GRAVITATIONAL RADIATION AND SPIRALLING TIME OF CLOSE BINARY SYSTEMS

(Letter to the Editor)

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Abstract. Power-output by gravitational radiation (P_B) and spiral time (τ_0) for individual systems of sixteen eclipsing binary stars have been evaluated, and a relation between P_B and τ_0 obtained.

1. Introduction

About 150 close binary systems have been considered by us for gravitational radiation study. These systems are mostly taken from a paper by Giannone and Giannuzzi (1974). The present study includes the following eclipsing binary systems: EI Cep, WX Cep, ST Per, VZ Hya, XY Cet, XY Cep, AS Cam, ZZ Cep and σ Aql, AO Mon, CW Cep, RT And, DI Peg, RX Her, TV Cas, CM Lac.

Absolute dimensions of EI Cep, VZ Hya, and AS Cam were determined by us (Padalia and Srivastava, 1975) and that of XY Cet by Srivastava and Padalia (1975) using our own light curves. The masses, period, and radii of relative orbits adopted in the present study are given in Table I.

2. Equations and Assumptions Used

For a binary system whose relative orbit is circular the power output by gravitational radiation P_B is given by the equation

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

where $\mu = m_1 m_2/M$ and m_1 and m_2 are masses of components of a binary system. $M = m_1 + m_2$, the total mass of the system, $M_\odot$ = the mass of the Sun, P = period of a binary system (in hours).

If a binary system has an elliptic orbit, the bodies will collide after a spiralling time given by Equation (2) – i.e.,

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

Parker (1983), where c is the velocity of light; a_0, the initial radius of the relative orbit; and G, the universal constant of gravitation. A few systems may have a very low orbital

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TABLE I

Gravitational radiation and spiral time of sixteen eclipsing binary systems

Name of the binary systems	$m_1(M_\odot)$	$m_2(M_\odot)$	Period (in days)	Radius of relative orbit $a_0(R_\odot)$	Power output (P_B) (W)	Spiral time (τ_0) (years)	X $(\log P_B - 19)$	Y $(\log \tau_0 - 10)$
ZZ Cep	4.10	1.90	2.142	2.89	1091×10^{19}	21.1×10^{10}	3.038	1.324
AS Cam	3.30	2.50	3.431	17.70	260.4×10^{19}	30.5×10^{10}	2.416	1.484
XY Cep	3.80	1.10	2.774	14.90	152.0×10^{19}	35.8×10^{10}	2.182	1.554
XY Cet	1.76	1.60	2.861	12.51	90.6×10^{19}	37.5×10^{10}	1.957	1.574
VZ Hya	1.20	1.10	2.904	11.40	21.5×10^{19}	82.7×10^{10}	1.332	1.917
ST Per	2.36	0.43	2.648	11.19	15.3×10^{19}	82.8×10^{10}	1.185	1.918
WX Cep	1.02	1.02	3.378	12.01	8.7×10^{19}	149.5×10^{10}	0.939	2.175
EI Cep	1.70	1.80	8.439	26.40	2.5×10^{19}	674.8×10^{10}	0.398	2.829
CW Cep	9.98	9.77	2.729	22.30	34467.5×10^{19}	1.89×10^{10}	4.537	0.276
σ Aql	6.80	5.40	1.950	18.95	20681×10^{19}	4.28×10^{10}	4.315	0.631 [1]
AO Mon	5.53	5.25	1.885	14.170	15712.5×10^{19}	1.92×10^{10}	4.196	0.283
RT And	1.52	1.00	0.629	4.12	4419.0×10^{19}	1.12×10^{10}	3.645	0.049
RX Her	2.72	2.32	1.779	9.75	1494.2×10^{19}	4.21×10^{10}	3.174	0.624 [a]
DI Peg	1.48	0.70	0.712	4.36	1491.3×10^{19}	2.38×10^{10}	3.173	0.376
TV Cas	3.10	1.39	1.813	8.89	706.5×10^{19}	4.80×10^{10}	2.849	0.681
CM Lac	2.01	1.50	1.605	8.51	610.9×10^{19}	7.38×10^{10}	2.786	0.868

Remarks:

[a] New observations are needed.

