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UBV PHOTOMETRY OF RV CrV

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UBV observations of RV CrV made on 11 nights in 1971 are reported. An improved period of 0.7472521 day is found. After rectifying the *V* light curve by the Russell-Merrill method a tentative photometric solution is obtained by the second method of Kopal. On combining our results with the spectroscopic elements found by Struve and Gratton it appears that the system might be a contact binary.

Key words: eclipsing binary – photometry

1. OBSERVATIONS

The light variability of RV CrV (HD 109796) was discovered by Swope, and the light elements were given by Buttery (1942). The single-spectrum orbit of this system was published by Struve and Gratton (1948). This system was observed by us photoelectrically in 1971 through *U, B,* and *V* filters, with the 48″ reflector of Rangapur Observatory. The observations were made with an unrefrigerated EMI 6256B photomultiplier tube, the output of which was fed into a direct current amplifier and then to a Brown recorder. In the beginning of observations BD $-18°3437$ was taken as the comparison star and BD $-17°3680$ as the check star. From the first few nights of observations we found BD $-18°3437$ to be a variable with an amplitude of $0^{m}.18$; observations of this star will be reported separately. Consequently, BD $-17°3680$ was taken as the comparison star and BD $-18°3438$ as the check star. The comparison star was used for determining the nightly extinction coefficients. After applying the extinction corrections the extra atmospheric magnitude differences Δm (variable – comparison) were transformed to the *UBV* system using the transformation relations obtained from the observations of standard stars. The magnitudes and colours of the comparison and check stars as well as those of the variable at maximum light on the standard system are given in table 1. The magnitude differences Δm (check star – comparison star) on various nights indicate that the comparison star was constant within the errors of observations.

2. PERIOD AND LIGHT CURVE

The light elements published by Buttery (1942) are: Min. = $JD_{\odot}$ 2429703.284 + $0^{d}.74728$ E. Struve and Gratton (1948) had found from their radial velocity data that there was a pronounced shift of -0.13 day in phase as computed from Buttery's ephemeris. Our observations can be best represented by a period slightly shorter than that given above. The following ephemeris was used for reducing our observations:

$$\text{Min. I} = JD_{\odot}\ 2441029.384 + 0^{d}.7472521\ E.$$

This ephemeris satisfies the radial velocity data of this system obtained by Struve and Gratton. But the time of minimum published by Koch and Koch (1962) from photographic observations is not in agreement with the

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above ephemeris; however, satisfactory agreement with their data can be achieved if we assume that the time of minimum published by them is less by one day, which is quite possible according to them.

Tables 2a, 2b and 2c give the heliocentric Julian Day, the phase computed from the above ephemeris and the magnitude difference between the variable and comparison in *V, B,* and *U,* respectively. The resultant light curves are shown in figure 1. The depths of primary and secondary eclipses are found to be roughly $0^{m}.56$ and $0^{m}.30$, respectively, as compared to $1^{m}.0$ and $0^{m}.6$ given in the Finding List of Eclipsing Binaries (Koch *et al.* 1963).

3. TENTATIVE SOLUTION

Although our light curves do not cover some phases satisfactorily, we have attempted a tentative solution mainly as a guide to future work.

After applying a zero point correction of $-0^{m}.140$, $-0^{m}.090$ and $-0^{m}.045$ for *V, B, U,* respectively, the light variation outside eclipse was represented by the Fourier expansion:

$$l = A_0 + A_1 \cos\theta + A_2 \cos 2\theta + B_1 \sin\theta + B_2 \sin 2\theta.$$

The values of the constants obtained by a least squares fit are given in table 3 together with their probable errors. It may be mentioned that the outside light was also expressed in terms of a consine series upto the cos 3 θ term. But the coefficient A_3 was found to be small, and negligible compared to its probable error. Hence the rectification was carried out with the above 5 term expansion according to the procepts of Russell and Merrill (1952). For obtaining the rectification constants C_0 and C_2 listed in table 3 we have taken the spectral types of the components to be F0 and G0 as given by Koch *et al.* (1963). A mean value of $z = 0.18$ was adopted for all the three colours.

