ANGULAR MOMENTUM CHANGES IN ECLIPSING BINARY STARS OF DIFFERENT TYPES

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ABSTRACT. Based on the characteristics on 303 eclipsing binary stars we calculated the angular moments and those dependence from the stellar masses. We got the clear correlations, when divided the stars on the groups with different masses and orbital periods. It was shown, that the angular moment successively descreases during passing from MS- through CE- towards to SD- system stars, and increasing the speed of changes. The maximal values of changes of the speed of changs was found for systems of small masses and periods. It was discussed the unsingle dependence in CE systems of small masses and periods.

Key words: Stars: binary, statistics, evolution

Up to the present time, the theory of the eclipsing binary systems evolution has been confirmed observationally. Generally, the theoretical predictions quite well agree with observational data (Masevich and Tutukov, 1988). In particular, it was shown that angular momentum of the close binaries decreases from MS systems (detached systems of the main sequence) toward the SD systems (semi-detached systems with subgiant) (Svechnikov, 1969). Taking into account that conception of the transition from one group of binary systems to another group is regarded to be established, one can state that comparing the angular momentum values for different stellar groups, we can understand the principal tendencies of the close binaries evolution.

The angular momentum values $\lg H$ have the natural distribution and vary within the large interval from 1.5 to 4.0. For MS systems $\lg H$ value is clearly proportional to the common mass $\lg M$ of system with the coefficient 1.85, while for SD systems some distortion of the dependence takes place with clear decreasing of the angular momentum comparably to MS systems. The difference between angular momentum values increases with the decreasing of the mass ratio parameter q. Comparison with angular momentum values for DS does not show any decreasing of those values. Perhaps, this fact testifies about differences in the mass transfer and mass loss processes which decrease the angular momentum.

Angular momentum decreasing indicates also non-conservative case in the mass transfer process. For example, in (Popov, 1970) it is shown that mass loss from the systems with primary of $10M_\odot$ can achieve 75 % of its mass and 90 % of this material leaves the system. Now, the estimates of mass loss rate are available for binary systems of the different masses. Therefore, it is necessary to take into account not only the differences in the mass ratio for different systems, but also the differences of full masses $M = M_1 + M_2$ (where M_1 - is mass of more massive star). It is important, because mass loss rate is linked with the general characteristics of binary systems.

The observations show that binary systems lose an angular momentum due to stellar and magnetic wind (like single stars do), and angular momentum can also be lost due to specific mechanisms operating only in close binary systems - gravitational radiation and mass transfer between components. Gas flows play a key role in the mass loss from binary systems. Accordingly to observational data, they can lead to mass loss up to $10^{-4}M_\odot/\mathrm{yr}$. Other mechanisms give more modest contribution in the mass loss process. For ordinary binary systems, the gravitational effect are negligible.

They should be taken into account only for very short-period objects.

One can state that at the present time very accurate observational data on the parameters of close binary systems are collected in the literature. The most accurate data are presented in (Popper, 1980), where some values have an accuracy of about of 3 %. Using the more complete catalogue (Svechnikov, 1986), one can expect to have an accuracy of about 15 %. We used the catalogue (Karetnikov and Andronov, 1989) for the determination of the angular momentum in close binaries. First of all we divided all systems on the groups taking into account their masses and orbital periods.

The groups were the following:

”$\underline{a}$” - close binaries with $M_1 < 1.5 M_\odot$ and $M_2 < 1.5 M_\odot$. Stars possess the magnetic wind. A role of an usual stellar wind in this case is negligible.

”$\underline{b}$” - masses are: $1.5 < M_1 < 10 M_\odot$ and $M_2 < 1.5 M_\odot$. Secondary component possesses magnetic wind, but primary does not. A role of usual stellar wind is still negligible. For primaries and some massive secondaries, the nuclear evolution is important.

”$\underline{c}$” - both stars have the masses between $1.5 M_\odot$ and $10 M_\odot$. Magnetic stellar wind is absent. Usual stellar wind is not important. The evolution of binary system is mainly caused by nuclear reactions.

”$\underline{d}$” - the mass of primary is $M_1 > 10 M_\odot$, secondary - $M_2 > 1.5 M_\odot$. Usual stellar wind is important for evolution, as well as nuclear reactions (in first place for secondary).

Further dividing of these groups on subgroups we performed separately for binary systems consisting of the main-sequence components (MS, ∼CW, CW, CE) and systems with subgiant (SD, DS, AR). In the first case the dividing was the following: subgroup 1a - systems of group ”a” with orbital period $P < 2.5^d$; subgroup 2a - periods are from 2.5^d to 3.5^d; subgroup 3a - $P > 3.5^d$. Similar designation were also adopted for groups ”b”,”c”,”d” . For systems of SD, DS and AR, more detailed specification was used: $1a - P < 1.5^d; 2a - 1.5 < P < 2.5^d; 3a - 2.5 < P < 3.5^d; 4a - 3.5 < P < 6^d; 5a - P > 6^d$ and similarly for groups ”b”,”c”,”d” of the binary systems with subgiant star.

