THE ASTROPHYSICAL JOURNAL, 319:325–333, 1987 August 1

RW COMAE BERENICES. III. LIGHT CURVE SOLUTION AND ABSOLUTE PARAMETERS[1]

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Received 1986 November 17; accepted 1987 January 22

ABSTRACT

UBV light curves of the W-type W UMa system RW Com have been modeled with the Wilson-Devinney synthetic light curve program and solution elements have been recovered despite the presence of a large O'Connell effect in the light curves. In the first stage, the asymmetries in the light curves were rectified by subtraction of sine terms from the Fourier fit before the basic elements were obtained. Although most of the modeling was carried out in a contact system mode, trials were also carried out for semidetached models, the results of which confirmed the contact nature of the system. In the next stage, the unrectified light curves were modeled by placing large spots on both components, and on each separately, to represent the asymmetric light variations with phase. The presence of spots in the model causes certain elements, most noticeably the orbital inclination, to differ from the sine-rectified light curve solution. The differences are small enough, however, to give limited confidence in the technique of sine rectification. An investigation of the optimum spot temperature was performed in the case of a cool spot on the cooler component. The absolute parameters were derived for the rectified case. The system is a W-type W UMa system in which the smaller and less massive component is the hotter one. The mass ratio of the system is about 2.9, as discussed in the second paper in this series. Combining the present results with those of that paper, we find the masses to be 0.20 ± 0.03 (s.d.) and 0.56 ± 0.06 solar masses; the bolometric magnitudes are 6.76 ± 0.24 and 5.97 ± 0.26, for the hotter and cooler components, respectively. The separation of centers is 1.48 ± 0.01 solar radii and the ratio of radii about 0.6. The components are shown to be in shallow contact with a contact parameter of 0.17 ± 0.02. If the system does not suffer from circumstellar absorption, its distance is 115 ± 13 pc.

On kinematic grounds, RW Com is not a member of the Coma star cluster despite its proximity on the plane of the sky.

Subject headings: clusters: open — stars: eclipsing binaries — stars: individual (RW Com) — stars: W Ursae Majoris

I. INTRODUCTION

The late-type W UMa system RW Com has been investigated photometrically (Milone *et al.* 1980, hereafter Paper I) and shown to have a variable light curve, with a large and apparently relatively stable, though not constant, O'Connell effect (asymmetry at maximum light) at optical wavelengths (Milone 1986), and a variable period. Paper I discusses the history of the O'Connell effect in RW Com; the O'Connell effect itself is comprehensively discussed by Davidge and Milone (1984). Since Paper I, additional optical light curves have been obtained by Hoffmann (1979) and by E. F. M. It has also been studied spectroscopically (Milone *et al.* 1985, hereafter Paper II), from which the mass ratio and systemic velocity were obtained. On the basis of earlier spectroscopic work, and preliminary light curve analysis, it was concluded (Milone 1976) that RW Com had infrared excesses at the *JHK* and *L* bands compared to the fluxes predicted for stars of the mid-G to late-G spectral types. In addition, infrared light curves obtained from 1977 and from 1979 at the Infrared Telescope Facility operated by the University of Minnesota and the University of California–San Diego on Mount Lemmon and *JHKL* light curves obtained by A. Longmore at the UKIRT facility on Mauna Kea have been reduced and are being analyzed. They and their solutions will be discussed elsewhere along with previously unpublished optical light curves. The system's variability precludes the combination of light curves from different epochs, so that in the present study only the most complete light curves thus far published—the *B* and *V* KPNO light curves from 1977 (Paper I)—were used to obtain the system solutions.

II. SINE-RECTIFIED LIGHT CURVE ANALYSIS

Light curve analysis has been difficult to carry out for RW Com. There were two initial problems: the lack of a mass ratio, a major source of indeterminacy in a partial eclipse light curve: and the large O'Connell effect.

The first problem was diminished by obtaining the spectroscopic mass ratio. This has become possible only in the last decade with the developments of the image intensifier, more sensitive plates, the reticon, and finally cross-correlation codes such as that of G. Hill (1982). That program now has been successfully applied to the blended, broadened, double-lined spectra that characterize the cool W UMa systems. The advantages of this technique for radial velocity work on short-period,

[1] Publications of the Rothney Astrophysical Observatory, No. 43.

late-type W UMa systems are discussed by Hrivnak *et al.* (1984) and in Paper II, in which preliminary values for the mass ratio, systemic velocity, and projected semi-major axis of RW Com are presented.