A limb-darkening coefficient of $x = 0.6$ was adopted for both the components in yellow and blue light, and $x = 0.8$ was used for the ultraviolet. In determining the geometrical elements of the system only the yellow light curve was analyzed. A preliminary analysis with the Russell and Merrill χ functions indicated that the primary eclipse is a transit and the secondary eclipse is an occultation, and the intersection of the depth and shape curves indicated a value of k in the range of 0.48 to 0.54. Using this preliminary estimate of k the yellow light curve was solved by the second method of Kopal (1959) employing the p–tables of Tsesevich (1939, 1940). The observations of both the primary and secondary minima were combined together into a single system of normal equations which were solved by the least squares method with the help of the IBM 1620 computer of the Regional Research Laboratory of Hyderabad. After a number of trials convergence was achieved for $k = 0.495$.

In table 4 we list the adopted geometrical and physical elements of the system. Using these elements the light curves in *V, B* and *U* have been computed and derectified. The solid lines in figure 1 represent the computed light curves. Within the errors of observation the derived elements represent the light curves satisfactorily.

4. DISCUSSION

In order to determine the colour indices of the two components we first corrected the values of L_g and L_s listed in table 4 for the reflection effect. The corrected values were renormalised and they are listed as L_g' and L_s' in table 4. On combining the fractional light L_g' of the larger star with standard magnitude and colours of the system outside eclipse given in table 1 we find for the primary component: $V = 8.67$, $B = 9.00$, $U = 9.10$, $(B–V) = +0.33$ and $(U–B) = +0.10$. These colours indicate that the primary is an F0 star in agreement with the spectroscopic determination of Struve and Gratton (1948). Further, from the mass function $f(m) = 0.033$ given by them and our value of sin i, and taking a mass of 1.8 $m_{\odot}$ for the primary (assuming it to be an F0 III to V star), we obtain $m_2/m_1=0.34$. This would give a mass of about $0.6m_{\odot}$ for the secondary corresponding to a spectral type K for that component. Finally, on comparing the derived radii of the two components given in table 4 with the radii of the Roche lobes for a mass ratio of ⅓, viz. $r_1=0.476$ and $r_2=0.286$, it appears that the system might be a contact binary. However additional photometric and spectroscopic data are needed for a better understanding of this interesting system.

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Table 1 Magnitude and Colours of the Variable and Comparison Stars

Star	BD No.	*V*	*B–V*	*U–B*
RV Corvi	−18°3431	8.60	+0.38	+0.06
Comparison	−17°3680	8.78	+0.31	+0.05
Check	−18°3438	9.60	+0.69	+0.34