Results of calculation are gathered in Tables 1 - 3, where for each group or subgroup one can find the total number of systems belonging to considered group and coeficients A and B of the linear formula ”$\lg H = A + B \cdot \lg M$” with the significance level of the correlation more than 0.95. For determined coefficients A and B we give sigma values σ(A) and σ(B). Here also the coefficient of correlation K and corresponding σ(K) values are presented. It should be noted that correlation coefficients for groups CE-a and CE-b of low-mass contact system are less reliable. Coefficient of correlation for group MS-b is unexpectedly small (0.74). Other stellar groups show significant correlations.

Our calculations demonstrate the successive decreasing of the angular momentum from MS systems through CE systems and then to SD systems. The rate of of angular momentum decreasing (coefficient B) is smallest for MS and largest for SD systems. This confirms the conclusion made by us previously about the direction of the evolutionary changes: MS – CE – SD, even in spite of some increasing of the mean mass of stars from CE group. This schematic picture is also valid for ”a” and ”b” groups. For ”c” group, the definite conclusion is difficult to draw. In ”d” group, the masses and angular momentum values are increasing from MS trough CE to SD systems. It can be considered as a result of distribution on the masses and mechanisms of mass transfer and angular momentum.

Small values of the correlation coefficients in subgroups CE-a (0.70) and CE-b (0.74) significantly increase after performing the dividing on orbital periods. Perhaps it can be explained by the merging effects in short-period low-mass CE-a and CE-b systems caused by magnetic stellar wind operation, like in CW systems (Karetnikov, 1997), while wide pairs escape the coalescence. As it follows from Table 2, more detailed classification shows different behaviour of angular momentum with mass variation (see B coefficients). Probably, it is indirect confirmation of hypothesis about differences of the evolutionary processes

Table 1. N - number of systems, full masses $\lg M$, angular momentum $\lg H$ values, coefficients A and B of formula "$\lg H = A + B \cdot \lg M$" and correlation coefficients with sigma values σ(A,B,K) for MS systems.

Name of group	N	Main values		Coefficients		
		$\lg M$	$\lg H$	A	B	K
MS-75	75	0.75	2.71	2.19	0.69	0.94
σ		0.36	0.27	0.02	0.03	0.04
MS-a	14	0.32	2.42	2.11	0.96	0.94
		0.20	0.21	0.04	0.10	0.10
MS-1a	4	0.12	2.17	2.08	0.75	0.98
		0.30	0.23	0.03	0.11	0.14
MS-2a	4	0.40	2.49	2.10	0.96	0.99
		0.03	0.03	0.03	0.08	0.08
MS-3a	5	0.40	2.56	1.89	1.71	0.91
		0.04	0.07	0.17	0.44	0.23
MS-b	13	0.54	2.57	2.04	0.98	0.52
		0.05	0.10	0.26	0.48	0.26
MS-1b	6	0.53	2.50	2.18	0.59	0.81
		0.05	0.03	0.10	0.21	0.29
MS-2b	3	0.52	2.54	2.08	0.91	0.94
		0.03	0.03	0.18	0.34	0.35
MS-3b	4	0.57	2.70	2.50	0.34	0.27
		0.06	0.08	0.50	0.86	0.68
MS-c	37	0.81	2.74	2.28	0.57	0.80
		0.19	0.14	0.06	0.07	0.10
MS-1c	18	0.86	2.71	2.21	0.58	0.96
		0.16	0.10	0.04	0.04	0.07
MS-2c	6	0.77	2.72	2.17	0.70	1.00
		0.19	0.13	0.02	0.03	0.04
MS-3c	13	0.74	2.80	2.24	0.74	0.95
		0.20	0.16	0.06	0.08	0.10
MS-d	10	1.41	3.18	2.57	0.44	0.56
		0.10	0.08	0.32	0.23	0.29
MS-2d	4	1.46	3.18	2.06	0.77	0.98
		0.06	0.05	0.16	0.11	0.14
MS-3d	5	1.36	3.20	2.28	0.67	0.77
		0.11	0.10	0.43	0.32	0.37

Table 2. N - number of systems, full masses $\lg M$, angular momentum values, coefficients A and B of formula "$\lg H = A + B \cdot \lg M$" and correlation coefficients with sigma values σ(A,B,K) for ∼CW, CW and CE systems.

