Research Article

BVR_cI_c Observations and Analysis of the Near-Contact Solar Type Eclipsing Binary, V530 Andromedae

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We present the first precision UBVR_cI_c light curves, an initial period study, and a simultaneous light curve solution for the near-contact solar type eclipsing binary V530 And. Our observations were taken with the 0.81 m Lowell reflector on 27 and 29 September, 2011, with time being granted from the National Undergraduate Research Observatory (NURO). Our Wilson Devinney Program solution yields a semidetached, V1010 Oph configuration: the more massive component is filling its Roche lobe. The system is apparently approaching contact for the first time. It is not a classic Algol.

1. History

V530 And [2MASS J01274106 + 3351552, NSVS 6447718, TYC 2300-116-1, $\alpha(2000) = 01^{\text{h}} 27^{\text{m}} 41.050^{\text{s}}$, $\delta(2000) = +33^{\circ} 51' 55.47''$ ICRS, $J = 11.679$, $H = 11.485$, $K = 11.421$] was discovered by Khruslov (2008) [1]. It was designated as EB with a 12.6–13.3 R-magnitude range ($\text{Min II} = 13.0$) with the ephemeris:

$$J.D. \text{ Hel Min I} = 2451479.632 \text{ d} + 0.57723 \cdot E. \quad (1)$$

Their light curve is given as Figure 1.

V530 And was observed by the Robotic Optical Transient Search Experiment [2] and found to have a period = 0.57721 d and a mean unfiltered magnitude of 12.769. A light curve amplitude of 0.633 mag was determined. It was stated that the light curve was calculated to be in the Fourier region where β Lyrae (EB) types are expected. Finally, V530 And appeared in the 80th namelist of variable stars (IBVS #5969, 2011). It was also designated as an EB type. EB binaries are very close together producing distorted curves from tidal and Coriolis

forces, but the stars are not in contact, so their light curves still maintain dissimilar eclipse depths.

2. Observations

This system was observed as a part of our student/professional collaborative studies of interacting binaries from data taken from NURO observations (National Undergraduate Research Observatory). Our light curves were taken with the Lowell 0.81 m reflector in Flagstaff with a CRYOTIGER cooled ($< -100^{\circ}\text{C}$) NASACAM and a 2048×2048 CCD chip with standard UBVR_cI_c filters. Observations were taken on 27 and 29 September, 2011, by Samec, Kring, and Faulkner. The time was awarded by the Lowell TAC as a part of the time allocated from NURO. Analyses were done by Flaaten and Samec. The individual observations included 92 in the U-filter, 93 in B, 92 in V, and 91 in R and I. The standard error of a single observation was 3 mmag in U and B, 2 mmag in V and R, and 4 mmag in I. Our observations are given in Table 1, in delta magnitudes, ΔB , ΔV , ΔR_c , and ΔI_c in the sense of variable minus comparison star.

FIGURE 1: Light curve for V530 And from Khruslov (2008) [1].

FIGURE 2: Finding chart, V530 And variable (V), comparison (C), and check (K).

3. Finding Chart

Our comparison star (C) was GSC 2300 0035, $[\alpha(2000) = 01^{\text{h}} 27^{\text{m}} 41.0660^{\text{s}}, \delta(2000) = +33^{\circ} 51' 55.298'' V = 12.832, B - V = 0.53$ Guide 9]. The check star (K) was GSC 2300 0053, $[\alpha(2000) = 14^{\text{h}} 05^{\text{m}} 13.8544^{\text{s}}, \delta(2000) = +38^{\circ} 57' 24.156'' V = 12.421, B - V = 0.64$, Guide 9]. We include a finding chart of these stars and the variable (V) in Figure 2.

4. Period Determination

Two mean times of minimum light were determined from our observations. These include HJD Min I = 2455832.74595 (± 0.00044) d and HJD Min II = 2455830.72806 (± 0.00045) d. We determined 9 more times of low light from the NSVS catalog data set for object number 6447718. We combined this data with Khruslov's ephemeris to calculate the following new ephemeris (see Table 2 for the calculation):

$$\begin{aligned} \text{J.D. Hel Min I} &= 2455832.7470 (\pm 0.0170) \text{ d} \\ &+ 0.577217 (\pm 0.000003) \cdot E. \end{aligned} \quad (2)$$

The following is from our Wilson-Devinney program light curve solution:

$$\begin{aligned} \text{J.D. Hel Min I} &= 2455832.7468 (\pm 0.0001) \text{ d} \\ &+ 0.576805 (\pm 0.000001) \cdot E. \end{aligned} \quad (3)$$

Each time of minimum light and low light used in the calculation and depicted in Figure 3 is given in Table 2 along with their residuals. Equation (3) is from the programs iterative fit to the light curve data while (2) is a least squares fit to the minima. The NSVS minima are times of low light and carry large uncertainties. We include both ephemerides since they are the best we have at this time.