Table 2a V Observations of RV CrV

Hel.J.D.	Phase	Δ V	Hel.J.D.	Phase	Δ V	Hel.J.D.	Phase	Δ V
2441000+			2441000+			2441000+		
14.2606	0.7613	-0.126	29.4056	0.0289	+0.408	40.3824	0.7185	-0.110
.2800	.7873	.100	.4236	.0530	.276	.4012	.7436	.138
.3015	.8161	.101	.4281	.0590	.230	.4194	.7680	.150
.3167	.8364	.071	.4445	.0810	.148	.4422	.7985	-0.113
.3321	.8570	.008	.4615	.1037	+0.058			
						41.3047	.9527	+0.314
17.2753	.7957	.139	30.2476	.1557	-0.059	.3236	.9780	.382
.2964	.8239	.099				.3442	.0056	.385
.3130	.8461	.077	37.2047	.4659	+0.122	.3583	.0244	.372
.3335	.8736	-0.021	.2084	.4709	.129	.3777	.0504	.257
.3967	.9582	+0.284	.2513	.5283	.134	.4058	.0880	.094
.4659	.0508	.296	.2719	.5559	.095	.4249	.1136	+0.013
			.2764	.5619	.079	.4461	.1419	-0.047
28.2344	.4616	.136	.2811	.5682	.062			
.2514	.4843	.146	.2983	.5912	.019	42.3416	.3403	.091
.2684	.5071	.160	.3013	.5952	+0.001			
.2910	.5373	.139	.3273	.6300	-0.089	44.1790	.7992	.090
.3114	.5646	.081	.3308	.6347	.084	.2005	.8280	.041
.3318	.5919	+0.003	.3486	.6585	.077	.2078	.8377	.041
.3611	.6311	-0.070	.3549	.6669	.113	.2234	.8586	-0.014
.3885	.6678	.103	.3954	.7211	.126	.2284	.8653	+0.017
.4344	.7293	.111	.3988	.7257	.153	.2442	.8865	.064
			.4274	.7640	.117	.2496	.8937	.069
29.2226	.7840	.105	.4327	.7711	-0.117	.2897	.9474	.276
.2389	.8058	.083				.2955	.9551	+0.315
.2573	.8304	.072	40.2230	.5051	+0.143			
.2719	.8500	-0.036	.2366	.5233	.137	69.2059	.2911	-0.122
.2879	.8714	+0.009	.2487	.5395	.163	.2090	.2953	.139
.3035	.8923	.041	.2764	.5766	.055	.2170	.3060	.138
.3195	.9137	.126	.2910	.5961	+0.038	.2269	.3192	.120
.3361	.9359	.209	.3076	.6184	-0.016	.2431	.3409	.097
.3531	.9586	.311	.3367	.6573	.072	.2608	.3646	.061
.3844	.0005	.410	.3503	.6755	.104	.2700	.3769	.058
.3893	0.0071	+0.402	.3671	0.6980	-0.133	.2781	0.3877	-0.033

Table 2b *B* Observations of RV CrV

Hel.J.D.	Phase	ΔB
2441000+		
14.2617	0.7628	-0.067
.2800	.7873	.041
.3015	.8161	-0.027
.3166	.8363	+0.005
.3324	.8574	+0.084
17.2751	.7954	-0.061
.2967	.8243	-0.018
.3121	.8447	+0.013
.3331	.8730	.068
.3950	.9559	.347
.4659	.0508	.389
28.2351	.4625	.209
.2521	.4853	.212
.2694	.5084	.228
.2917	.5382	.206
.3125	.5661	.164
.3333	.5939	+0.058
.3635	.6343	-0.010
.3892	.6687	.064
.4354	.7305	.067
29.2240	.7859	.065
.2403	.8077	.037
.2580	.8314	-0.003
.2726	.8509	+0.033
.2886	.8723	.071
.3042	.8932	.135
.3202	.9146	.218
.3368	.9368	.288
.3538	.9596	.387
.3851	.0015	.487
.3882	0.0056	+0.486

Hel.J.D.	Phase	ΔB
2441000+		
29.4066	0.0302	+0.454
.4247	.0545	.329
.4275	.0582	.318
.4452	.0819	.207
.4625	.1051	+0.113
30.2487	.1572	-0.011
37.2052	.4666	+0.156:
.2075	.4697	.193
.2518	.5290	.207
.2726	.5568	.143
.2757	.5610	.164
.2802	.5670	.111
.2990	.5921	.078
.3006	.5943	+0.089
.3280	.6309	-0.029
.3302	.6339	.001
.3500	.6604	.004
.3527	.6640	.040
.3961	.7221	.074
.3981	.7248	.085
.4287	.7657	.056
.4318	.7699	-0.052
40.2235	.5058	+0.188:
.2373	.5243	.212
.2494	.5405	.213
.2779	.5786	.099
.2922	.5978	.095
.3083	.6193	.040
.3364	.6569	+0.002
.3510	.6764	-0.058
.3680	0.6992	-0.090