The O'Connell effect in the 1977 light curves amounted to $\Delta m \equiv m_{II} - m_I = -0.07 \pm 0.01$, -0.08 ± 0.03, and -0.08 ± 0.03 in the V, B, and U bands, respectively. It was dealt with in two ways. An important first step was to obtain provisional elements which could be further tested. Only the B and V light curves were used for this initial modeling. The light curves were partially rectified through the subtraction of the outside of eclipse sine terms of the Fourier representations. This is similar to the subtraction technique described by Russell and Merrill (1952) but without assignment of cause to either component. The Fourier coefficients are discussed in Paper I. The system was then modeled with a recent version of the Wilson-Devinney (Wilson and Devinney 1971; Wilson 1979) program, and run on the Honeywell Multics computer at the University of Calgary. The program was run in a mode in which the components are shaped to a common equipotential surface, appropriate for contact systems, except for some tests for the semidetached condition, which are described below. The initial values for the temperatures, mass ratio, and semimajor axis were taken from the spectroscopic study. The surface potentials (Ω) were determined from the latter two quantities, and the hotter star's temperature (T_1) was fixed at 5400 K from the adopted G8 system spectral type (Paper II). The initial blue light luminosity ratio was obtained from the relative strengths of the peaks in the cross-correlation functions obtained in the spectroscopic study. Limb-darkening coefficients $x_{1,2}$ were taken from Al-Naimiy (1978). The bolometric albedoes $A_{1,2}$ from the work of Rucinski 1969, and the gravity-darkening exponents $g_{1,2}$ from Lucy (1967), appropriate for convective atmospheres, were adopted. No attempt was made to adjust these parameters. The relative light curve weights were derived from the mean standard error of the fit (i.e., the standard deviation of a single observation) of the full intensity light curve to a nine-term Fourier representation. The values of the quantity σ in the differential corrections (dc) program adopted for these and other fittings were ± 0.007, ± 0.011, and ± 0.022 for V, B, and U, respectively. The weights of the individual normal point observations were obtained from the larger of the following two quantities: the standard deviation of a single observation in the normal point and the standard deviation of a single observation in the light curve divided by the square root of the number of observations making up the normal point. As a consequence of this weighting scheme, the usual application of the level-dependent weights was bypassed by setting the quantity *noise* equal to zero for all light curves. Trial runs with *noise* = 1 did not, however, change the results significantly. Several initial values of the inclination were tested. The parameters which were adjusted included the inclination, the temperature of the second component, the surface potential, the luminosity of the first component, and third light. The usual convention of designating as component *1* that star which is eclipsed at zero phase has been adopted here. It was immediately perceived that third light was not significant and modeling proceeded with adjustments only to the remaining parameters. Third light adjustments appeared to be important initially for one of the several spot models, however, and will be discussed in that section. The method of subsets (Wilson and Biermann 1976) was applied because of consistent correlations among the parameters, especially between T_2 and L_1. In strongly interacting binaries, the observed velocity curves are modified by the light distribution in the system. Therefore both the light and velocity curves were analyzed. The parameters which can be determined from the radial velocity data (viz., a from the projected semimajor axis $a \sin \iota$, the systemic velocity V_0, and the mass ratio $q = \mathcal{M}_2/\mathcal{M}_1$, were adjusted in separate fitting operations involving only the velocities. The weights of the observations used in the modeling were derived from the standard errors, as described in Paper II. After each run, these parameters were entered into the photometric DC runs and were kept fixed. Adjustments continued until the probable errors were less than the corrections for both velocities and light curve runs. The resulting parameters are displayed under model A_1 in Table 1, which also shows the properties of two other models with higher T_1. The relative luminosity is indicated by L^V or $L^B \equiv L_1/(L_1 + L_2)$. The probable error in each parameter, as obtained from a DC run combining light and radial velocity curves, is also given. The success of the model A_1 parameters in representing the partially rectified light curves and the radial velocity curves is apparent in Figures 1 and 2, respectively. The solid lines in Figure 1 are the synthetic light curves created by the application of the parameters of Table 1. The larger squares represent higher weighted data. The fits to the observations are clearly satisfactory at all phases. Figure 2 actually displays three sets of computed radial velocity curves: the first is the sinusoid pair representing the motions of the mass centers of the components; the second is the predicted set as corrected for photometric and eclipse effects of the sine-rectified light of the system; and the third set is also corrected for photometric and eclipse effects but includes the effect of a large, cool spot placed on the photosphere of the cooler component. While the radial velocity fits to the available data are satisfactory, the observations are neither so abundant nor so precise as to permit discrimination among the models.

Tests were performed to explore the effects of increasing the temperature of the hotter component. The spectral classification (cf. Paper II) is sufficiently uncertain to make it impossible to rule out a classification as early as G5 for the primary component. Accordingly, models were also attempted for $T_1 = 5600$ and 5800 K, beginning with the provisional elements obtained with $T_1 = 5400$. The modeling took only about seven trials for each higher T_1 case before the adjustments

TABLE 1

RECTIFIED, UNSPOTTED *BV* SOLUTIONS

ELEMENT	MODEL: A_1 (adopted)	A_2	A_3
a (R_0)	1.475 ± 0.014	1.475 ± 0.014	1.475 ± 0.013
V_0 (km s^{-1})	−56.8 ± 1.4	−56.8 ± 1.4	−56.8 ± 1.3
ι^0	75.2 ± 0.2	75.3 ± 0.2	75.4 ± 0.2
$g_{1,2}$	0.320	0.320	0.320
T_1 (K)	5400	5600	5800
T_2 (K)	5078 ± 9	5260 ± 10	5430 ± 12
$A_{1,2}$	0.500	0.500	0.500
$\Omega_{1,2}$	6.395 ± 0.028	6.380 ± 0.032	6.332 ± 0.026
q	2.920 ± 0.017	2.896 ± 0.024	2.861 ± 0.019
L_1^V	0.3406 ± 0.0054	0.3397 ± 0.0029	0.3440 ± 0.0032
L_1^B	0.3571 ± 0.0060	0.3558 ± 0.0034	0.3505 ± 0.0039
$x_{1,2}^V$	0.680	0.690	0.690
$x_{1,2}^B$	0.830	0.840	0.840
$\Sigma w r_1^2$	0.01438	0.01460	0.01302