What we have here is an initial period study. The Wilson programs determination (3) may be better than the one determined from the minima. Further observations, over the course of 10 years or more, are needed to better determine a precision ephemeris and the nature of the period behavior of the system.

TABLE 1: Photometry of V530 And.

ΔU	U_{HJD} 2455800+	ΔU	U_{HJD} 2455800+	ΔU	U_{HJD} 2455800+	ΔU	U_{HJD} 2455800+	ΔU	U_{HJD} 2455800+
1.066	30.6497	1.269	30.7671	1.034	30.8610	1.384	32.6971	1.148	32.8347
1.100	30.6569	1.224	30.7736	1.035	30.8669	1.425	32.7031	1.118	32.8411
1.127	30.6642	1.143	30.7868	1.032	30.8728	1.546	32.7142	1.096	32.8470
1.158	30.6714	1.133	30.7937	1.039	30.8794	1.640	32.7225	1.081	32.8529
1.205	30.6796	1.114	30.8003	1.046	30.8853	1.727	32.7292	1.064	32.8587
1.247	30.6874	1.093	30.8070	1.056	30.8912	1.758	32.7350	1.050	32.8645
1.314	30.6958	1.287	32.6839	1.082	30.9016	1.775	32.7417	1.035	32.8728
1.358	30.7035	1.324	32.6899	1.091	30.9075	1.776	32.7475	1.025	32.8786
1.395	30.7108	1.384	32.6971	1.103	30.9133	1.781	32.7546	1.015	32.8857
1.402	30.7174	1.425	32.7031	1.124	30.9193	1.756	32.7604	1.021	32.8915
1.398	30.7244	1.546	32.7142	1.140	30.9251	1.704	32.7669	1.010	32.8974
1.397	30.7309	1.640	32.7225	1.160	30.9310	1.619	32.7727	1.011	32.9032
1.388	30.7383	1.133	30.7937	1.188	30.9381	1.549	32.7791	1.030	32.9093
1.395	30.7449	1.114	30.8003	1.765	31.0202	1.473	32.7849	1.023	32.9151
1.352	30.7536	1.093	30.8070	1.112	32.6514	1.401	32.7924	1.036	32.9210
1.309	30.7602	1.083	30.8135	1.140	32.6587	1.340	32.7981	1.058	32.9268
1.269	30.7671	1.079	30.8217	1.165	32.6646	1.290	32.8043	1.052	32.9335
1.224	30.7736	1.057	30.8324	1.202	32.6713	1.257	32.8101	1.054	32.9393
1.143	30.7868	1.048	30.8390	1.229	32.6773	1.220	32.8160	1.064	32.9454
1.352	30.7536	1.042	30.8474	1.287	32.6839	1.194	32.8218	1.086	32.9512
1.309	30.7602	1.032	30.8532	1.324	32.6899	1.168	32.8283	1.123	32.9670
								1.134	32.9728
ΔB	B_{HJD} 2455800+	ΔB	B_{HJD} 2455800+	ΔB	B_{HJD} 2455800+	ΔB	B_{HJD} 2455800+	ΔB	B_{HJD} 2455800+
1.074	30.6520	1.131	30.7892	1.104	30.9215	1.741	32.7497	1.025	32.8667
1.109	30.6593	1.108	30.7961	1.124	30.9274	1.729	32.7568	1.012	32.8750
1.130	30.6666	1.087	30.8027	1.142	30.9333	1.718	32.7626	1.005	32.8808
1.161	30.6738	1.073	30.8093	1.170	30.9404	1.641	32.7691	0.996	32.8879
1.209	30.6820	1.058	30.8159	1.075	32.6452	1.567	32.7749	0.990	32.8937
1.249	30.6897	1.048	30.8240	1.111	32.6536	1.490	32.7813	1.002	32.8996
1.304	30.6982	1.028	30.8348	1.137	32.6609	1.422	32.7871	1.000	32.9054
1.358	30.7059	1.020	30.8414	1.157	32.6669	1.351	32.7945	1.009	32.9115
1.370	30.7132	1.016	30.8496	1.179	32.6735	1.297	32.8003	1.003	32.9173
1.380	30.7198	1.010	30.8555	1.220	32.6795	1.251	32.8065	1.019	32.9232
1.373	30.7267	1.009	30.8633	1.271	32.6862	1.220	32.8123	1.033	32.9290
1.381	30.7333	1.011	30.8691	1.309	32.6921	1.190	32.8182	1.037	32.9357
1.370	30.7407	1.012	30.8750	1.378	32.6994	1.158	32.8240	1.037	32.9415
1.361	30.7472	1.012	30.8817	1.431	32.7054	1.143	32.8305	1.046	32.9476
1.325	30.7560	1.027	30.8875	1.538	32.7164	1.122	32.8369	1.065	32.9534
1.277	30.7626	1.033	30.8934	1.637	32.7247	1.077	32.8433	1.117	32.9692
1.235	30.7694	1.059	30.9039	1.709	32.7314	1.063	32.8492	1.137	32.9750
1.190	30.7760	1.068	30.9097	1.743	32.7372	1.055	32.8551		
1.160	30.7826	1.052	30.9156	1.746	32.7439	1.032	32.8609		
ΔV	V_{HJD} 2455800+	ΔV	V_{HJD} 2455800+	ΔV	V_{HJD} 2455800+	ΔV	V_{HJD} 2455800+	ΔV	V_{HJD} 2455800+
1.128	30.6529	1.175	30.7901	1.121	30.9163	1.739	32.7504	1.072	32.8674
1.157	30.6602	1.147	30.7970	1.142	30.9222	1.734	32.7575	1.057	32.8757
1.181	30.6675	1.132	30.8036	1.168	30.9281	1.722	32.7633	1.045	32.8815
1.218	30.6747	1.118	30.8103	1.180	30.9339	1.654	32.7697	1.042	32.8885
1.270	30.6829	1.104	30.8168	1.124	32.6461	1.581	32.7755	1.040	32.8943
1.320	30.6907	1.093	30.8250	1.144	32.6544	1.505	32.7820	1.041	32.9003
1.378	30.6991	1.086	30.8277	1.173	32.6617	1.452	32.7878	1.045	32.9061

