RELATIONS BETWEEN THE ABSOLUTE CHARACTERISTICS OF THE COMPONENTS OF THE DIFFERENT-TYPE ECLIPSING BINARY SYSTEMS

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Abstract. By using our compiled catalogues of the characteristics of 303 eclipsing binaries with the constant and variable orbital periods, we computed the «Mass-Luminosity», «Mass-Radius» and «Mass-Temperature» relationships. These relationships are analyzed, the coefficients vary from one type of the eclipsing systems to another. It is assumed that the changes of the coefficients are of the evolutionary origin. The sequence of the studied systems according to the ages of the components is proposed.

Key Words: Stars: Binaries; Stars: Evolution

The eclipsing binary stars being simultaneously the photometric and speetroscopic binary systems allow the most accurate determination of the main absolute characteristics : the masses M_i, radii R_i, temperatures T_i, luminosities L_i of the stars and the separation A between them. The accuracy of the determination of these characteristics amounts to 5 per cent (Popper, 1980), thus it is possible to determine accurately the relationships between the parameters of the stars and their systems. At the same time, the different types of the eclipsing binary systems are at the different evolutionary stages, and one may compare the coefficients of the relationships with the evolutionary status. This paper is devoted to the empirical investigation of this problem.

The main astrophysical relationships «Mass-Luminosity», «Mass-Radius» and «Mass-Temperature» were studied by many investigators. The most recent results of high reliability were obtained by Svechnikov (1986) for the components of the systems with the detached Main-Sequence stars (MS-systems). For the stars of other types of the eclipsing systems, the similar relationships did not yield the significant results. However, it was known, that the subgiants do not obey the derived relationships. Recently the new data on the absolute characteristics of the components of the binary systems were obtained, thus making actual the study of the main relationships for all types of the eclipsing binaries.

The data for such study were taken from the two compiled catalogues published by Karetnikov and Andronov (1989). The first Catalogue contains the data for 127 eclipsing systems with the secular period changes ($Q \neq 0$). The second Catalogue contains the data on 176 eclipsing binaries with the constant orbital periods ($Q=0$). Both catalogues contain information on 75 MS-systems, 8 systems similar to W UMa (SimCW), 25 W UMa-type systems (CW), 89 contact early pairs (CE), 80 semi-detached (SD), 13 systems with a detached subgiant (DS), and 13 AR Lac-type binaries (AR).

From the Catalogues' data, we computed the dependencies of the type

$$\begin{aligned} M_{B_i} &= a + b \log M_i \\ \log R_i &= c + d \log M_i \\ \log T_i &= e + f \log M_i \end{aligned} \qquad (1)$$

separately for the different types and the systems with the constant and variable periods. Here M_{B_i} - is the bolometric absolute magnitude. For all approximations, the correlation coefficients k and the error estimates σ were computed. The results are shown at Tables 1-3, where n - is the used number of the objects, the index '1' corresponds to the more massive component of the binary. Six objects were excluded from the analysis. These are MS-systems WX and ZZ Cep with the poorly known parameters; YY Gem and CM Dra, the classification of which is ambiguous; as well as RR Cen and AW UMa from the groups od SimCW and CW systems.

The analysis of the data presented in Tables 1-3 shows a good agreement of the results obtained for the MS systems with those published by Svechnikov (1986). All the results are of the high significance at th 0.0-2.0 level. The results of the lower significance are avoided. They appeared, if there is the unsufficient number of pairs and/or the characteristics are very similar. These are CW and SimCW systems, the masses of the stars are from 0.2-2.0 solar masses, as well as the AR systems with the masses of 0.6-2.3 solar masses. For these objects, the intervals of the radii and temperature's changes are not wide as well. If one takes into account the difficulties and the uncertainties of the determination of their absolute characteristics, the low significance of the relationships will be quite natural.

The numerical values of the coefficients show their systematic changes while investigating the systems from the not-evolved ones to the objects with the higher evolutionary age, containing the subgiants in the SD, DS and AR-type systems. Thus one may study, how the main secondary characteristics of the stars depend on the mass. Let us represent the relationships in the form:

$$L_i \sim M^{\alpha_i}, \qquad R_i \sim M^{\beta_i}, \qquad T_{eff\,i} \sim M^{\gamma_i}, \qquad (2)$$

where $\alpha = -0.4b$, $\beta = d$, and $\gamma = f$.

As one may see, the power index , corresponding to the dependence of the luminosity on the mass, is at its maximum for the MS stars (excluding DS_1 for $Q = 0$ and $n = 4$), the initial evolutionary stage of the eclipsing systems. The lowest values of

α correspond to the primary stars of the SimCW systems. Similar behavior proceeds in the values of γ, slightly different - in the values of β.