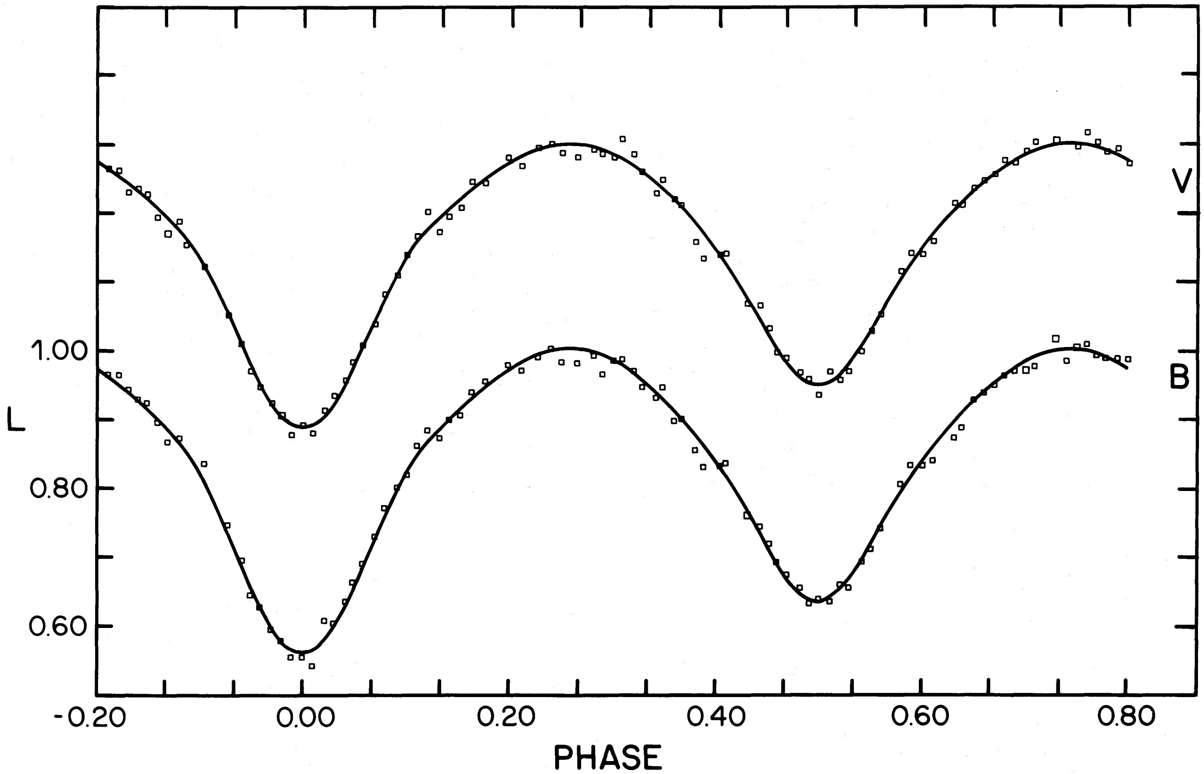

FIG. 1.—Synthetic light curve models fitted to 1977 *B* and *V* light curves of RW Com, rectified by subtraction of sine terms of the outside eclipse Fourier representation (cf. Paper I). The parameters characterizing the models are presented in Table 1. The larger symbols represent higher data of higher weight. See text for details.

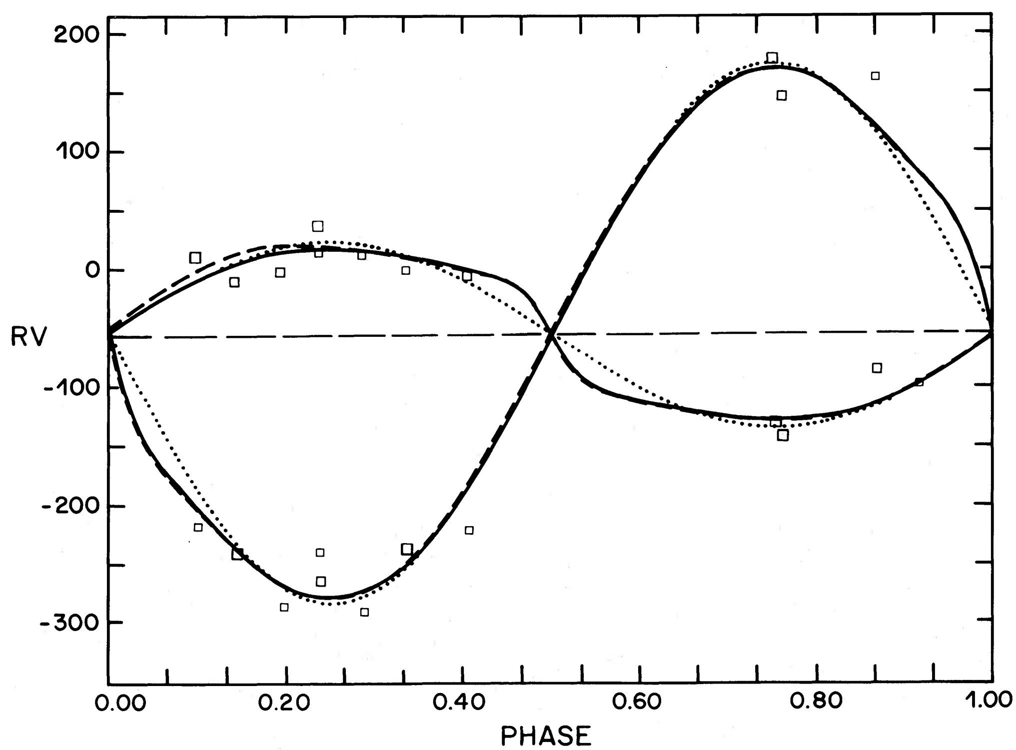

FIG. 2.—Radial velocities of RW Com from Paper II and three radial velocity models. (*solid curves*) Model A_1 characterized by the parameters given in Table 1, and therefore corrected for photometric effects. (*dotted curves*) The same model but now showing the motion of the mass centers only. (*dashed curves*) The velocity curves for a spotted solution (Model DII of Table 2).

became smaller than their probable errors. The parameter adjustments in these cases were also carried out in subsets. The solutions are labeled A_2 and A_3 in Table 1. The results show that the changes in the final adjusted parameters are at best only marginally significant. The largest departures are seen in the temperature differences, which are, respectively, 322 ± 9, 340 ± 10, and 370 ± 12 K for $T_1 = 5400$, 5600, and 5800 K. However, the maximum difference is only 48 K, a difference of barely two standard deviations. The error of fit, or the error in a single observation, is slightly lower in the 5800 K best-model case, but not significantly so. In the sections to follow, case A_1 was taken as the provisional solution.

Subsequent to all the other modeling, the contact configuration assumption was examined by modeling the system both in a mode of the Wilson-Devinney program in which the primary component fills its lobe exactly and Ω_2 is adjusted, and another mode in which the secondary component fills its lobe exactly and Ω_1 is adjusted. In the final DC run for each case, the adjusted component exceeded its critical lobe, so that the light curves cannot in fact be fitted by the semidetached model. The fitting parameters of the final resulting configurations were not significantly different from those for the previous model fits and the weighted sums of squares of the residuals were not less than those of the provisional solution. Therefore, the shallow *contact* configuration is confirmed.

We now describe the analysis of spotted components.

III. SPOTTED LIGHT CURVE ANALYSIS

The provisional parameters were applied to the unrectified light curves as initial parameters, and large, monolithic spots were placed on one or both components. All of the work described in this section, except that noted below, was carried out at the University of Florida on an IBM 3090 computer operated by the Northeast Regional Data Center (NERDC) and on a VAX 750 of the Department of Astronomy. Three sets of light curves were modeled. In one set a hot spot was placed on one component and a cool spot on the other. A second set had a single hot spot placed on one of the components so as to face the observer at maximum II; and a third set had a single cool spot placed to face the observer at maximum I. The initial parameters were adjusted for each case with the spots assumed to be fixed in temperature and area; these quantities were selected to suit the qualitative appearance of the light curve perturbations. The spot regions were centered in latitude on the equators of the components. The mass ratio was fixed at the value found in solution A_1: 2.9119. The parameters which were varied were $\imath$, T_2, Ω, L_1, and l_3. The differential corrections were done as before (i.e., until the adjustments became smaller than their probable errors). The version of the DC program which was used did not include differential corrections to the spot parameters and no effort was made at this point to adjust the spot parameters manually. Third light proved to be initially important in only one case; the final results in that case showed that the third light was less than the probable error.

