MASS LOSS AND MASS TRANSFER IN ALGOLS

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ABSTRACT

We have examined the observational data of 60 Algols in order to check some theoretical views on mass loss and mass transfer in Algols. Not negligible contradictions between some theoretical non-conservative attempts and the observational scenario have been emphasized.

INTRODUCTION

The evolutionary status of Algols has been qualitatively explained in terms of mass exchange, but the agreement between theory and observations is still poor, since the scenario is complicated by possible loss of mass and angular momentum from the binary systems. In this study we have touched on some general aspects of mass loss and mass transfer in Algols by examining the observational data of 60 Algol-type binaries (known as sd or sd-d systems), whose lightcurves have been analyzed by means of modern techniques of lightcurve synthesis. More specifically, from the total mass, the orbital period, and the mass ratio of these Algols, we tried to estimate the original period and total mass of each binary, focusing our attention on the conservative case (i.e., total mass M and total angular momentum J constant) and on the two very different hypotheses of mass and angular momentum loss proposed by Plavec et al. (1973) (PUP) and by Drobyshevski and Reznikov (1974) (DR). The PUP approach takes f (=fraction of the mass exchanged, which is lost from the system) as a free parameter and is characterized by a relatively small ratio (g) between the specific angular momentum of the lost matter and that of the original system; g is defined as follows:

M. J. Plavec, D. M. Popper and R. K. Ulrich (eds.), Close Binary Stars: Observations and Interpretation, 207–210.

$$g=(1-J/J_o)(1-M/M_o) \qquad (1)$$

where J_o and M_o are the initial values of J and M. The DR approach is characterized by intermediate values of f ($0.4 \leq f \leq 0.6$) and relatively high values of g ($g \cong 3$).

ORIGINAL PERIODS AND MASSES

Table 1 lists the parameters used in our computations for each binary, i.e., the period P (in days), the mass ratio $q=M_c/M_h$ (M_h=mass of the hotter component, M_c=mass of the cooler component) and the masses M_h and M_c (in solar units) of each component, as found in the literature. The data of the double-lined spectrum binaries (starred in Table 1) have been taken from Batten et al. (1978), except for δ Lib (see Tomkin 1978) and β Per (see Tomkin and Lambert 1978). For the remaining stars, photometrically determined mass ratios along with estimates of the masses have been taken from Cester et al. (1979), Chambliss (1976), Mancuso et al. (1977), Mardirossian et al. (1979a), Mardirossian et al. (1979b), Mezzetti et al. (1979a), and Mezzetti et al. (1979b). In some cases we have evaluated the errors on M_h, M_c, and q, by inspecting the original published data.

In the conservative case the original period P_o and total mass M_o follow from the formulae:

$$M_o=M \qquad (2)$$

$$P_o=P(q/q_o)^3(1+q_o)^6/(1+q)^6 \qquad (3)$$

where $q_o \geq 1$ is the original mass ratio.

Within the framework of the PUP approach it is easy to work out the initial values for total mass and period:

$$M_o=M(1+q_o)(1+q(1-f))/((1+q)(1+q_o(1-f))) \qquad (4)$$

$$P_o=P(q/q_o)^{3-3f}((1+q)/(1+q_o))^2(1+q_o(1-f))^{8-3f}(1+q(1-f))^{3f-8} \qquad (5)$$

where f is a free parameter.

For estimating P_o and M_o, DR give the following analytical formulae:

