GRAVITATIONAL RADIATION AND SPIRALLING TIME OF CLOSE BINARY SYSTEMS (III)

(Letter to the Editor)

T. D. PADALIA

Uttar Pradesh State Observatory, Manora Peak, Naini Tal, India

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Abstract. Twenty-seven typical binary systems have been investigated to study their power-output by gravitational radiation (P_B) and spiralling time (τ_0) relation. It was found that these binary systems form two distinct groups. New relations have been given between P_B and τ_0 for each group.

1. Introduction

In continuation of our (Padalia, 1987, 1988) earlier work on this subject we have evaluated P_B and τ_0 values for 27 close binary systems for which absolute dimensions are known. New relations between P_B and τ_0 have been established. Out of these 27 systems, 19 binaries appear to form one group since they lie along one curve whereas the remaining eight systems follow another curve. The systems considered, for gravitational radiation study, are in the mass range 0.5 $M_\odot$ to 47 $M_\odot$. Unlike our second paper (Padalia, 1988) where almost all the systems discussed were B-type, the spectral type of the systems described in the present paper are from O to K.

The masses, period, spectral type, and radii of relative orbits adopted in the present paper are given in Table I.

2. Discussions and Results

For determining P_B and τ_0 values of individual systems, equations and assumptions used by us have been reported in Paper I (Padalia, 1987). However, for the sake of completeness, the equations are

$$P_B = \left(\frac{\mu}{M_\odot}\right)^2 \left(\frac{M}{M_\odot}\right)^{4/3} P^{-10/3} = 3.0 \times 10^{26}\ \mathrm{W}\,, \tag{1}$$

$$\tau_0 = \frac{5c^5 a_0^4}{256 G^3 \mu M^2}\,. \tag{2}$$

The values of P_B and τ_0 have been determined for 27 binary systems. Gravitational radiation P_B (in watts) along the X-axis and spiralling time τ_0 (in years) along the Y-axis have been plotted in Figure 1. It is found that X and Y follow the relations

$$Y = 0.0071X^3 + 0.1X^2 - 1.18X + 3.30$$

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TABLE I(a)

Gravitational radiation and spiralling time of nineteen binary systems

Name of the binary systems	Sp. type	$M_1(M_\odot)$	$M_2(M_\odot)$	Period in days	Radius of relative orbit $a_0(R_\odot)$	Power output $(P_B X$ (W)	Spiral time (τ_0) (years)	X $(\log P_B - 19)$	Y $(\log \tau_0 - 10)$
AO Cas	O9III, O9III	23.0	18.0	3.524	32.77	162858.4×10^{19}	1.01×10^{10}	5.218	0.004
V444 Cyg	O6, WN54.5	25.6	10.1	4.212	35.85	38428.4×10^{19}	2.06×10^{10}	4.584	0.315
CW Cep	B0.5, B0.5IV	11.8	11.1	2.730	23.30	34467.5×10^{19}	1.898×10^{10}	4.537	0.276
AO Mon	B3, B5	5.5	5.2	1.885	14.17	15712.5×10^{19}	1.92×10^{10}	4.196	0.283
U Oph	B5V, B5V	5.0	4.5	1.677	12.85	15369.6×10^{19}	1.87×10^{10}	4.186	0.273
U Her	M6.5E, G8III–IV	8.0	2.8	2.050	13.60	7154.0×10^{19}	2.08×10^{10}	3.854	0.319
AV Vir	K0V, K0V	1.4	0.6	0.408	2.22	6106.7×10^{19}	2.30×10^{10}	3.785	0.362
RX Her	A0V, A0V	2.7	2.3	1.779	9.74	1494.2×10^{19}	4.21×10^{10}	3.174	0.624
TV Cas	B9V, F7IV	3.1	1.4	1.813	8.89	706.5×10^{19}	4.80×10^{10}	2.849	0.681
CM Lac	A2V, A8V	2.0	1.5	1.605	8.51	610.9×10^{19}	7.38×10^{10}	2.786	0.868
U Cep	B7VE, G8III–IV	3.1	1.5	2.493	12.62	302.9×10^{19}	14.88×10^{10}	2.481	1.214
YY Gem	dM, E, –	0.5	0.5	0.814	5.02	136.2×10^{19}	27.02×10^{10}	2.134	1.432
WW Dra	G2IV, K0IV	4.0	2.3	4.630	21.60	121.2×10^{19}	53.52×10^{10}	2.083	1.726
TX Leo	A2V, –	2.4	1.0	2.445	11.10	97.0×10^{19}	27.6×10^{10}	1.987	1.441
β Aur	AP, B9V	2.3	2.2	3.960	19.57	76.7×10^{19}	90.3×10^{10}	1.884	1.955
AR Aur	AP, B9V	2.5	2.3	4.135	18.47	75.4×10^{19}	63.88×10^{10}	1.877	1.805
TX UMa	B8V, G0III	3.1	1.9	3.063	13.76	56.5×10^{19}	47.07×10^{10}	1.753	1.672
β Per	G2IB	3.1	0.7	2.867	11.71	49.3×10^{19}	32.00×10^{10}	1.693	1.505
Z Her	FIV–V	1.2	1.1	3.993	15.09	7.6×10^{19}	14.88×10^{10}	0.883	2.394