The two-spot model has a hot spot on the hotter star (component 1) and a cool spot on the cooler star. These spots were placed at longitudes of 270° on each component. Longitudes are reckoned from the direction of the other component and measured clockwise around each component as viewed from above its north pole. The temperature factors, T_f, are defined as the ratios of local temperature to local unperturbed temperature. The temperature factors of these spots were assumed to be 1.03 and 0.97, respectively. Finally, the spot angular radii, subtended at each star center, were assumed to be 40° and 25°, respectively, on the basis of the large perturbed regions in the light curve. For all spot models, the parameters a, V_0, and q were kept fixed at the provisional values. The resulting two-spot light curve fit for each wavelength is contrasted to the unspotted, sine-rectified light curve fit and the unrectified observational normal points in Figure 3. The fits, while not excellent, are adequate to demonstrate the feasibility of fitting the unrectified light curves with an appropriate set of spots.

The other modeling sets involved the placing of one spot on one component. In the first series of single spot cases, a *hot* spot was placed on one face of one component. The enhancement at maximum II required the spot to be centered at longitude 270° if it were on star 1 or at 90° if on star 2. The spot on star 1 was assumed to have a temperature factor of 1.060 and an angular radius of 40°. A trial with angular radius of 25° for the spot on star 1 gave a larger Σwr^2 result, but no further spot size trials were carried out. The spot temperature of star 2 was found to be optimized, as described below, at a factor of 1.035 with assumed angular radius 40°. The final parameters were used to generate the synthetic light curves in Figure 4. It is interesting to see that the curves are quite similar to each other and to those of Figure 3.

In the final series of single spot models, a *cool* spot was placed on one face of one component. In this case, the *perturbed* region was assumed to be visible at maximum I. This model requires that a cool spot be placed at longitudes 90° and 270° for components 1 and 2, respectively.

To test the correctness of the temperature factor assigned to a spot in the present study, a number of DC runs were performed with different values for the spot temperature factor. Two sets of runs were made: one involving a hot spot on the cool component; the other involving a cool spot on the cool component. The sums of the squares of weighted residuals for each set of runs is plotted against the assumed temperature factor of each run in Figure 5. Minima occur near the temperature factors 0.957 and 1.035.

The final fits involving a cool spot on one of the components are seen in the light curve plots in Figures 6 and 7. The fit in the light curve of lowest weight (U) is not good at secondary minimum but is acceptable elsewhere, and is quite good for the B and V light curves.

The final adjusted parameters for the spotted star models can be compared to those of the provisional fit (model A_1) in Table 2. As in Table 1, the relative luminosity, $L = L_1/(L_1 + L_2)$, is given for each bandpass. Other model designations are B (two spots), C (spot on hot = primary star), and D (spot on cool star); subtype designations are I (hot spot) and II (cool spot) with arabic numbers and lowercase letter indicating best models under additional, special conditions which are described below. The errors given here are the formal probable errors produced in the adjustment of the subset of photometric parameters only. The insignificance of third light is illustrated for the case of the hot spot on the hotter star, where initial and continued third light adjustment led to the auxiliary solution (CI_2) shown in Table 2. In this case, since the light was normalized to maximum I, the reference phase for l_3 is 0.25. Another auxiliary solution (DIa) was obtained for the case of a hot spot placed 30° north of the equator of the cool star.

It can be seen that while the elements are not identical, and in some cases one or more elements are significantly different, the differences are not so great as one might have expected