Name of group	N	Main values		Coefficients		
		$\lg M$	$\lg H$	A	B	K
∼CW	7	0.27	2.18	2.02	0.58	0.96
σ		0.11	0.07	0.02	0.08	0.12
CW-25	25	0.23	2.04	1.87	0.76	0.96
		0.13	0.10	0.01	0.04	0.05
CW-a	7	0.23	2.08	1.92	0.67	1.00
		0.16	0.11	0.01	0.02	0.03
CW-b	18	0.23	2.03	1.84	0.81	0.98
		0.12	0.10	0.01	0.04	0.05
CE-89	89	0.80	2.54	1.82	0.90	0.93
		0.49	0.47	0.04	0.04	0.04
CE-a	8	0.28	2.13	2.12	0.03	0.03
		0.09	0.10	0.12	0.42	0.41
CE-1a	4	0.27	2.05	2.11	-0.24	-0.42
		0.11	0.06	0.11	0.37	0.64
CE-2a	4	0.29	2.22	2.09	0.43	0.87
		0.06	0.03	0.05	0.17	0.34
CE-b	38	0.44	2.21	1.96	0.56	0.27
		0.08	0.17	0.15	0.33	0.16
CE-1b	26	0.42	2.24	1.90	0.81	0.44
		0.08	0.14	0.14	0.34	0.18
CE-2b	12	0.53	2.19	1.51	1.28	0.68
		0.14	0.25	0.22	0.41	0.22
CE-c	18	0.86	2.55	1.74	0.93	0.66
		0.21	0.29	0.24	0.26	0.19
CE-d	24	1.50	3.18	1.81	0.91	0.85
		0.24	0.26	0.18	0.12	0.11

Table 3. N - number of systems, full masses $\lg M$, angular momentum values, coefficients A and B of formula ”$\lg H = A + B \cdot \lg M$” and correlation coefficients with sigma values σ(A,B,K) for systems with subgiants.

Name of group	N	Main values		Coefficients		
		$\lg M$	$\lg H$	A	B	K
AR-12	12	0.42	2.54	2.33	0.49	0.67
σ		0.10	0.07	0.07	0.17	0.23
AR-a	10	0.39	2.52	2.43	0.23	0.26
		0.06	0.05	0.12	0.30	0.34
DS-11	11	0.51	2.74	2.46	0.55	0.83
		0.19	0.13	0.07	0.12	0.19
DS-b	9	0.47	2.74	2.08	1.39	0.80
		0.06	0.10	0.18	0.39	0.22
SD-82	82	0.61	2.60	2.11	0.80	0.94
		0.32	0.27	0.02	0.03	0.04
SD-a	6	0.26	2.23	2.24	-0.04	-0.03
		0.05	0.06	0.17	0.64	0.50
SD-1a	4	0.26	2.19	2.16	0.09	0.24
		0.05	0.02	0.07	0.24	0.69
SD-b	58	0.50	2.52	2.15	0.76	0.77
		0.14	0.14	0.04	0.08	0.08
SD-1b	12	0.44	2.36	2.06	0.69	0.91
		0.09	0.07	0.05	0.10	0.13
SD-2b	10	0.50	2.47	2.13	0.68	0.98
		0.13	0.09	0.03	0.05	0.07
SD-3b	17	0.48	2.52	2.20	0.68	0.99
		0.14	0.09	0.01	0.03	0.04
SD-4b	12	0.56	2.63	2.29	0.61	0.98
		0.19	0.12	0.02	0.04	0.06
SD-5b	7	0.50	2.69	2.39	0.60	0.94
		0.13	0.08	0.05	0.10	0.16
SD-c	12	0.90	2.80	1.90	0.99	0.85
		0.08	0.09	0.18	0.19	0.17
SD-d	6	1.46	3.31	2.33	0.67	0.82
		0.18	0.14	0.34	0.23	0.28

in low-mass CE systems.

Unfortunately, it is not possible to perform an analysis using all the types of eclipsing binaries, because of scarcity of reliable observational material for some types. For example, there are only 7 systems of CW type, 11 systems of DS type, group DS-b contains 9 systems. AR type (12 systems, where both components are subgiants) forms AR-a subgroup (10 systems). Each of two DS and AR groups contains only one system. There is very small number of stars in W UMa (CW systems) type, where one can select only two groups. In addition, we excluded from the analysis some binary systems with strongly deviating characteristics.

Thus, more reliable analysis of the evolutionary changes in close binary systems should be based on the investigation of angular momentum values for different groups. It should be also mentioned that distribution of the systems on their masses gives us an information about the evolutionary changes and possibility of the increasing of massive stars number on some evolutionary stages. Probably, it could explain the peculiarities observed in massive systems of ”*d*” group (among the MS systems there are less massive stars than in CE systems). Generally, our results confirm the adopted hypotheses about binary stars evolution.

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