TABLE I: Continued.

1.423	30.7068	1.073	30.8357	1.195	32.6677	1.376	32.7952	1.054	32.9122
1.437	30.7141	1.061	30.8423	1.219	32.6744	1.328	32.8010	1.055	32.9180
1.439	30.7207	1.056	30.8503	1.257	32.6803	1.281	32.8071	1.067	32.9239
1.441	30.7277	1.053	30.8562	1.303	32.6870	1.243	32.8129	1.074	32.9297
1.434	30.7342	1.046	30.8640	1.341	32.6929	1.215	32.8188	1.081	32.9364
1.435	30.7416	1.055	30.8698	1.401	32.7002	1.195	32.8247	1.087	32.9422
1.418	30.7481	1.055	30.8757	1.460	32.7062	1.168	32.8311	1.096	32.9482
1.372	30.7569	1.063	30.8824	1.570	32.7171	1.159	32.8375	1.116	32.9540
1.326	30.7635	1.066	30.8882	1.654	32.7254	1.133	32.8439	1.163	32.9698
1.276	30.7704	1.079	30.8941	1.730	32.7321	1.110	32.8499	1.182	32.9757
1.245	30.7769	1.097	30.9045	1.749	32.7379	1.089	32.8557		
1.203	30.7836	1.108	30.9104	1.744	32.7446	1.079	32.8616		
ΔR	R_{HJD} 2455800+	ΔR	R_{HJD} 2455800+	ΔR	R_{HJD} 2455800+	ΔR	R_{HJD} 2455800+	ΔR	R_{HJD} 2455800+
1.163	30.6536	1.222	30.7908	1.188	30.9285	1.735	32.7509	1.108	32.8620
1.198	30.6608	1.177	30.7977	1.205	30.9344	1.741	32.7579	1.098	32.8678
1.227	30.6681	1.170	30.8042	1.238	30.9415	1.720	32.7638	1.090	32.8761
1.261	30.6754	1.150	30.8109	1.145	32.6468	1.657	32.7702	1.081	32.8819
1.312	30.6835	1.133	30.8175	1.172	32.6550	1.595	32.7760	1.073	32.8890
1.355	30.6913	1.143	30.8256	1.191	32.6623	1.511	32.7825	1.069	32.8948
1.419	30.6997	1.104	30.8364	1.213	32.6682	1.458	32.7883	1.078	32.9008
1.463	30.7074	1.097	30.8429	1.241	32.6749	1.394	32.7957	1.074	32.9066
1.481	30.7148	1.086	30.8508	1.291	32.6809	1.339	32.8014	1.085	32.9126
1.480	30.7213	1.089	30.8566	1.330	32.6875	1.300	32.8076	1.085	32.9184
1.486	30.7283	1.085	30.8644	1.372	32.6935	1.266	32.8134	1.098	32.9244
1.494	30.7349	1.084	30.8762	1.422	32.7007	1.252	32.8193	1.101	32.9302
1.482	30.7422	1.092	30.8828	1.491	32.7067	1.216	32.8251	1.106	32.9368
1.464	30.7488	1.095	30.8887	1.584	32.7175	1.205	32.8316	1.119	32.9426
1.410	30.7576	1.103	30.8946	1.680	32.7258	1.190	32.8380	1.152	32.9545