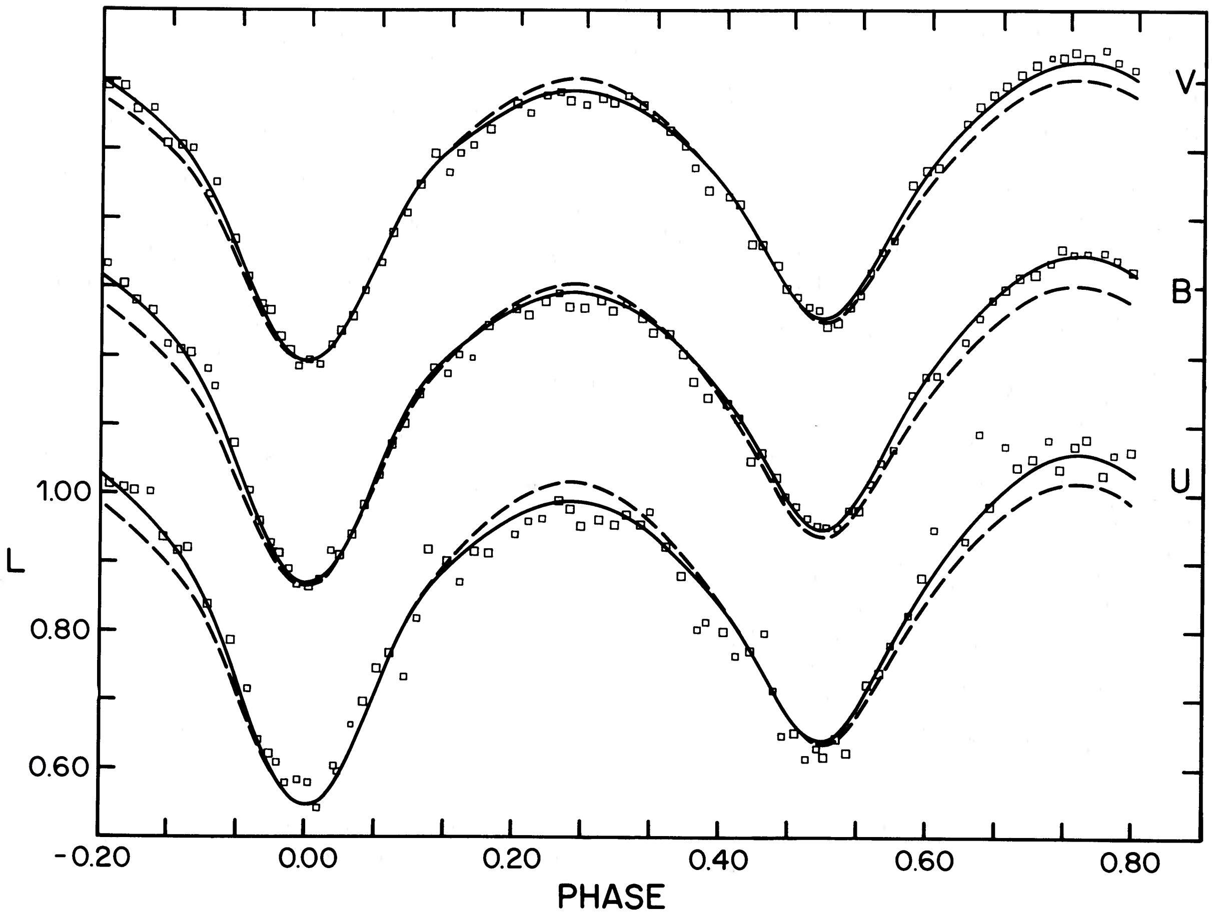

FIG. 3.—*UBV* light curve fits. (*dashed curves*) The rectified light curve solution shown in Fig. 1, applied here to the *U* light curve as well. (*solid curves*) A two-spot model fitted to the unrectified observational normal point data, the relative weights of which are indicated by sizes of squares. The data have been normalized to the mean of the two maxima. In this model, a hot spot has been placed on the hotter component and a cool spot placed on the cooler component, each centered in latitude on the equator at longitude 270°.

given the size of the O'Connell effect in this system. This gives one limited confidence in the technique of rectification of sine terms prior to light curve analysis. It also reinforces the conviction that the provisional elements represent reasonable approximations to the true elements. The provisional elements were used to compute the absolute dimensions of the system discussed in the next section.

In the present study, as with all modeling, the uniqueness of the adopted set of elements is unproved. This fact notwithstanding, more than 60 DC runs with many variations in subsets have failed to demonstrate the existence of other convincing minima in other parts of parameter space for the unrectified light curves, and the runs of the sine-rectified light curves have yielded similar elements under a variety of input assumptions. That they are not identical illustrates that the elements are to a certain extent captive to the modeling process in the sense that the placement and temperatures of spotted regions affect the resulting elements of the binary system. This

TABLE 2

SPOTTED AND UNSPOTTED MODEL PARAMETERS

	Model								
Element	A_1	B_1	B_2	CI_1	CI_2	CII_1	DI	DIa	DII
i	75.21 ± 0.15	75.40 ± 0.20	75.43 ± 0.17	74.41 ± 0.22	75.21 ± 0.88	76.26 ± 0.19	74.80 ± 0.21	75.25 ± 0.20	76.23 ± 0.21
T_2	5078 ± 8	5089 ± 10	5108 ± 10	5135 ± 10	5115 ± 13	5097 ± 8	5124 ± 10	5118 ± 10	5114 ± 9
Ω	6.395 ± 0.012	6.416 ± 0.013	6.419 ± 0.012	6.440 ± 0.008	6.430 ± 0.018	6.390 ± 0.013	6.462 ± 0.010	6.467 ± 0.009	6.376 ± 0.009
L^V	0.341 ± 0.004	0.337 ± 0.004	0.333 ± 0.002	0.326 ± 0.005	0.330 ± 0.017	0.337 ± 0.004	0.327 ± 0.005	0.327 ± 0.004	0.334 ± 0.004
L^B	0.357 ± 0.004	0.352 ± 0.005	0.347 ± 0.003	0.339 ± 0.005	0.345 ± 0.017	0.352 ± 0.005	0.341 ± 0.006	0.340 ± 0.005	0.348 ± 0.005
L^U	...	...	0.363 ± 0.004	0.353 ± 0.006	0.360 ± 0.018	0.369 ± 0.006	0.355 ± 0.007	0.355 ± 0.007	0.364 ± 0.005
l_3^V	...	...	...	...	+0.017 ± 0.032	...	...	...	...
l_3^B	...	...	...	...	+0.029 ± 0.032	...	...	...	...
l_3^U	...	...	...	...	+0.056 ± 0.033	...	...	...	...
Σwr_1^2	0.010	0.062	0.069	0.083	0.080	0.063	0.063	0.063	0.061

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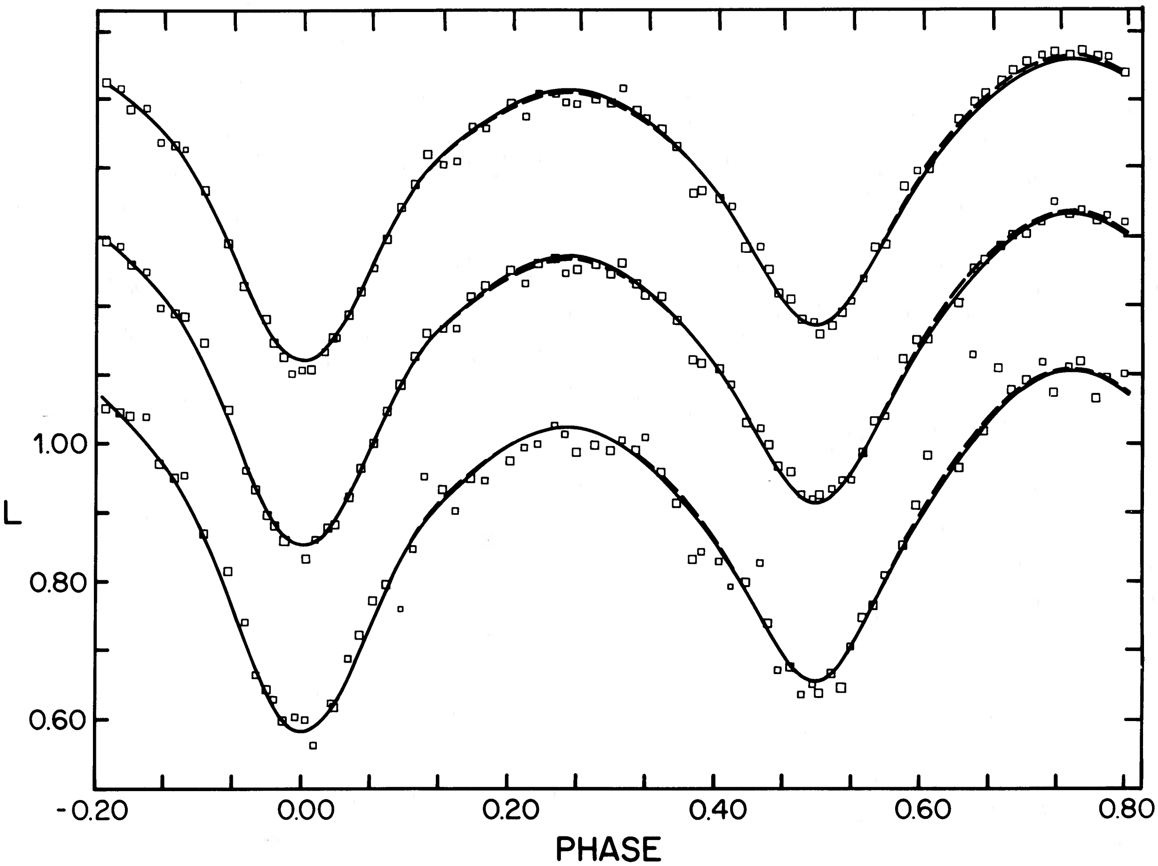