The investigation of the significance of the coefficients of the equations (1) showed, that the relationships are mainly unsignificant, if the number of objects is low. This is the case for the majority of the relationships for SimCW, Cw, DS and AR systems with $Q \neq 0$, and sometimes with $Q = 0$. Suggesting that this situation is due to the low number of the data, one may exclude from the analysis the mass dependence of the luminosities, masses and temperatures of the SimCW, CW, DS and AR-type systems. The number of the systems for other groups is sufficient for the reliable analysis of the variations of the coefficients from one type to another.

The results of the comparison of the power coefficients are shown in Table 4, where the eclipsing binaries are located according to the suggested evolutionary sequence. In fact, the most evolutionary young is the less massive component MS_2 of the Main Sequence type system. The most evolved must be the subgiant SD_2 in the semi-detached system. It is not only inconsistent with the modern evolutionary conception, but confirms the latter numerically. As regards the exclusions from the mentioned above binaries, which were not shown in Table 4, one may note, that the available data on the CW, DS and AR systems are unsufficient for the reliable location of them onto the suggested evolutionary sequence.

The analysis of the dependencies shows, that the parameters α, β and γ are changing differently for the systems with the constant and variable orbital periods. The coefficients α and γ are monotonically decreasing during the evolution. The coefficient β is changing in a more complicated manner, because for the contact and semi-detached systems, the radius of the star filling (or nearly filling) its Roche lobe star depends not only on the mass, but on the orbital separation as well. Thus the obtained values of β must be interpreted very carefully.

The subdivision of the eclipsing binaries into the groups with the constant and variable periods points out the difference in the processes, which take place for the different manner of the mass transfer. According to Huang (1963), the constancy of the orbital period may indicate that the ratio of the accreted to the ejected matter is strongly determined. In this case, the changes of the coefficients α, β and γ are larger. For the variable orbital periods, there are no restrictions on the accretion and ejection rates, and the dependence of the main characteristics on mass is not so clear.

Thus one may see that the dependence of the luminosities, radii and temperatures of the stars is changing during the evolution of the eclipsing binaries. The result is statistically significant for the MS, CE, SD systems, and one may suppose that the location of the subsytems according to the sequence shown in Table 4, may have the evolutionary sense. This idea may be confirmed by the present results, as well as by the general considerations on the evolutionary status of the MS and CE systems (containing the Main Sequence stars), and the SD-type binaries (containing the highly evolved subgiant star). The stars of other types (SimCW and CW with the Main Sequence Stars as well as the systems with one (DS) or two (AR) subgiants) need the further investigation.

References

Huang S.-S.: 1963, Ap.J. **138**, 471.
Karetnikov V.G., Andronov I.L.: 1989, Preprint Ukr.Res.Inst. Sci.-Tech.Inform. (UkrNIINTI) No. **2629-89**
Popper D.M.: 1980, Ann.Rev.As.Ap., **18**, 115
Svechnikov M.A.: 1986, Classification and Physical Characteristics of the Eclipsing Variable Stars, Thesis, Moscow Univ.Press

Table 1 The coefficients of the 'Mass-Luminosity' relation for the stars of the different-type eclipsing systems

Type	$Q \neq 0$				$Q = 0$			
	a	b	k	n	a	b	k	n
MS_1	4.31	-9.00	0.99	15	4.48	-9.79	0.98	56
	±0.20	±0.29	±0.03		±0.15	±0.24	±0.02	
MS_2	4.32	-9.02	0.99		4.42	-9.90	0.97	
	0.20	0.20	0.03		0.15	0.33	0.03	
$SimCW_1$	4.38	-3.31	0.99	3	4.30	-2.69	0.97	4
	0.04	0.38	0.11		0.06	0.50	0.18	
$SimCW_2$		Correlations are			4.55	-9.42	0.95	
		not significant			0.42	2.18	0.22	
CW_1		Correlations are		11	4.88	-6.29	0.82	13
		not significant			0.19	1.34	0.17	
CW_2		Correlations are			4.33	-4.86	0.65	
		not significant			0.45	1.71	0.23	

CE_1	3.69 0.27	-7.76 0.38	0.98 0.05	23	3.43 0.13	-8.00 0.17	0.99 0.02	6
CE_2	3.09 0.34	-8.28 0.61	0.95 0.07		2.66 0.20	-7.29 0.31	0.95 0.04	
SD_1	4.06 0.12	-8.69 0.22	0.98 0.02	62	4.44 0.23	-9.20 0.41	0.98 0.04	18
SD_2	1.45 0.20	-5.84 0.46	0.85 0.07		1.28 0.45	-3.58 1.19	0.60 0.20	
DS_1	5.04 0.08	-12.02 0.26	1.00 0.02	11	3.36 0.36	-7.87 0.57	0.98 0.07	9
DS_2		Correlations are not significant			0.70 0.51	-5.12 1.15	0.86 0.19	
AR_1		Correlations are not significant		7	3.44 0.57	-7.54 2.86	0.80 0.30	6
AR_2		Correlations are not significant				Correlations are not significant		

Remark: The index 1 and 2 after the type correspond to the primary (the star of the higher mass) and the secondary, respectively.

