherepashchuk, 1985), for a constant period from formula (2) one may suppose that 40% of the plasma is accreted, and 60% is ejected from the system. Thus, using independent formulae, one obtains an approximate agreement. This confirms the possibility of the determination of mass loss and mass transfer rates. Knowing the masses of circumstellar structures and the accretion flow, one may take into account their influence on the radiation transfer and evolution rate of close binary systems. However, there is an incorrect moment because of the disputable application of formula (1), which was derived using the assumption of the conservation of the total mass and angular moment in binary systems. The existence of stellar winds does not confirm the justification of this assumption.

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