FIG. 4.—Two single-spot models fitted to the unrectified 1977 *UBV* light curves. Both spots are hotter than the stellar photospheres. Here unity represents the assumed unperturbed light level of maximum I. Solid and dashed curves signify models incorporating spots on the hotter and cooler components, illustrating models CI_1 and DI respectively, of Table 2.

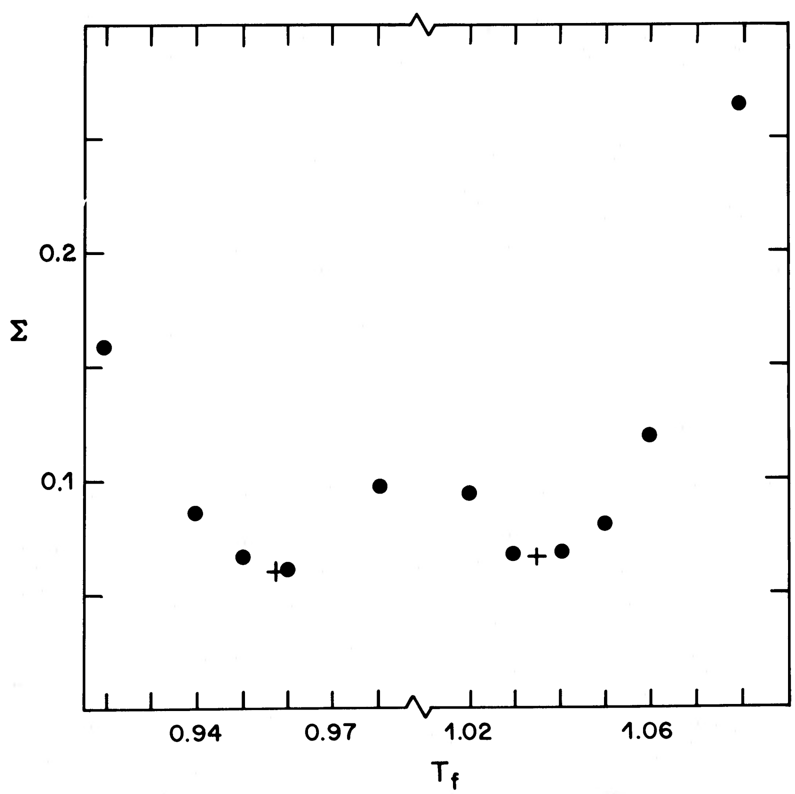

FIG. 5.—Determinations of optimum spot temperatures for the case of a single spot on the cooler component. See text for details.

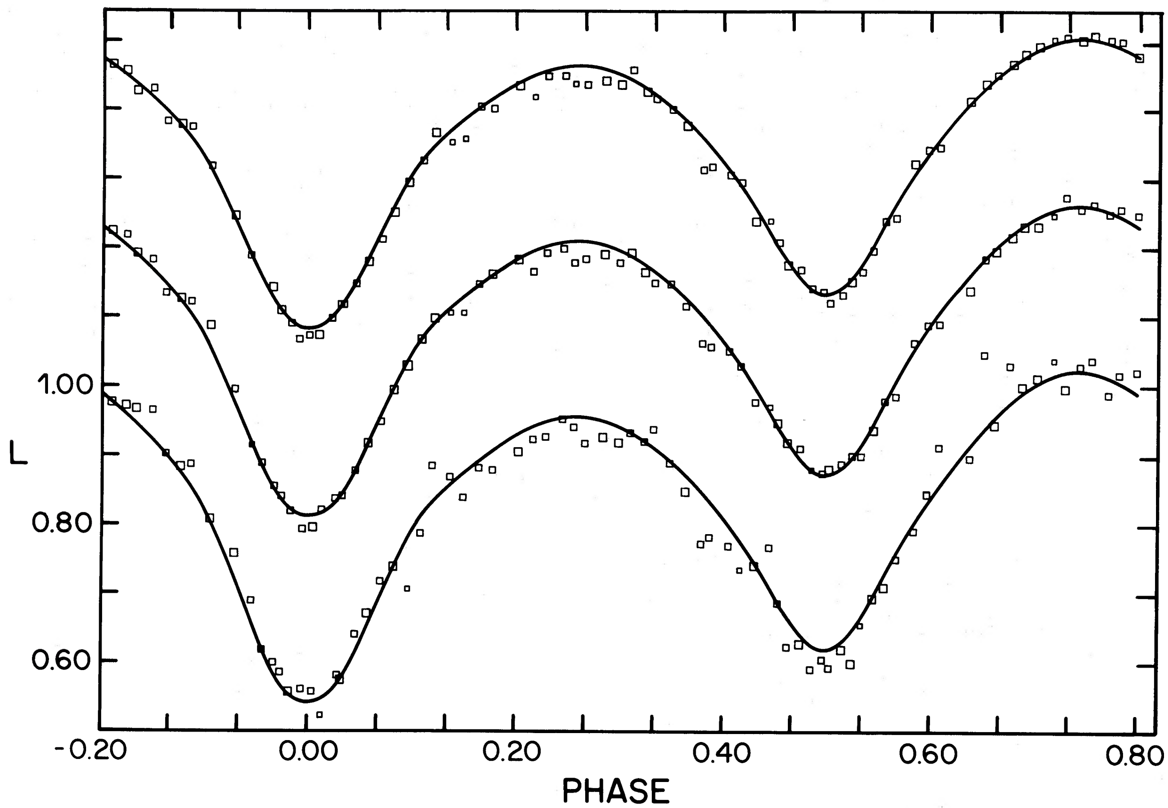

FIG. 6.—A single cool-spot model (CII_1 of Table 2) in which the spot has been placed on the hotter component. Here unity represents the assumed unperturbed intensity level of maximum II.

is inevitable. What is surprising is that the sine rectification process apparently yields a result which is sufficiently accurate to justify the procedure and precludes the need for a detailed physical model for this system in order to find the elements.

