MASS TRANSFER IN ECLIPSING BINARY STARS

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ABSTRACT. Analysis of the properties of the eclipsing binary stars shows, that the stream–like mechanism of the mass transfer switches on at a contact evolutionary stage, preceding to a stage of binaries with a subgiant. The computations of the gas streams near the inner Lagrangian point have been made for the intermediate–mass contact systems of the early spectral classes ($CE-$ systems). The properties of the streams are discussed and the conclusions are done concerning the evolutionary stage of the stars of this type.

Key words: Stars: binaries: close, eclipsing; circumstellar matter.

Mass transfer in eclipsing binary systems exists since their origin and continues as a stellar (for all stellar masses) and magnetic (for stellar masses $\leq 1.5 M_{\odot}$) winds. However at some evolutionary stages of close binary stars the stream mechanism becomes more efficient as compared with the wind. This stream–like mass transfer via vicinities of the Lagrangian points (at first of the point L_1), under certain conditions, shows a largest mass transfer. Clarification of such conditions is the aim of the present work.

Investigation of the properties of the eclipsing binary stars of various types shows that a stream–like mechanism of the mass transfer is not observed in MS–systems, but is present in $SD-$ and $DS-$ systems which contain a subgiant star. Mass streams are well observed in contact early $CE-$systems and are possibly present in $CW-$type stellar systems. While locating the mentioned above types of systems according to their evolutionary stage (Karetnikov 1987, 1991) one may say that the stream–like mechanism of mass transfer arises at a contact stage of evolution, when the systems consist of stars having properties close to that of the main sequence stars.

Contact stage is characteristic for $CW-$ and $CE-$ systems. In the average, the degree of filling the Roche Lobe is $R1A = 1.03$ for more massive star and $R2A = 1.03$ for the secondary both for $CW-$ and $CE-$ systems. According to Karetnikov (1990), progenitors of the contact $CW-$ systems are low–mass ($M \leq 1.5 M_{\odot}$) stars from the $MS-$ systems which have orbital periods less than 4 days. Later on, due to the angular momentum loss via magnetic stellar wind, they must shrink after $\approx 4 \cdot 10^6$yrs into single star, if there are no mechanisms preventing such a process. $CW-$ systems exhibit circumstellar gaseous components. However, no clear evidence for the gaseous streams was detected besides Dumitrescu (1974).

In contact $CE-$systems the gaseous streams are well observed and play a significant role in their evolution. Optically thick gaseous disks and gaseous envelopes with a complex structure existing in these systems may arise and be fed only by a strong stream–like mechanism of the mass transfer. They show largest among eclipsing systems mass loss rates and degrees of overfilling (up to 20 per cent) their Roche lobes (Karetnikov 1987; Wilson & Rafert 1981). Al these circumstances make necessary the creation of the gaseous streams in the contact early stars.

Let's study probable properties of the mass streams in the $CE-$systems near L1 assuming that : a) mass–losing star overfills its Roche Lobe and the point L1 lies deep inside its atmosphere; b) stars of the contact pair have properties corresponding to the Main Sequence.

Table 1. Main parameters of the investigated systems.

Star	P(d)	$M_1/M_\odot$	$M_2/M_\odot$	$A/R_\odot$	$R_1/R_\odot$	$R_2/R_\odot$	Reference
β Lyr	12.914	2.0	11.7	55.0	12	25:	Ziolkowski (1976)
V367 Cyg	18.598	2.3	3.6	53.0	18	21:	Menchenkova (1990)
RY Sct	11.125	10	33	75	21	36:	Antokhina & Cherepashchuk (1988)

Table 2. Stream parameters in the vicinity of the point L1.

Star	Xo	XL	NL(cm^{-3})	TL(K)	VL(km/s)	Rs	M($M_\odot$/yr)
β Lyr	0.38	0.32	$6.4 \cdot 10^{14}$	46000	29.5	0.15	$6.4 \cdot 10^{-6}$
V367 Cyg	0.54	0.45	$5.2 \cdot 10^{14}$	51800	28.5	0.19	$1.8 \cdot 10^{-5}$
RY Sct	0.40	0.39	$1.4 \cdot 10^{15}$	69100	32.3	0.15	$1.0 \cdot 10^{-5}$

By using these assumptions, the properties of the gaseous streams near L1 were computed for 3 contact early objects β Lyr, V 367 Cyg and RY Sct (Karetnikov et al., 1994). The computations were made by using an algorithm proposed by (Nazarenko 1993) and are based on the application of the Kurucz's (1979) model atmospheres.

The absolute characteristics were published by Żiolkowski (1976), Menchenkova (1990), Antokhina & Cherepashchuk (1988) and were used for computations. Initial conditions were obtained from the observed concentration of matter near the first Lagrangian point (NL), which allowed to determine co-ordinates of the initial shell X_0, location of the point L1 (XL), environment temperature TL, speed of motion VL and of sound VL, and radius of the stream Rs corresponding to the decrease of the density by a factor of $\approx 10^3$. The origin of co-ordinates is in the center of the mass-losing star, the abscissa coincides with the line of centers and the ordinate lies in the orbital plane. Separation between the centers of stars a is used as a unit distance.