Hel.J.D.	Phase	ΔB
2441000+		
40.3842	0.7209	-0.082
.4020	.7447	.096
.4205	.7694	.085
.4428	.7993	-0.073
41.3055	.9538	+0.381
.3240	.9785	.458
.3447	.0062	.457
.3590	.0254	.436
.3784	.0513	.309
.4065	.0889	.154
.4256	.1145	.062
.4468	.1429	+0.030
42.3437	.3431	-0.036
44.1783	.7983	.049
.2012	.8289	-0.009
.2071	.8368	+0.027
.2241	.8596	.039
.2283	.8652	.080
.2449	.8874	.125
.2489	.8928	.145
.2903	.9482	.372
.2955	.9551	+0.407
69.2067	.2922	-0.088
.2080	.2939	.061
.2177	.3069	.057
.2274	.3199	.040
.2438	.3418	-0.040
.2614	.3654	+0.018
.2710	.3782	.015
.2788	0.3887	+0.018

Table 2c *U* Observations of RV CrV

Hel.J.D.	Phase	ΔU
2441000+		
14.2617	0.7628	-0.058
.2800	.7873	.017
.3015	.8161	-0.010
.3165	.8361	+0.044
.3323	.8573	+0.109
17.2752	.7956	-0.047
.2967	.8243	+0.011
.3129	.8460	.038
.3331	.8730	.089
.3952	.9562	.382
.4656	.0504	.424
28.2358	.4634	.224
.2528	.4862	.233
.2705	.5099	.267
.2927	.5396	.230
.3135	.5674	.173
.3344	.5954	.086
.3642	.6353	+0.035
.4354	.7319	-0.014
29.2247	.7868	.023
.2417	.8096	-0.007
.2587	.8323	+0.033
.2733	.8519	.066
.2896	0.8737	+0.119

Hel.J.D.	Phase	ΔU
2441000+		
29.3045	0.8936	+0.168
.3212	.9160	.240
.3379	.9383	.335
.3549	.9611	.429
.3861	.0028	.528
.3872	.0043	.546
.4077	.0317	.469
.4254	.0554	.369
.4264	.0567	.359
.4462	.0832	.257
.4636	.1065	.150
30.2500	.1589	.040
37.2060	.4677	.201
.2067	.4686	.210
.2527	.5302	.235
.2734	.5579	.176
.2738	.5584	.205
.2767	.5623	.188
.2995	.5928	.137
.2999	.5933	.130
.3285	.6316	.007
.3293	.6327	.024
.3500	.6604	.022
41.3064	0.9550	+0.423

Hel.J.D.	Phase	ΔU
2441000+		
41.3247	0.9795	+0.482
.3445	.0060	.522
.3626	.0302	.442
.3798	.0532	.354
.4072	.0899	.189
.4263	.1154	.086
.4483	.1449	.083
44.1774	.7971	.014
.2025	.8307	.055
.2061	.8355	.052
.2246	.8602	.093
.2271	.8636	.126
.2458	.8886	.187
.2480	.8915	.185
.2920	.9504	.422
.2941	.9532	+0.434
69.2073	.2930	-0.047
.2080	.2939	.055
.2188	.3084	.045
.2281	.3208	.033
.2445	.3428	-0.001
.2625	.3669	+0.030
.2717	.3792	.059
.2802	0.3905	+0.083

Table 3 Rectification Coefficients

	V	B	U
A_0	+0.9071±0.0046	+0.8857±0.0041	+0.8837±0.0071
A_1	−0.0215±0.0057	−0.0217±0.0049	−0.0239±0.0073
A_2	−0.0888±0.0064	−0.1098±0.0056	−0.1249±0.0094
B_1	+0.0041±0.0027	+0.0054±0.0024	+0.0088±0.0032
B_2	−0.0028±0.0033	+0.0046±0.0028	−0.0074±0.0040
C_0	+0.0391	+0.0587	+0.0356
C_2	+0.0118	+0.0177	+0.0107

Table 4 Tentative Photometric Elements of RV CrV

Element	V	B	U
x	0.6	0.6	0.8
k	0.495		
H_e	57°		
p_o	−0.863		
α_o^{oc}	0.971		
α_o^{tr}	0.935		
i (true)	73°.1		
r_g	0.575		
r_s	0.285		
$(1-\ell_o)_{pri}$	0.222	0.188	0.175
$(1-\ell_o)_{sec}$	0.09	0.05	0.04
L_g	0.91	0.93	0.96
L_s	0.09	0.07	0.04
L'_g	0.974	0.996	≈ 1
L'_s	0.026	0.004	≈ 0

