REMARKS ON THE COMPLICATED CLOSE BINARY SYSTEMS RT LACERTAE, CG CYGNI, AND RW CORONAE BOREALIS

E.F. Milone and S.A. Naftilan
Rothney Astrophysical Observatory,
The University of Calgary.

The three systems differ in period, scale and degree of contact: RW Com is a contact system, RT Lac is semi-detached and CG Cyg is a detached system. Yet they share the properties of a variable asymmetric light curve in the UBV, Ca II H and K emission, apparent infrared excesses, and period variability. If it may be argued that this ensemble of symptoms has similar origins in the different systems, then our intensive studies of these three binaries may have implications for the nature of all systems showing the RS CVn properties. We feel that the evidence points to the presence of circumstellar matter in the three binaries. We pose the questions: does this material create the photometric pecularities, is it incidental to them or does it arise from some other light-curve perturbing source?

Salient properties of the systems are reproduced in Table I and the evidence for mass loss or exchange in Table II. The systems are discussed individually below.

RT Lac has been included in the list of RS CVn systems or rather a list of close binaries with H & K emission by Popper (1976). A preliminary solution has been published by one of us (Milone, 1977) and a spot model for it published by Eaton and Hall (1979). RT Lac has a regressing sinusoidual distortion in its light curve. The amplitude of this distortion is greater at shorter wavelengths; for example, in the 1965 light curve the difference between maxima was 0.12, 0.17, and 0.24 mag. in V, B and U respectively. This and other circumstances indicate that the more massive star, seen at primary minimum, and having the later spectra type, *viz*, K1(IV), is more responsible for the distortion than is the other component. The most interesting property of the system is the apparent paradox raised by the blue primary minimum and the red secondary minimum; this datum alone suggests the presence of an envelope around the more massive (what we call the primary) component. Other arguments for circumstellar material in this system are as follows: 2) Our preliminary solution indicated that the secondary star is larger than the star it eclipses at secondary minimum but smaller than that which eclipses it at primary minimum; 3) The

M. J. Plavec, D. M. Popper and R. K. Ulrich (eds.), Close Binary Stars: Observations and Interpretation, 419–422.

https://doi.org/10.1017/S0074180900065256 Published online by Cambridge University Press

secondary star is within 10% of filling its Roche lobe (Milone, 1976), providing the enabling condition for mass transfer; 4)Hall and Haslag (1977) have presented evidence of period changes and also 5)noted a change in light curve shape from an Algol-type light curve to a β-Lyrae type in the second decade of this century and again towards the end of the third; and 6)in 1972 and 1974 the system had both phase-independent and phase-dependent infrared excesses at JHK and L (Milone, 1976). A reasonable explanation for the phase-independent component is an anomalous interstellar reddening, brought about by material lost from the system. A simple spot model appears inadequate to explain these phenomena, although the presence of spots cannot be excluded.

TABLE I - Properties of the Systems

System	P	Sp	M_g/M_s	L_g/L_s	r_g,r_s
RT Lac	$5^{d}.07$	G9IV,K1IV	0.40	0.59,0.41	0.28,0.26
CG Cyg	0.63	G9V,K3V	1.0	0.46,0.54	0.28,0.22
RW Com	0.24	$\lesssim$G5V		[0.65,0.35]:	

The photometric observations of the dwarf system CG Cyg are discussed in detail by Milone et.al., (1979a); therefore the properties are only briefly summarized here. CG Cyg has increased in brightness by about 14% since 1965. Between 1965 and 1967 it suffered an abrupt change in period amounting to -2.5 (±0.8) dex (-6) day. Since then, the O-C curve has been following a parabola implying that $\dot{P} \sim 3.0$ (±0.6) dex (-10) day/day. In addition to variable H and K emission, CG Cyg has a migrating light curve distortion which is somewhat blue, and is advancing at an accelerating rate. This acceleration may be tied to the period increase and we are investigating this possibility. A study of the details of the light curve at every epoch, including a fine light curve of Jassur (1978) suggests that substantial variation may occur over periods of weeks or less. In particular, the regions in the maxima near external contact seem especially susceptible. Recent synthetic light curve runs, using Wood's code, have succeeded in fitting the minima from nearly every epoch but show varying degrees of departure at the maxima. In 1972 and 1974 and probably in 1977 as well, the apparent infrared excess measured in this system has been modest; $\lesssim$ 0.15 magn; with new observations made at Mt. Lemmon in April 1979, we will be able to examine the long-term variability in the infrared although the phase behavior is not well known at any epoch. There is also evidence for a strong ultraviolet excess in the system: the primary minimum in U is too deep to fit any reasonable model consistent with B and V and the ultraviolet flux at maximum light predicted for a combination of stars of the same spectral types and with the same intrinsic V in combined light is less than what is observed. The H and K emission appears to be equally strong from both components, but since the eclipsing star at PM is contributing about 35% of the system's light in the maxima, it is relatively speaking, the stronger emitter at H & K. Present work indicates that the observed light curves could not be reproduced with a spot model alone. Finally, our spectroscopic study of this system (Naftilan and Milone 1979) has revealed 1) that the masses are equal; and 2) the presence of a weak but persistent emission component present at both quadratures near the systemic velocity, identifying material to be present at or near L_1 or around the system. These properties are consistent with the presence of circumstellar matter in the system although the period changes are not attributable to mass exchange in a simple way. Again they do not exclude spots from being present.