TABLE I(b)

Gravitational radiation and spiralling time of eight binary systems

Name of the binary systems	Sp. type	$M_1(M_\odot)$	$M_2(M_\odot)$	Period in days	Radius of relative orbit $a_0(R_\odot)$	Power output ($P_B X$ (W)	Spiral time (τ_0) (years)	X ($\log P_B - 19$)	Y ($\log \tau_0 - 10$)
UW CMa	O7IA, FP-OB	47.4	37.2	4.393	53.18	874112.9×10^{19}	7.98×10^9	5.941	− 0.098
AH Cep	B0.5V, B0.5V	16.1	13.9	1.775	18.05	576568.5×10^{19}	2.35×10^9	5.761	− 0.628
V470 Cyg	B2, B2	13.7	12.1	1.874	15.32	291844.6×10^{19}	1.92×10^9	5.465	− 0.718
AB And	G5, G5	1.8	1.1	0.332	2.81	61027.4×10^{19}	1.54×10^9	4.785	− 0.812
U Peg	F3, F3	1.3	1.1	0.375	2.21	22376.4×10^{19}	1.05×10^9	4.349	− 0.812
VW Cep	G5, K0VE	0.8	0.3	0.278	1.15	2192.5×10^{19}	1.22×10^9	3.341	− 0.914
V380 Cyg	B1III, B3V	13.9	7.9	12.426	27.66	264.3×10^{19}	7.91×10^9	2.422	− 0.102
RZ Com	K0, G9	1.6	0.8	0.339	2.836	251.4×10^{19}	3.11×10^9	2.400	− 0.507

for 19 binary systems and

$$Y = 0.23X^2 - 1.889X + 2.84$$

for remaining 8 binary systems, where

$$X = \log P_B - 19 \quad \text{and} \quad Y = \log \tau_0 - 10 .$$

The curves representing these equations are shown by solid lines in Figure 1. It is interesting to note that eight systems lying along the curve II in Figure 1 actually have the spiralling time range 10^9 year whereas the upper curve I in the same figure gives a spiralling time range of 10^{10} years for the remaining 19 binaries. The binaries lying along curves I and II of Figure 1 are listed in Tables I(a) and I(b), respectively. In our earlier papers we have found that P_B is inversely proportional to τ_0. This finding is also true for almost 19 binary systems of Table I(a). However, this relation of P_B versus τ_0 is not true for the remaining 8 systems listed in Table I(b).