1.357	30.7641	1.129	30.9050	1.738	32.7325	1.155	32.8444	1.189	32.9703
1.313	30.7710	1.146	30.9109	1.741	32.7383	1.135	32.8504	1.215	32.9761
1.286	30.7776	1.151	30.9167	1.734	32.7451	1.120	32.8562	1.179	32.9763
1.242	30.7842	1.171	30.9227						
ΔI	I_{HJD} 2455800+	ΔI	I_{HJD} 2455800+	ΔI	I_{HJD} 2455800+	ΔI	I_{HJD} 2455800+	ΔI	I_{HJD} 2455800+
1.181	30.6541	1.236	30.7913	1.224	30.9289	1.745	32.7583	1.135	32.8765
1.210	30.6613	1.212	30.7982	1.247	30.9348	1.736	32.7642	1.124	32.8823
1.238	30.6687	1.191	30.8048	1.264	30.9419	1.669	32.7706	1.118	32.8952
1.274	30.6759	1.177	30.8114	1.161	32.6473	1.608	32.7764	1.108	32.9011
1.315	30.6841	1.161	30.8180	1.211	32.6553	1.538	32.7829	1.113	32.9070
1.372	30.6918	1.141	30.8261	1.227	32.6626	1.479	32.7887	1.118	32.9130
1.426	30.7002	1.138	30.8369	1.239	32.6686	1.416	32.7961	1.131	32.9188
1.476	30.7079	1.129	30.8434	1.257	32.6752	1.368	32.8019	1.148	32.9248
1.486	30.7153	1.120	30.8512	1.329	32.6812	1.332	32.8080	1.145	32.9306
1.501	30.7218	1.113	30.8570	1.348	32.6878	1.296	32.8138	1.148	32.9372
1.501	30.7288	1.104	30.8648	1.402	32.6938	1.274	32.8197	1.155	32.9430
1.506	30.7354	1.121	30.8707	1.452	32.7011	1.250	32.8255	1.168	32.9491
1.516	30.7427	1.129	30.8832	1.510	32.7071	1.232	32.8320	1.184	32.9549
1.485	30.7493	1.138	30.8891	1.606	32.7179	1.227	32.8384	1.240	32.9707
1.424	30.7581	1.136	30.8950	1.689	32.7262	1.196	32.8448	1.253	32.9765
1.379	30.7646	1.157	30.9054	1.733	32.7329	1.177	32.8508		
1.345	30.7715	1.174	30.9113	1.766	32.7387	1.164	32.8566		
1.286	30.7781	1.185	30.9172	1.748	32.7455	1.157	32.8624		
1.260	30.7847	1.206	30.9231	1.751	32.7513	1.134	32.8682		

HJD is the Heliocentric Julian Date.

FIGURE 3: The $O-C$ residuals are calculated from (2) and appear in Table 2. The residuals on the left are low precision points with low weights from times of low light.

FIGURE 4: (a) B, V delta mags of V530 And phased with (2). (b) R, I delta mags of V530 and phased with (2). (c) U, B delta mags of V530 And Phased with (2).