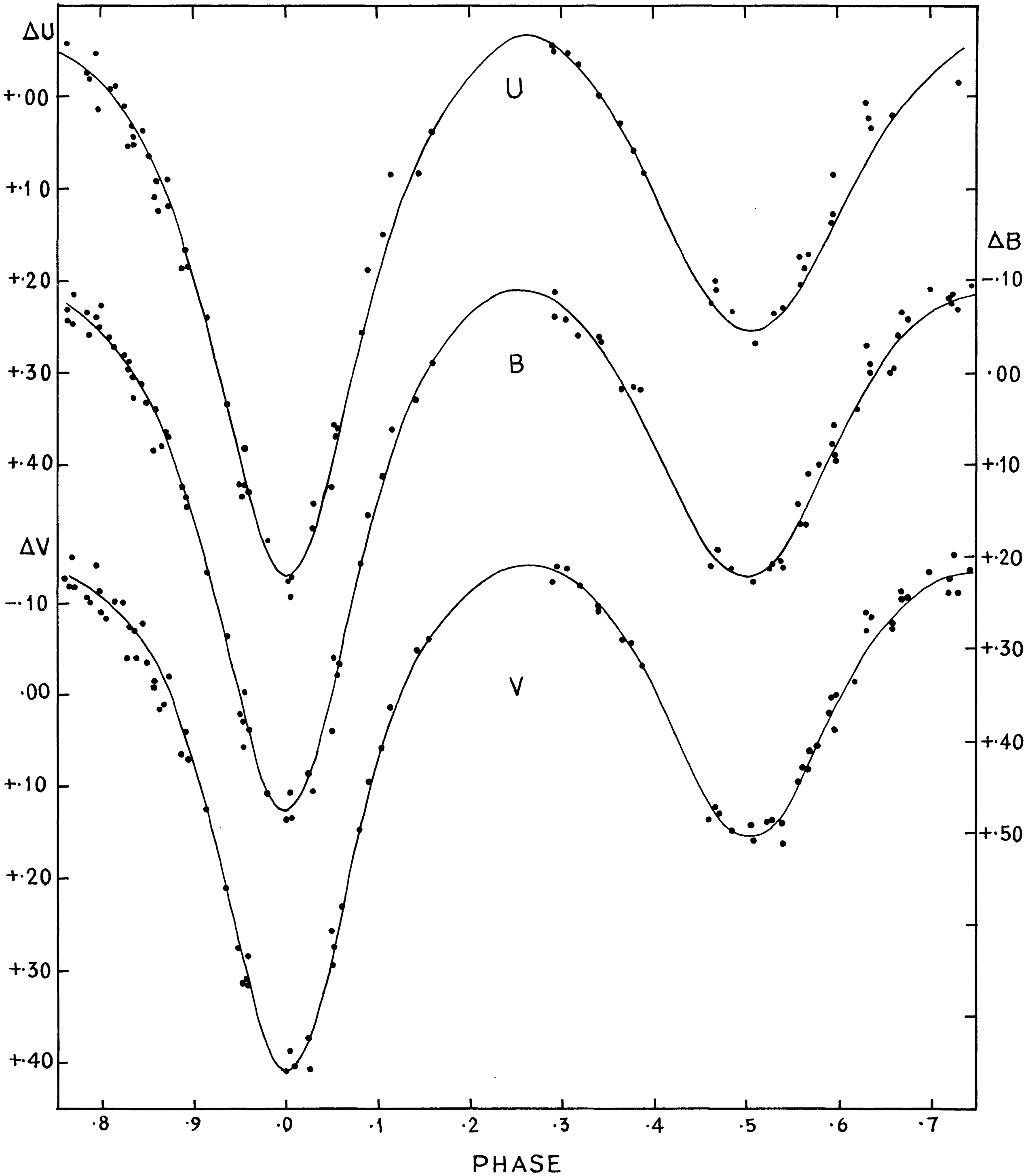

Figure 1 The observed (dots) and computed (solid lines) light curves of RV CrV.