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LOSS OF ORBITAL ANGULAR MOMENTUM AND PERIOD CHANGES IN ALGOLS

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Abstract. The observational data of Algols have been examined in order to clarify the implication of the assumption concerning the orbital angular momentum loss on their orbital period change. It is found that the agreement between theory and observational data of Algols is much better when a non-conservative approach of evolution is adopted.

1. Introduction

The conventional theory of binary evolution (Paczynski, 1971), in which total mass and orbital angular momentum are conserved, faces great difficulties in explaining the evolutionary processes, period variations and luminosity excesses of the cooler secondary in the Algol-type systems. The term Algol-type systems means those semdetached binaries whose less massive components filling their Roche lobes, are apparently more evolved.

In an earlier paper (Chaubey, 1979b; hereafter referred to as Paper I) it has been found that, for the same mass, a semi-detached binary system has a larger orbital angular momentum than that of a contact system and less than that of a detached one. Based on the empirical relations between the systemic mass and orbital angular momentum, this latter finding implies that in a close binary system the orbital angular momentum decreases during its evolution. These results have already been used by us in studying the evolutionary process of 54 semi-detached binaries (Chaubey, 1980b; hereafter referred to as Paper II). The conclusion given in Paper II, i.e. all the observed semi-detached binary stars are evolving in Case B, is recently confirmed by Mardirossian and Giuricin (1982) and Giuricin *et al.* (1983).

In this paper the initial values of orbital period P_0 for 50 Algol type binaries, by using the relations given in Paper I, have been computed and then compared with the observational data. The binaries studied in this investigation are listed in Table I.

2. Initial Orbital Period

The initial orbital period, P_0 has been calculated from the relations:

$$H = \left(\frac{G^2}{2\pi}\right)^{1/3} \frac{\mu_0}{(1+\mu_0)^2} P_0^{1/3} M^{5/3} \tag{1}$$

and

$$\log H = 1.8 \log M - 1.98. \tag{2}$$

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TABLE I

Comparison between the computed period ratio and observed trend of period variation in Algols

No.	Binary	Computed P_0/P	Observed trend of period variation		
			Trend	Year of observations	Reference*
1	RT And	2.18	decrease	1913–1967	1
2	TW And	0.49	increase	1909–1965	1
3	IM Aur	2.10	–	–	–
4	Y Cam	0.51	increase	1890–1966	1
5	TV Cas	1.62	decrease	1900–1977	2
6	TW Cas	1.84	decrease	1901–1967	1
7	RZ Cas	1.67	decrease	1897–1982	3
8	XY Cep	0.99	–	–	–
9	GK Cep	3.03	–	–	–
10	U Cep	1.26	increase	1828–1976	4
11	S Cnc	0.65	increase	1848–1971	4
12	U CrB	0.85	increase	1856–1965	4
13	KU Cyg	0.08	increase	1929–1963	4
14	SW Cyg	0.53	increase	1890–1978	5
15	V367 Cyg	0.29	increase	1932–1972	1
16	V548 Cyg	1.34	–	–	–
17	W Del	0.45	–	–	–
18	AI Dra	2.76	–	–	–
19	TW Dra	0.89	increase	1858–1969	1
20	AS Eri	0.76	–	–	–
21	S Equ	0.69	–	–	–
22	UX Her	1.11	decrease	1913–1969	1
23	RX Hya	0.87	increase	1912–1964	1
24	CM Lac	1.60	decrease	1899–1967	1
25	TX Leo	1.02	–	–	–
26	Y Leo	0.78	–	–	–
27	CV Leo	3.11	–	–	–
28	UV Leo	3.74	decrease	1926–1966	1
29	δ Lib	1.34	–	–	–
30	TU Mon	0.89	–	–	–
31	UX Mon	0.47	–	–	–
32	TY Peg	0.41	–	–	–
33	β Per	0.87	increase	1783–1967	1
34	RT Per	2.23	decrease	1895–1967	1
35	ST Per	0.75	–	–	–
36	Y Psc	0.60	increase	1886–1958	1
37	AU Pup	2.63	–	–	–
38	V Pup	3.71	–	–	–
39	U Sge	0.89	increase	1895–1968	1
40	V Sge	5.05	–	–	–
41	V505 Sgr	2.06	–	–	–
42	V356 Sgr	0.51	–	–	–
43	μ_1 Sco	4.46	–	–	–
44	λ Tau	0.89	increase	1857–1976	4
45	RW Tau	0.87	increase	1857–1968	1
46	X Tri	2.54	decrease	1921–1974	1
47	VV UMa	3.01	–	–	–
48	TX UMa	0.78	increase	1904–1967	1
49	Z Vul	1.35	decrease	1895–1968	1
50	RS Vul	0.67	–	–	–

* 1. Kreiner (1971). 2. Chaubey (1979a). 3. Present study. 4. Kreiner and Ziolkowski (1978). 5. Chaubey (1980a).

In the above equations, H is the orbital angular momentum; G is the universal gravitational constant; μ_0 is the initial mass ratio of the systemic components; P_0 initial orbital period in days; and M is the systemic mass of the binary in solar units. Equation (1) is the well known relation between the orbital angular momentum, orbital period and masses of the systemic components of a binary star and Equation (2) is the empirical relation between the systematic mass and orbital angular momentum of detached binary stars, taken from Paper I.