$$M_o=M((1+1/q_o)(1+1/q))((1+1.59/q)(1+1.59/q_o))^{1.02} \qquad (6)$$

TABLE 1

N	Star	P	q	M_h	M_c
1	TW And	4.1228	0.19±0.01	2.4±0.9	0.5±0.2
2	XZ And	1.3573	0.47±0.03	3.2	1.5
3	RW Ara	4.3674	0.21±0.01	3.2	0.7
4	IM Aur	1.2473	0.26±0.01	4.4±0.7	1.1±0.2
5	SU Boo	1.5612	0.11±0.03	2.7	0.3
6	Y Cam	3.3055	0.24±0.02	1.7±1.0	0.4±0.2
7	RZ Cnc *	2.1643	0.18±0.03	3.1±0.2	0.6±0.1
8	R CMa	1.1359	0.17±0.01	1.1±0.8	0.2±0.1
9	RZ Cas	1.1953	0.35	1.75	0.61
10	TV Cas	1.8126	0.41±0.07	3.8±1.5	1.6±0.6
11	TW Cas	1.4283	0.41±0.02	2.9±0.3	1.2±0.1
12	U Cep *	2.4930	0.67±0.07	4.2±0.6	2.8±0.5
13	XX Cep	2.3373	0.17±0.07	1.4±1.4	0.2±0.2
14	U CrB *	3.4522	0.38	6.7	2.6
15	RW CrB	0.7264	0.22±0.01	2.0±0.6	0.4±0.1
16	SW Cyg	4.5730	0.21±0.03	2.5±1.6	0.5±0.3
17	VW Cyg	8.4303	0.28±0.04	2.1±1.5	0.6±0.5
18	WW Cyg	3.3178	0.31±0.05	6.2±2.6	1.9±0.8
19	ZZ Cyg	0.6286	0.63±0.03	1.8	1.1
20	MR Cyg *	1.6770	0.56±0.06	4.5±1.1	2.5±0.4
21	V548Cyg	1.8053	0.29±0.01	3.9±0.5	1.1±0.1
22	W Del	4.8060	0.18±0.02	3.2±1.3	0.6±0.2
23	TW Dra	2.8069	0.39±0.01	2.2±0.2	0.9±0.1
24	AI Dra	1.1988	0.43±0.02	2.7±1.1	1.1±0.5
25	S Equ	3.4361	0.12±0.01	3.1±1.2	0.4±0.1
26	AS Eri *	2.6642	0.11±0.01	1.92±0.04	0.208±0.009
27	RW Gem	2.8655	0.29±0.01	5.6±1.1	1.6±0.3
28	RX Gem	12.2085	0.20±0.05	3.4±2.0	0.7±0.4
29	AL Gem	1.3913	0.10±0.01	1.3	0.1
30	UX Her	1.5489	0.21±0.01	2.7±0.6	0.6±0.1
31	AD Her	9.7666	0.33±0.01	2.9±0.3	0.9±0.1
32	V338Her	1.3057	0.16±0.01	1.8	0.3
33	u Her *	2.0510	0.36±0.01	7.7±0.2	2.8±0.1
34	T LMi	3.0199	0.10±0.03	6.1±4.8	0.6±0.4
35	δ Lib *	2.3274	0.35±0.01	4.7±0.2	1.7±0.2
36	RW Mon	1.9061	0.33±0.10	4.0±3.0	1.3±0.9
37	TU Mon *	5.0490	0.21±0.06	12.7±2.3	2.7±0.6
38	AR Mon *	21.208	0.30±0.01	2.69±0.10	0.80±0.05
39	RV Oph	3.6871	0.10±0.01	3.2	0.3
40	AW Peg *	10.6225	0.16±0.03	2.0±0.1	0.32±0.05
41	β Per *	2.8673	0.22±0.01	3.7±0.3	0.81±0.05
42	RT Per	0.8494	0.24	1.71	0.42
43	ST Per	2.6484	0.16±0.03	3.3±1.9	0.5±0.3
44	IZ Per	3.6877	0.31±0.10	3.2±2.5	1.0±0.7
45	Y Psc	3.7658	0.25±0.01	2.8±0.6	0.7±0.2
46	XZ Pup	2.1924	0.41±0.01	3.0±0.3	1.2±0.1
47	U Sge *	3.3806	0.33±0.02	5.8±1.0	1.9±0.3
48	XZ Sgr *	3.2755	0.14±0.02	1.9±0.8	0.3±0.1
49	V356Sgr *	8.8961	0.38±0.05	12.2±1.0	4.7±0.4
50	v505Sgr	1.1829	0.49±0.01	2.7±0.3	1.3±0.2
51	μ^1 Sco *	1.4463	0.66±0.01	13.6±0.4	9.0±0.2
52	λ Tau *	3.9530	0.27±0.02	6.8±0.3	1.8±0.1
53	RW Tau	2.7688	0.19±0.01	5.5±0.9	1.0±0.2
54	X Tri	0.9715	0.51±0.06	2.3±0.7	1.2±0.3
55	TX UMa *	3.0632	0.30±0.03	3.6±1.1	1.1±0.3
56	VV UMa	0.6874	0.21±0.01	2.4±0.5	0.5±0.1
57	W UMi	1.7012	0.48±0.01	2.4±0.3	1.2±0.2
58	Z Vul *	2.4549	0.43±0.05	5.4±0.4	2.3±0.2
59	RS Vul *	4.4777	0.31±0.03	4.4±0.7	1.4±0.2
60	BE Vul	1.5520	0.40±0.03	3.2	1.3

$$P_o = P/\exp(4.92(q^{1/2}-q_o^{1/2})+3.52(q^{-1/2}-q_o^{-1/2})-$$
$$-0.115(q^{-3/2}-q_o^{-3/2})+0.0028(q^{-5/2}-q_o^{-5/2}) \qquad (7)$$

DISCUSSION

Our results may be profitably discussed if one bears in mind Popov's (1970) analysis. He found $1/3 \leq f \leq 2/3$ for the less massive binaries, $f \cong 2/3$, $g \cong 3$ for systems with $M \leq 6M_{\odot}$, $f=0.9$, $g \cong 1.5$ for systems with $6M_{\odot} \leq M \leq 12M_{\odot}$. The following conclusions can be drawn: (i) The conservative hypothesis can not account for the evolutionary scenario of all Algols; (ii) The PUP approach gives rise to serious problems for $M \leq 6M_{\odot}$ and too small g values with respect to Popov's, while for $M \geq 6M_{\odot}$ it is consistent with Popov's analysis; (iii) The DR approach can bring the $M \leq 6M_{\odot}$ systems into a consistent picture, but for $M \geq 6M_{\odot}$ the DR g value is greater than that given by Popov.

As regards the type of mass transfer, case A and B seem to predominate in systems with $M \geq 10M_{\odot}$ and $M \leq 6M_{\odot}$ respectively; both cases or case AB seem to be possible for $6M_{\odot} \leq M \leq 10M_{\odot}$.

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