IV. ABSOLUTE PARAMETERS OF THE RW COMAE SYSTEM

Elements of the system have been obtained through modeling of the light and radial velocity curves. The parameters of model A_1 of Table 1 were used in the calculation of the absolute elements shown in Table 3. In addition to these elements, independent proper motion investigations by Klemola (1983) and by Frederick and Ianna (1983) have provided the means to investigate the kinematic properties of the system. The preliminary, unpublished data of those investigators have been combined to form the weighted means shown in Table 3. The effects on the transverse and space velocities of the weighted means of the proper motion determinations are also noted. The errors cited are propagated errors from the combinations of the uncertainties of the modeled parameters and are standard deviations, not probable errors. In computing errors in the absolute elements, an uncertainty of $\pm 1°$ in the inclination was assumed, based on the large differences in this quantity among the models. An unusually large uncertainty in the temperature of each component of ± 300 K was assumed. This was done because of the uncertainty in the spectral class of component 1, discussed in § II. As we have seen, the models are slightly different if T_1 is assumed to be hotter by 200 or 400 K, although not greatly so, except in the values of the temperature difference between the components.

TABLE 3

ABSOLUTE PARAMETERS OF RW COMAE BERENICES

Parameter	Component 1	Component 2
R_{pole}/R_0	0.412 ± 0.002	0.667 ± 0.003
R_{side}/R_0	0.430 ± 0.004	0.717 ± 0.006
R_{back}/R_0	0.486 ± 0.006	0.759 ± 0.010
L/L_0	0.15 ± 0.03	0.31 ± 0.07
$M_{bolometric}$	6.76 ± 0.24	5.97 ± 0.26
M_V	6.95 ± 0.25	6.26 ± 0.26
$\mathcal{M}/\mathcal{M}_0$	0.20 ± 0.03	0.56 ± 0.06
r (pc)	115 ± 13	
f	0.169 ± 0.019	
$\mu_\alpha \cos\delta$ (arcsec yr^{-1})	−0.112 ± 0.006	
μ_δ (arcsec yr^{-1})	−0.021 ± 0.002	
V_T (ks^{-1})	62 ± 8	
V_{space} (ks^{-1})	84 ± 9	

The contact parameter,

$$f \equiv (\Omega_1 - \Omega)/(\Omega_1 - \Omega_2) = 0.17 \pm 0.02 ,$$

is small. However, the results of semidetached system modeling, discussed in § II, confirms a contact status for the binary in which both components at least fill, and likely exceed, their critical lobes.

Kraft and Landolt (1959) noted the possibility that RW Com was a member of the Coma star cluster (Mel 111). We can now exclude this possibility. From the known properties of the Coma cluster, the proper motion, radial velocity, and space motion do not support membership for RW Com. The proper motion of the cluster according to Artyukhina as

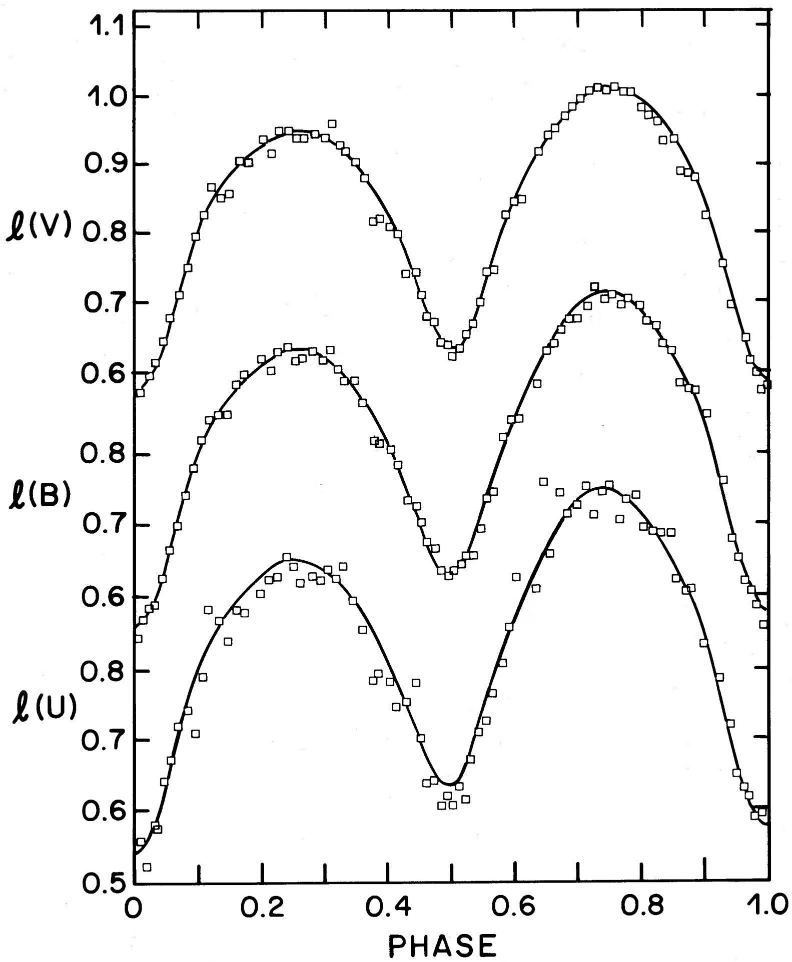

FIG. 7.—A single cool-spot model (DII of Table 2) in which the spot has been placed on the cooler component. This figure was produced from output generated on the University of Calgary's Cyber 205 computer. Although all data symbols have the same size in this figure, the data were weighted for this fitting as for the others. Refer to Fig. 6 for the relative weights of the data.

cited in Klemola (1977) is

$$\mu_\alpha \cos \delta = -0''.010 \pm 0''.007 \text{ yr}^{-1}$$

and

$$\mu_\delta = -0''.012 \pm 0''.007 \text{ yr}^{-1}$$

If the distance to the cluster is 80 pc (Hagen 1970), the binary is beyond it by more than 2 σ, or nearly 50%. The distance to the binary was computed under the assumption that there is no visual circumstellar absorption for it, i.e., $A_V = 0$.