In our calculation, we have assumed the initial mass ration $\mu_0 = 1.2$, which is the average mass ratio (hotter over cooler) for unevolved binaries. The data concerning the masses have been taken from Paper II. Table I shows a comparison between the computed orbital period ratio (P_0/P) and the observed trend of period variation in Algol-type binaries.

3. Discussion

The period variability of Algols have been studied by various investigators in relation to the binary evolution. Assuming the conservation of orbital angular momentum, it has already been shown (Huang, 1963) that during evolution the orbital period of all Algol-type binaries should increase because of increasing the

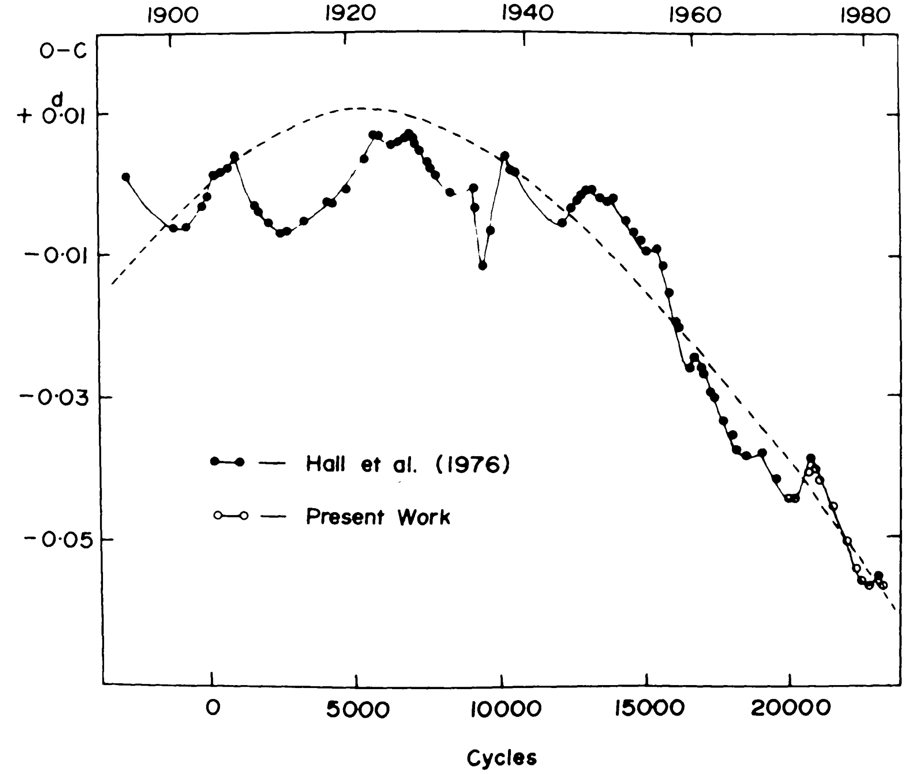

Fig. 1. The O–C curve of RZ Cas between 1897 and 1982. Points are the normal O–C i.e. residuals of the time of minimum light of RZ Cas based on the linear ephemeris: Min JD(Hel) = 2417355.4233 + $+1\overset{\mathrm{d}}{.}19525\,19$ E. The dashed curve is the best-fitting single parabola which suggests that the period is gradually decreasing.

difference in masses of the systematic components. But observationally it is not true for 40 % of the observed systems (Nos. 1, 5, 6, 7, 22, 24, 28, 34, 46, and 50) as listed in Table I. But keeping in mind that the mass ratio of the initial Main-Sequence progenitors of Algol-type binaries is 1.2, the non-conservative calculation of P_0/P is in agreement with the observations for nearly 96 % of our studied systems (except No. 10).

RZ Cas ($P = 1^{\mathrm{d}}.2$, $M = 2.3\,M_{\odot}$, and $q = 0.27$) is a system to consider as an example because it is one of the well observed, its O–C curve is clearly parabolic in the long term (Figure 1). Its O–C curve corresponds to a mean rate of period decrease of the order of 0.02 $\mathrm{s\,yr^{-1}}$. Hall *et al.* (1976), however, suggest that period decrease is not steady, but consists of a series of increase intrupted by sharp decrease. They explain these parabolic segments superimposed on a downward parabola very neatly into the theory of alternate period change model of Biermann and Hall (1973). The net effect is still decrease in period. On the other hand $P_0/P = 1.67$ computed by us, assuming the non-conservation of orbital angular momentum, also suggests a net decrease in orbital period of the system.

4. Selection Effects

Table II gives the agreement between the observed and computed trend of period variation based on non-conservation of orbital angular momentum for various initial mass ratio for the 26 Algols whose observational data, concerning their orbital period, are available (viz. Table I).

TABLE II

Computed trend of period variation for various initial mass ratio

μ_0	No. of systems
1.2	25
1.4	25
1.6	24
1.8	23
2.0	20

Thus in present investigation there appears to be no bias in favour of assuming the initial mass ratio 1.2 in very close to unity, which is the mass ratio of the Main Sequence progenitors of Algols (Lucy and Ricco, 1979; Garmany *et al.*, 1980; Van't Veer, 1981).

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