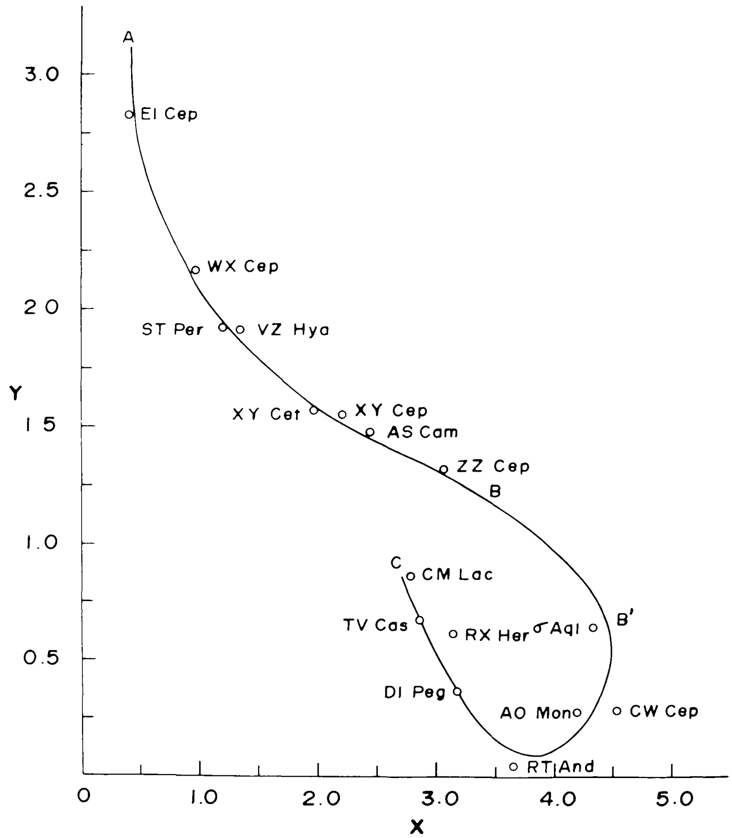

Fig. 1. Curve ABC showing parabolic relation between spiral time (along the Y-axis) and gravitational radiation (along the X-axis) for sixteen eclipsing binary systems, where $Y = \log \tau_0 - 10$ and $X = \log P_B - 19$. The solid curve indicate a free-hand curve drawn through the systems. The shape of the curve between B and B' is tentative.

eccentricity whereas the others may have considerable eccentricity (in case of AS Cam e determined by us is 0.157). Therefore, in determining the values of P_B and τ_0 for 16 systems in question, we have assumed that (1) the relative orbits are circular and (2) the orbits are elliptic.

3. Discussions and Results

Gravitational radiation P_B and spiral time τ_0 have been determined with the aid of Equations (1) and (2), respectively. The values are reported in Table I. The systems divided in two groups (between curve A to B and B to C) have been arranged in Table I following an order from maximum power output to minimum. It is interesting to note that the order of spiralling time is mostly reverse – i.e., that the system which has the maximum power output has the shortest spiralling time, or it should collapse first. The order of spiralling time may vary slightly within the uncertainties of the parameters determined by various authors, or else they are poorly observed.

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 (curve ABC). It is found that X and Y follow the relation, viz.:

$$Y = \frac{2.1}{X^{1/2}} \pm 0.1\,, \tag{3}$$

where $X = \log P_B - 19$ and $Y = \log \tau_0 - 10$ for the part A to B, and from B to C follows a parabolic relation:

$$Y = \frac{(X - 3.8)^2}{1.5} + 0.1\,. \tag{4}$$

However, the systems which happen to lie in the region B to B' are yet to be investigated.

4. Conclusions

Gravitational radiation for the remaining 134 close binary systems have also been determined by us. Spiralling times will be determined for the systems for which radii of relative orbits are available. The above relations (3) and (4) are of new type. These can be used to catalogue in a different way a large number of binary systems falling in various mass groups, period, and evolutionary status. More can be concluded for the systems lying right, left or on the curve ABC, itself.

Since P_B depends on ω (angular velocity of a single star) it may happen that two systems may have the same mass and period but different values for P_B. In that case, the two systems will be situated in different portions of the $\tau_0 - P_B$ diagram if the values are different for the two systems. This may explain the fact that one such system lies on the curve AB while the other system far away along the X-axis for the same spiralling time. If higher gravitational radiation is observed, this may indicate that the system has components of high rotational velocity which would compensate for extra gravitational radiation, or else some alternative explanation may be required.

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