The large motion of the binary does, however, make it interesting in its own right and raises the question of its origin. The position angle of its motion transverse to the line of sight is $\sim 259° \pm 1°$ and since its radial velocity is negative, it is seen to be approaching, not receding from, the Coma cluster. Finally, with its high galactic latitude ($\approx 89°$), albeit small z, and high space motion and z-velocity, it is a candidate for Population II status. Augensen (1986) has calculated the galactic orbit which RW Com should have, given the kinematic properties indicated here. He finds $R_{\max} = 11.35 \pm 0.01$ kpc and $R_{\min} = 6.94 \pm 0.41$ kpc, assuming that $R_0 = 10$ kpc. The "eccentricity" of the orbit is therefore ~ 0.24. On kinematic grounds, he considers the system to be intermediate between the old disk population and Population II.

V. DISCUSSION

In summary, RW Com has now been shown to be in shallow contact, as determined by modeling the system with the Wilson-Devinney program. Additional modeling was carried out for higher T_1 values and showed few significant differences from the provisional solution except, of course, for higher temperatures for both components. Absolute parameters were then determined from the provisional elements, the radial velocity study, and from proper motion information. The proper motions, kindly supplied by A. Klemola from the Lick Observatory proper motion program and by L. W. Fredrick and P. Ianna from the University of Virginia program, indicate that RW Com is not a member of the Coma star cluster. RW Com thus joins another W UMa system, the still shorter period system CC Com, which has previously been shown (Klemola 1977) to be not a member of Mel 111 despite proximity on the sky. Calculations by H. Augensen show that RW Com is on a highly elliptical orbit around the Galaxy and is intermediate in its kinematic properties between objects of the old disk population and Population II.

Since RW Com is a W-type system, with the primary component being the smaller and less massive component, and is clearly in contact, the system is *not* a candidate for the broken contact phase of thermal relaxation oscillations (Flannery

1976; Lucy 1976) although it shares many of the properties of the candidate systems, especially W Crv and RW PsA, discussed by Lucy and Wilson (1979). With those systems, RW Com shares light curve asymmetries, red color indices, shallow contact configurations, and temperature differences between the components. Whether those systems are truly A-type W UMa systems or not, however, the hotter component in the A-type systems is the more massive component. In the hypothetical subclass called the B-type systems, contact is broken and a potential difference exists between the critical lobe surface of star 1 and the surface of star 2. This permits the occurrence of a transient stream and collision-caused high-temperature region on the following side of star 2. Such an occurrence is a possible mechanism to account for an O'Connell effect with *positive* sign. In the modeled light curves of RW Com, however, the O'Connell effect has a *negative* sign. Moreover, in W-type systems, the less massive star is the hotter and in RW Com, at least, *both* components overfill their critical lobes. Hence, a gravitational potential difference does not appear to provide the mechanism to explain the O'Connell effect in this system.

The luminosities are in excess of those expected of typical main-sequence stars of the same masses by more than a factor of 2 for star 2 and by more than an order of magnitude for the hotter component. Presumably, component 2—the more massive component—is responsible for the excess seen in star 1, making the anomaly even worse. Apparently, W-type W UMa stars have a complicated evolutionary history behind them.

The evolutionary status of RW Com and the mechanism for the asymmetries in this system are fundamental unsolved problems common to many W UMa systems, discussion of which we must defer. We can point out, however, that the age of an old disk population star is of the order 5 dex (9) yr; RW Com is *not* a young system.

In their search for poor thermal contact B-type W UMa systems, Lucy and Wilson had to use sine correction terms. Perhaps one of the more significant results of this study is a demonstration of the extent to which elements obtained from sine-rectified, O'Connell effect light curves seem to be trustworthy. It should be noted, however, that the spot models were carried out without adjustment of the mass ratio, systemic velocity, and semimajor axis nor were complex spot configurations explored so that the improvement in fitting error that more modeling parameters usually provide was not completely realized. Nevertheless, the sine rectification process prior to light curve modeling may prove to be of value in uncovering the true elements of O'Connell effect systems with a minimum of modeling, in the absence of detailed spot or other perturbation information obtained, for example, from Doppler profile studies. Further work is planned by one of us (E. F. M.) to test the applicability of the parameters of model A_1 to light curves of other epochs, and the method to other systems.

Of nearly equal importance in the present work, are the small but significant differences found among the models of RW Com. The effective temperatures of the two components are probably not entirely recoverable since the perturbations in the light curves can only be modeled, at present, by nonunique combinations of spot temperature variation with longitude and latitude on either component. Additional information is necessary to understand the nature of the perturbation. Probably the best sources of such information are multicolor, especially infrared, light curves (Milone 1986). With such information, one should be able to utilize the wavelength dependence of residuals to discover the type and temperature of the perturbation source. In the case of RW Com, infrared light curves from different epochs have seemed to differ more than the optical light curves. This means that only complete and coeval light curves can be used. Procurement of these is a goal that, until recently, has been elusive. Modeling of selected infrared light curves is being carried out, however, and will be discussed elsewhere (Milone *et al.* 1986), along with the details of the observations themselves and the implications for the source of the light curve variability.

It is a pleasure to thank the University of Florida Astronomy Department for the warm hospitality accorded one of us (E. F. M.) during his recent sabbatical leave. The Lick proper motion data are from the Lick Observatory program to obtain proper motions with respect to galaxies. The work in this paper was supported by grants to E. F. M. from the University of Florida Graduate School of the Arts and Sciences and from the Department of Astronomy, the University of Calgary Research Grants Committee and from the Natural Sciences and Engineering Research Council of Canada. Support also came from NSF grant AST 8412610 to R. E. W. and from shared university Postdoctoral Fellowships to B. J. H. at Calgary. All of these are gratefully acknowledged.

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