ON THE TRANSITION OF LOW-MASSIVE ECLIPSING SYSTEMS OF THE MAIN SEQUENCE INTO W UMa-TYPE STARS

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ABSTRACT. In orbital periods less than 3 days the low-massive MS-systems of stars turn into CW-systems within the time of nearly 9×10^8 years maintaining the properties of stars of the main sequence. In great periods low-massive MS-systems turn into other types possibly those of AR-systems of stars.

The consideration of properties of eclipsing binary systems shows that originating as detached stars of the main sequence (MS-systems) they seem to have a contact stage of stars of the main sequence and evolve into pairs involving a subgiant-star (SD-, DS-systems). However such a simple solution is far from being valid for all the eclipsing systems. More detailed study is necessary of the evolutionary ways for the binary stars differing in physical parameters. Let us consider the evolutionary ways of low-massive eclipsing MS-systems comprising stars which masses do not exceed 1.5 Sun's mass.

Low-massive stars are comprised in many eclipsing binary systems. They constitute nearly 20 % of stars of MS-systems, practically all the similar to (~CW-systems) and ordinary (CW-systems) W UMa-type stars as well as the systems of AR Lac-type (AR-systems). There are many low-massive stars in semidetached (SD-systems) binaries and in pairs with a detached subgiant (DS-systems). They are involved in the group of low-massive contact early (CE-systems) binary stars. As the stars in these systems belong to two classes of luminosity: V - to normal dwarfs (MS-, ~CW-, CW-systems) and IV - to subgiants (companions SD-, DS- and both stars of AR-systems), and the belonging of satellites of low-massive CE-systems is not clear, we confine ourselves to the consideration of evolution ways of normal dwarfs at the stage of MS- to CW-systems of binary stars.

Mean characteristics of stars of MS-, ~CW- and CW-systems according to

Svechnikov's Catalogue, (Svechnikov, 1986), are described in Table 1 where 15 low-massive MS-systems [WX Cep are omitted, masses M_i and radii R_i (i=1,2) of which are not dependent on "mass-radii" relation for the main sequence stars] are divided into three groups according to the values of orbital periods P. Table 1 contains data of all the 7 detached binary ~CW-systems and 18 contact CW-systems.

Table 1

Type of system	n	P	M_1	M_2	A	R_1	R_2	R1A
MS_1	5	6.12	1.29	1.21	18.96	1.50	1.33	0.20
MS_2	5	3.15	1.34	1.30	12.47	1.69	1.61	0.32
MS_3	5	1.58	1.00	0.90	6.92	1.01	0.92	0.36
~CW	7	0.72	1.07	0.84	4.14	1.18	0.94	0.72
CW	18	0.34	1.06	0.55	2.39	1.07	0.69	1.04

'n' designates the number of averagings, A - the size of binary system in $R_\odot$, R1A - the degree of filling up of the Roche lobe by the more massive star of the pair calculated according to formulae

$$R1A = \frac{R_1}{RR_1}, \qquad RR_1 = 0.52 \times A \times (M_2/M_1+M_2))^{0.44} \qquad (1)$$

where RR_1 is the radius of the star's Roche lobe (Iben and Tutukov, 1984). The analysis of the data in Table 1 results in the conclusion on the non-increase of stellar radii in the transition from MS-systems to CW-systems. The stellar radii and masses decrease within this transition whereas the degree of filling up of Roche lobe increases. The latter is accounted for the significant decrease of sizes of Roche lobe because of the decrease of size of the binary star, A, and the orbital period, P. Then we can affirm that in the absence of big losses of matter in low-massive MS-systems the filling up of the Roche lobe is accounted not for the evolutionary star's expansion but for the decrease of orbital periods of binary systems.