Table 2 The coefficients of the 'Mass-Luminosity' relation for the stars of the different-type eclipsing systems

Type	$Q \neq 0$				$Q = 0$			
	c	d	k	n	c	d	k	n
MS_1	0.12 ±0.03	0.59 ±0.04	0.97 ±0.07	15	0.11 ±0.03	0.70 ±0.04	0.92 ±0.05	56
MS_2	0.11 0.02	0.55 0.02	0.99 0.04		0.08 0.02	0.70 0.04	0.91 0.06	
$SimCW_1$		Correlations are not significant		3	0.07 0.01	0.48 0.08	0.97 0.17	4
$SimCW_2$		Correlations are not significant			0.04 0.02	0.79 0.11	0.98 0.14	
CW_1	0.01 0.02	0.04 0.15	0.68 0.25	11	0.00 0.02	0.69 0.13	0.85 0.16	13
CW_2		Correlations are not significant			-0.01 0.04	0.63 0.17	0.74 0.20	
CE_1	0.00 0.06	0.96 0.09	0.92 0.08	23	0.12 0.02	0.66 0.03	0.95 0.04	66
CE_2	0.15 0.06	0.83 0.10	0.88 0.11		0.16 0.02	0.63 0.03	0.93 0.04	
SD_1	0.09 0.02	0.71 0.04	0.92 0.05	62	0.04 0.08	0.74 0.14	0.81 0.15	18
SD_2	0.56 0.02	0.46 0.06	0.71 0.09		0.62 0.05	0.38 0.14	0.55 0.21	
DS_1	0.01 0.09	1.28 0.28	0.96 0.21	4		Correlations are not significant		9
DS_2		Correlations are not significant				Correlations are not significant		
AR_1		Correlations are not significant		7		Correlations are not significant		6
AR_2		Correlations are not significant				Correlations are not significant		

Table 3 The coefficients of the 'Mass-Temperature' relation for the stars of the different-type eclipsing systems

Type	Q ≠ 0				Q = 0			
	e	f	k	n	e	f	k	n
MS_1	3.75 ±0.02	0.58 ±0.03	0.98 ±0.05	15	3.76 ±0.02	0.59 ±0.03	0.95 ±0.05	56
MS_2	3.76 0.02	0.59 0.03	0.99 0.04		3.76 0.01	0.63 0.02	0.96 0.04	
$SimCW_1$		Correlations are not significant		3	3.77 0.01	0.20 0.07	0.90 0.31	4
$SimCW_2$		Correlations are not significant			3.76 0.04	0.72 0.22	0.92 0.28	
CW_1		Correlations are not significant		11	3.74 0.01	0.35 0.10	0.71 0.21	13
CW_2		Correlations are not significant				Correlations are not significant		
CE_1	3.83 0.03	0.40 0.04	0.89 0.10	23	3.83 0.01	0.45 0.02	0.95 0.04	66
CE_2	3.83 0.02	0.47 0.03	0.95 0.07		3.84 0.02	0.41 0.03	0.88 0.06	
SD_1	3.81 0.01	0.47 0.02	0.93 0.05	62	3.80 0.03	0.50 0.05	0.93 0.09	18
SD_2	3.80 0.01	0.36 0.03	0.82 0.07		3.80 0.03	0.24 0.08	0.63 0.19	
DS_1	3.71 0.06	0.64 0.19	0.92 0.28	4	3.79 0.03	0.44 0.05	0.96 0.11	9
DS_2		Correlations are not significant			3.78 0.04	0.39 0.09	0.86 0.19	
AR_1		Correlations are not significant		7		Correlations are not significant		6
AR_2		Correlations are not significant				Correlations are not significant		

Table 4 The values of the coefficients α, β, γ for the stars in the eclipsing binary systems, according to the sequence of their evolutionary stage

Type	Q ≠ 0			Q = 0		
	α	β	γ	α	β	γ
MS_2	3.61 ±0.12	0.55 ±0.02	0.59 ±0.03	3.96 ±0.13	0.70 ±0.04	0.63 ±0.02
MS_1	3.60 0.12	0.59 0.04	0.58 0.03	3.91 0.10	0.70 0.04	0.59 0.03
SD_1	3.48 0.09	0.71 0.04	0.47 0.02	3.68 0.16	0.74 0.14	0.50 0.05
CE_2	3.31 0.24	0.83 0.10	0.47 0.03	2.92 0.12	0.63 0.03	0.41 0.03
CE_1	3.10 0.15	0.96 0.09	0.40 0.04	3.20 0.07	0.66 0.03	0.45 0.02
SD_2	2.34 0.19	0.46 0.06	0.36 0.03	1.43 0.48	0.38 0.14	0.24 0.08