5. Light Curves

The light curves were folded ΔU , ΔB , ΔV , ΔR , ΔI , $\Delta(U - B)$, $\Delta(B - V)$, and $\Delta(R - I)$ color curves using (2). They are given in Figures 4(a), 4(b), and 4(c).

Light curve characteristics are given in Table 3. The primary light curve amplitudes of this EB system average 0.8–0.6 mags from U to I , respectively, and 0.4 mags in the secondary amplitudes. A small O’Connell effect (MAX II-MAX I) [3] of about 1% exists with MAX II being slightly depressed. Thus, we expect some spot activity. The secondary

eclipse showed a time of constant light of 41.5 minutes. This means that the eclipses are total and that the more massive, larger star is the hotter component. This is to be expected in normal stellar evolution. We also note that this binary is not one of the common W-type shallow contact types.

6. Synthetic Light Curve Solution

2MASS Photometry yielded a $J - H$ value of ≈ 0.19 . From this, we assumed that the primary component was $\sim F2$ type,

FIGURE 5: (a) B , V synthetic light curve solutions overlaying the normalized flux curves. (b) U , B synthetic light curve solutions overlaying the normalized flux curves. (c) R , I synthetic light curve solutions overlaying the normalized flux curves.

FIGURE 6: (a) Geometrical surface of V530 And, phase 0.0. (b) Geometrical surface of V530 And, phase 0.25. (c) Geometrical surface of V530 And, phase 0.50. Note total eclipse. (d) Geometrical surface of V530 And, phase 0.75.

TABLE 2: Times of minimum light, V530 And.

No.	EPOCHS	Cycles	Weight	O-C	
1	51335.3990	-7791.5	0.1	0.0390	NSVS
2	51335.4000	-7791.5	0.1	0.0400	NSVS
3	51442.1819	-7606.5	0.1	0.0367	NSVS
4	51442.1822	-7606.5	0.1	0.0370	NSVS
5	51454.3080	-7585.5	0.1	0.0413	NSVS
6	51454.3091	-7585.5	0.1	0.0423	NSVS
7	51507.4016	-7493.5	0.1	0.0309	NSVS
8	51507.4019	-7493.5	0.1	0.0312	NSVS
9	51518.3594	-7474.5	0.1	0.0216	NSVS
10	51479.6320	-7541.5	1.0	-0.0323	Khruslov (2008) [1]
11	55830.7281	-3.5	1.0	0.0013	Present observations
12	55832.7460	0.0	1.0	-0.0010	Present observations

TABLE 3: Light curve characteristics, V530 And.

Filter	Phase 0.25	MAX I, MAG	Phase 0.75	MAX II, MAG
<i>U</i>		1.017 ± 0.008		1.033 ± 0.002
<i>B</i>		0.999 ± 0.006		1.001 ± 0.001
<i>V</i>		1.043 ± 0.002		1.053 ± 0.004
<i>R</i>		1.075 ± 0.004		1.086 ± 0.002
<i>I</i>		1.114 ± 0.004		1.115 ± 0.007
Filter	Phase 0.5	MIN II, MAG	Phase 0.0	MIN I, MAG
<i>U</i>		1.396 ± 0.006		1.774 ± 0.007
<i>B</i>		1.375 ± 0.005		1.729 ± 0.009
<i>V</i>		1.437 ± 0.003		1.740 ± 0.006
<i>R</i>		1.485 ± 0.005		1.738 ± 0.003
<i>I</i>		1.502 ± 0.010		1.754 ± 0.008
Filter	MIN I-MAX I	MAX II-MAX I	MIN II-MAX I	MIN I-MIN II
<i>U</i>	0.757 ± 0.015	0.016 ± 0.010	0.379 ± 0.014	0.378 ± 0.013
<i>B</i>	0.730 ± 0.015	0.003 ± 0.007	0.376 ± 0.011	0.354 ± 0.014
<i>V</i>	0.697 ± 0.008	0.010 ± 0.006	0.394 ± 0.005	0.303 ± 0.009
<i>R</i>	0.663 ± 0.008	0.011 ± 0.006	0.410 ± 0.009	0.253 ± 0.008
<i>I</i>	0.640 ± 0.013	0.001 ± 0.012	0.388 ± 0.014	0.252 ± 0.018

with a surface temperature of ≈ 7000 K [4] so this value was used for the primary components temperature in modeling. The light curves were premodeled with Binary Maker 3.0 [5]. From this work, it was determined that the synthetic light curve fits would be done in Mode 4, semidetached with component one filling its Roche lobe. The parameters resulting from this premodeling were used as starting values for the Wilson-Devinney program [6–9]. The secondary component remained under-filling its Roche lobe throughout the iterations. Adjusted parameters were those with parentheses in Table 4. A simultaneous 5-color synthetic light curve solution was undertaken with the Wilson-Devinney program. No q-search was needed since the curves display total eclipses. A mode 3 solution (contact binary) was also run with much poorer goodness of fit parameters.