TABLE II - Mass Exchange/Loss Indicators

Indicator/System	RT Lac	CG Cyg	RW Com
Period change	Discrete, then smaller cyclic variations.	Discrete, then parabolic;	Parabolic
$\dot{P}$ or ΔP	+8.3 dex (-5) day.	-2.5 (±0.8) dex (-6) day; +3.0 (±0.6) dex (-10) day/day.	-0.40 dex (-10) day/day.
Roche lobe (y_g)	0.29	0.37	$\lesssim r_g$ (contact system).
Infrared Excess (2.2μ)	∿0.7 magn.	$\lesssim$0.15 magn.	∿0.6 magn.
Ca II H & K emission	From both comps., but peaks at P.M.	From both stars and a component at γ-velocity.	From both components.

All known light curves of the W UMa system RW Com were examined (Milone et.al., 1979b), and revealed a long-standing asymmetry - a brighter second maximum - with short term fluctuations. There is no evidence of a migration of this distortion feature, and it is not satisfactorily represented as a simple sine wave. The asymmetry at maximum, or the "O'Connell Effect", amounts to dV ∿ 0.07 and appears slightly blue; in the infrared, it is less than half this amount, and has the same sign. The system has a relatively large infrared excess at both maxima (Milone et.al., 1978). Significant variations in the Fourier representations of the light curve are found from epoch to epoch and the O-C data for the minima also differ significantly from epoch to epoch. The period has clearly varied and may be continuously decreasing; the weighted mean, $\dot{P}$ = -0.40 (±0.03) dex (-10) day/day. The H & K emission was discovered by Struve (1950, who noted that it appeared weak and complex at each maximum but strong at each minimum. He also noted that the Ca K_1 absorption feature was stronger from the approaching star at each quadrature. We have not yet been

https://doi.org/10.1017/S0074180900065256 Published online by Cambridge University Press

able to obtain sufficiently high-resolution, short-exposure plates to confirm this effect. Two spectrograms have revealed a spectral type of $\lesssim$ G5 for the combined light; the G5 assignment, however, rests on the weakness of the Balmer lines, so that Struve's G2 classification for each component may prevail, the discrepancy being attributable to in-filling by emission in Hγ and Hδ. Using Rucinski's (1973) A_4/A_2 criterion, the fill-out parameter is about 0.9, so that considerable space is available between the inner and outer Lagrangian surfaces for material to circulate about both stars. It is difficult to understand how spots can account quantitatively for the infrared or even qualitatively for the reported radial velocity effects in this system. The infrared excess determination based on 1972 and 1974 material has been confirmed with a preliminary examination of 1977 Mt. Lemmon data. The apparent excess depends on the adopted spectral types but it is out of the question that the spectra are later than G5 at maxima, though the minima are assumed to be later and redder. An assignment of G8 to the cooler component is appropriate for the ratio of visual surface brightnesses, $J_g/J_s = 1.17$, obtained in one of the limiting solutions: total secondary occultation.

All three of these systems have properties which strongly implicate the presence of circumstellar matter. All three show period changes and infrared excesses (which are computed using the latest possible spectral types - appropriate to the gravity-darkened elongated ends of the stars seen at the minima - and allowing for a reasonable amount of interstellar reddening). Because of the size of some of the effects it appears that circumstellar material is contributing in an important way to the photometric pecularities.

REFERENCES

Eaton, J. and Hall, D.S.: 1979. Astrophys. J. 227, p. 907.
Hall, D.S. and Haslag, K.P.: 1976, in IAU Colloquium No. 29, Multiple Periodic Variable Stars, Part II, ed. W.F. Fitch (Budapest: Academic Press), p. 331.
Jassur, D.M.Z.: 1978. IAU Com. 27, Inf. Bul. Var. Stars, No. 1458.
Milone, E.F.: 1976. Astrophys. J. Suppl. 31, p. 93.
Milone, E.F.: 1977. Astron. J. 82, p. 998.
Milone, E.F., Castle, K.G., Robb, R.M., Swadron, D., Burke, E.W., Michlovic, J.E., and Zissell, R.E.: 1979a. Astron. J. 84, p. 417.
Milone, E.F., Chia, T.T., Castle, K.G., Robb, R.M., and Merrill, J.E.: 1979b. Astron. J. submitted for publ.
Naftilan, S.A. and Milone, E.F.: 1979. Astron. J. 84, p. 1218.
Popper, D. 1976: IAU Com. 27, Inf. Bul. Var. Stars, Nos. 1083, 1090.
Rucinski, S.M.: 1973. Acta Astr. 23, p. 79.
Struve, O.: 1950. Astrophys. J. 111, p. 658.