The analysis of the computations has lead to the following conclusions:

1. Observed gas streams in the systems studied arise due to the overfilling the Roche Lobe by the star and needs no other conditions. The overfilling is really observed and may be resulted by a fast variation of the stellar radius during the $B-$çase evolution.

2. Gas stream near L1 moves along the line of centers towards the more massive stars. It is axially symmetrical with a density maximum near the axis and a density decrease to the borders according to a complex law. Behaviour of the stream far from L1 was not yet computed.

3. Speed of the stream near the axis is $\approx 20 - 30$ km/s and is close to the speed of sound in this gas. In the orthogonal direction the expansion speed is not large (despite observed) and is of few hundred m/s.

4. Dimensions of the gaseous stream are only two times smaller than that of the mass-losing star and is compared with dimensions of the second star in a pair. It is not a thin stream, but a wide flow which can envelop the mass-gaining star.

5. Mass flux via vicinity of the inner Lagrangian point in the systems studied is high – $10^{-6} M_\odot$ for β Lyr and $10^{-5} M_\odot$ for V367 Cyg and RY Sct. It may be noted that two last stars show more strong and complex circumstellar gaseous features.

By taking into account the small probability of observations of the fast processes of the maximal mass transfer rate, especially in case B, which lasts $\approx 10^2 - 10^5$yrs (Sybesma 1986), one may conclude that during such stages the stream dimensions are larger than the radius of the mass-gaining star. Such stream carries tremendous masses of matter and transfers an initially more massive star into a mass-losing secondary. A process of the 'role exchange' occurs. However, only further slow mass flow takes away a remaining part of an envelope and transfers a star into a subgiant and a system into $SD-$type binary.

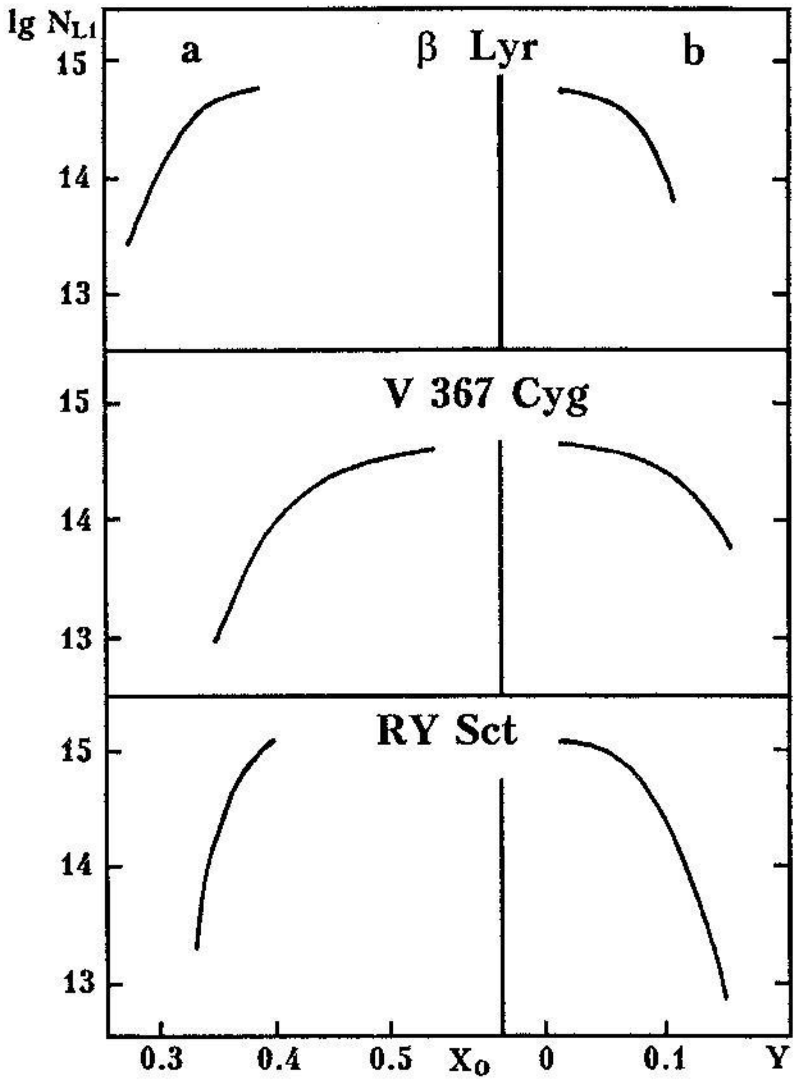

Figure 1. *a* – Dependence of the concentration of matter N_{L1} at the point L1 on parameter Xo, *b* – Distribution of the concentration of matter in the stream along the Y–axis near the point L1.

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