In case of low-massive MS-systems the change of orbital periods is caused by the losses of mass M_L and angular momentum J_L due to stellar wind as well as by the loss of an angular momentum due to magnetic stellar wind J_{MSW} (mass losses are negligible relative to this). The mass loss in the first case is calculated by formula

$$M_L = 10^{-9.48}(R/R_o)^2 \times (T/10^4)^4 \qquad (M_\odot/yr) \qquad (2)$$

(Vilkoviski and Tambovceva, 1984) where T is the stellar temperature. Then it was recalculated into the change of the orbital period $(\dot{P}/P)_L$. The angular momentum change J_{MSW} was found according to formula

$$(\dot{J}/J)_{MSW_2} = -9.6 \times 10^{-15} \times R_2^4 \times (M_1 + M_2)^2 \lambda^{-2} A^{-5} M_1^{-1} \qquad (s^{-1}) \qquad (3)$$

(Iben, Tutukov, 1984) for a less massive star ($\lambda = 1$). Then summing of all effects the orbital period change $(\dot{P}/P)$ was derived

$$(\dot{P}/P)_{MSW} = -6.9 \times 10^{-10} \frac{(M_1 + M_2)^{1/3}}{M_1 \times M_2} \times \frac{R_1^4 \times M_1 + R_2^4 \times M_2}{P^{10/3}} \qquad (yr^{-1}) \qquad (4)$$

The changes of orbital periods calculated for MS-systems are presented in Table 2 wherein for ~CW- and CW-systems mean values $(\dot{P}/P)_p$ are also given which are calculated from the objects' period variations. The analysis of the data shows that the change of orbital period due to the stellar wind is small and practically invariable during the transition from MS- to CW-systems. As to the period variation due to the magnetic stellar wind, $(\dot{P}/P)_{MSW}$ has a four-order change and must greatly influence the evolutionary ways of MS-systems. It should be noted that for ~CW- and CW-systems the period variability is of great significance, being caused by mass transfer in the systems which in the average exceeds the losses of angular momentum due to the magnetic stellar wind.

The consideration of working factors according to star's groups allows to make a conclusion that the orbital period in MS-systems must increase since mass losses caused by the radiative stellar wind gives a greater positive value of the period variation (by an order) than the magnetic stellar wind which decreases the value of an orbital period. The stars of this group seem to evolve to AR-systems, according to Svechnikov (1986) having greater periods than in MS_1-systems but similar stars' masses. The role of magnetic stellar wind increases with the transition to the stars of group MS_2 and particularly to MS_3 where the decrease of period $(\dot{P}/P)_{MSW}$ is by an order greater than $(\dot{P}/P)_L$.

Thus it is clear that magnetic stellar wind is able to change the orbital period of MS_3-systems of binary stars and bring them to the stages of ~CW- and CW-systems. The time of transition between the stages can be determined by formula (4) integration assuming stellar masses and radii to be constant

$$\Delta t = t - t_o = -4.3 \times 10^8 \frac{M_1 M_2}{(M_1+M_2)^{1/3}} \times \frac{P^{10/3} - P_o^{10/3}}{R_1^4 M_1 + R_2^4 M_2} \qquad (yr) \qquad (5)$$

The results of calculations are as follows: for MS_3-systems their transition into ~CW-systems takes $\Delta t' = 8.7 \times 10^8$ years but the transition from ~CW- into CW-systems takes $\Delta t'' = 3.5 \times 10^7$ years. Then one can suppose that CW-systems of stars formed from MS_3-systems are young enough and they have no nuclei burnt out (the time of hydrogen burning out in these stars is markedly greater and constitutes 3 ÷ 6 x 10^9 years).

At such fast losses of angular momentum in CW-systems these stars must coalesce into one star and their number should be negligible. As we observe a great number of CW-systems, we can assume that there may be a mechanism hindering this process. The determination of this mechanism is of urgent importance for the evolution theory of eclipsing binary stars. It should be also noted that for stars of MS_2-systems the transition into CW-systems is problematic whereas for MS_1-systems it is impossible.

Table 2

Type of system	P	$(\dot{P}/P)_L$	$(\dot{P}/P)_{MSW}$	$(\dot{P}/P)_p$
MS_1	6.12	$+1.8\times10^{-10}$	-2.8×10^{-11}	-
MS_2	3.15	$+2.1\times10^{-10}$	-3.2×10^{-10}	-
MS_3	1.58	$+1.1\times10^{-10}$	-0.5×10^{-9}	-
~CW	0.72	$+0.8\times10^{-10}$	-1.1×10^{-8}	-1.3×10^{-7} *
CW	0.34	$+1.0\times10^{-10}$	-0.9×10^{-7}	-4.0×10^{-7} **

* - the averages from 3 objects; ** - from 10 systems.

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