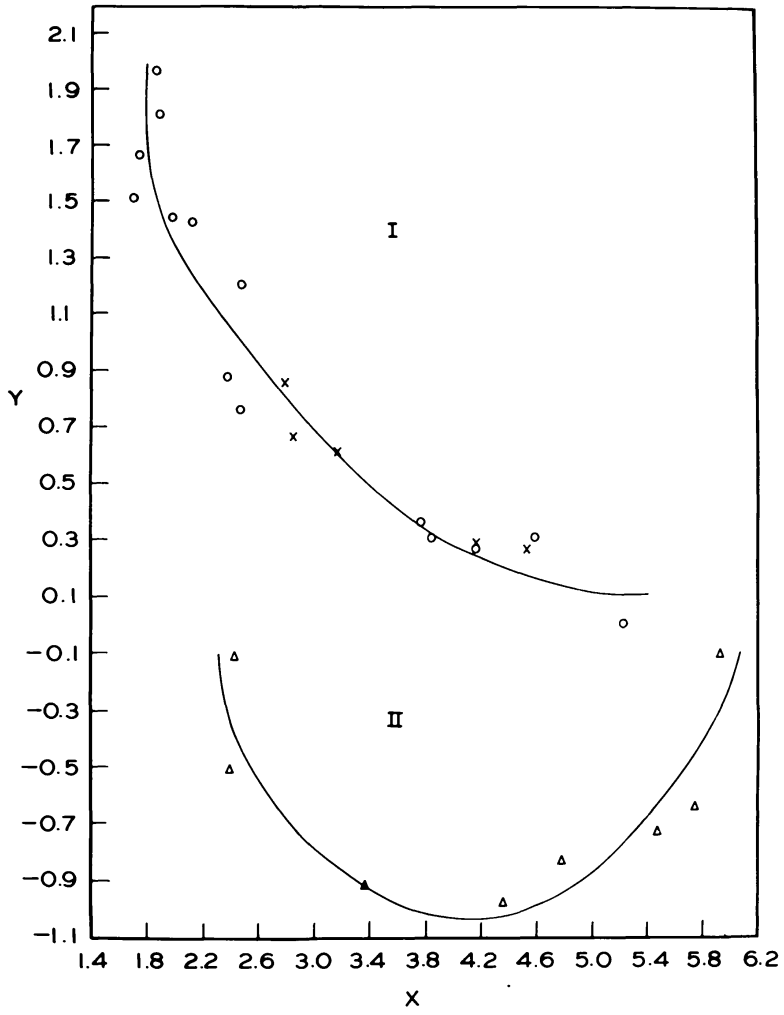

Fig. 1. Relation between spiralling time and gravitational radiation for 27 binary systems, curve I stands for 19 binary systems given in Table I(a) and curve II stands for the remaining 8 systems listed in Table I(b).

In Figure 1 of Paper I it was mentioned that the binary systems lie in two different parts of the curve, one from A to B and another from B' to C. The 5 systems lying in $B'C$ part of the curve were CM Lac, TV Cas, RX Her, AO Mon, and DW Cep. This left a question whether $B'C$ is the part of the curve AB or a separate curve. Here we find that all these 5 systems, makng mostly $B'C$ part of the earlier curve, fit very well in the present curve I of Figure 1. This indicates that these 5 systems belong to the present curve I of Figure 1 but not of Figure 1 of Paper I. These 5 systems are marked as crosses in Figure 1.

It is concluded from the present study that a large number of binary systems can be arranged to follow a few equations (of P_B and τ_0 relations), and subsequently an individual system can be catalogued as Equation (1) or Equation (2) binary, etc. For example in our Paper II (Padalia, 1988) all binaries in the mass range 7 to 19 $M_\odot$ and P_B, τ_0 range to 10^{23} W and 10^9 years, respectively, were found to be early type, mostly B-type binaries. However, this could not be true for the present 27 systems. For conclusive results investigation of a large number of binary systems is needed for finding out common properties of the systems following these equations.

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