7. Discussion

We find that V530 And is a V1010 Oph type near contact binary. The primary, more massive component is filling its Roche lobe and the secondary is under-filling. This means that the binary is likely achieving contact for the first time. The temperature difference ($T_2 - T_1$) in components is ~ 500 K. The mass ratio was found to be somewhat extreme, $q = m_1/m_2 = 0.38$. The potentials are given as Ω 's, and the L -values are the relative flux from each stars. The values of g are the gravity darkening's, x 's are the two dimensional limb darkening, and the r 's are the dimensions of the Roche lobes. The more massive star is filling its Roche lobe with a fillout, f , of 100% while the smaller star is just under-filling with a fillout of 99% calculated by potentials. Thus, the state

TABLE 4: Light curve solution, V530 And.

Parameters	Values
$\lambda_U, \lambda_B, \lambda_V, \lambda_R, \lambda_I$ (nm)	360, 440, 550, 640, 790
$x_{\text{boll},2}, y_{\text{boll},2}$	0.644, 0.643, 0.231, 0.160
$x_{1I,2I}, y_{1I,2I}$	0.572, 0.647, 0.267, 0.183
$x_{1R,2R}, y_{1R,2R}$	0.655, 0.735, 0.278, 0.165
$x_{1V,2V}, y_{1V,2V}$	0.728, 0.797, 0.269, 0.108
$x_{1B,2B}, y_{1B,2B}$	0.817, 0.853, 0.215, -0.018
$x_{1U,2U}, y_{1U,2U}$	0.859, 0.855, 0.208, -0.209
g_1, g_2	0.32
A_1, A_2	0.5
Inclination ($^\circ$)	87.1 ± 0.2
T_1, T_2 (K)	7000, 6499 $\pm$ 2
Ω_1, Ω_2	$2.63423, 2.662 \pm 0.001$
$q(m_2/m_1)$	0.3786 ± 0.0003
Fill-outs: $F_1 = F_2$	100%, $98.97 \pm 0.72\%$
$L_1/(L_1 + L_2)_I$	0.7687 ± 0.0007
$L_1/(L_1 + L_2)_R$	0.7790 ± 0.0008
$L_1/(L_1 + L_2)_V$	0.790 ± 0.001
$L_1/(L_1 + L_2)_B$	0.8064 ± 0.0008
$L_1/(L_1 + L_2)_U$	0.8140 ± 0.0006
JD ₀ (days)	55832.7468 ± 0.0001
Period (days)	0.57680 ± 0.00006
r_1, r_2 (pole)	$0.437 \pm 0.001, 0.273 \pm 0.005$
r_1, r_2 (point)	$0.598 \pm 0.001, 0.35 \pm 0.02$
r_1, r_2 (side)	$0.467 \pm 0.002, 0.284 \pm 0.006$
r_1, r_2 (back)	$0.494 \pm 0.001, 0.313 \pm 0.009$
Cool Spot	
Spot 1 on STAR 1	
Colatitude ($^\circ$)	64.1 ± 0.3
Longitude ($^\circ$)	1.1 ± 0.2
Spot radius ($^\circ$)	26.0 ± 0.1
Spot T-factor	0.694 ± 0.004
Spot 2 on STAR 1	
Colatitude ($^\circ$)	58 ± 7
Longitude ($^\circ$)	346 ± 2
Spot radius ($^\circ$)	26 ± 1
Spot T-factor	0.92 ± 0.01

of the star is near contact or has just come into contact. We reason this is true because of the temperature disparity. It is of interest that both surface spots stayed remarkably stable throughout the iterations and are near the L_1 points of both stars. There may be some thermodynamic reason why the hemispheres of dark spots are facing each other. The solution is seen overlaying the normalized flux curves shown in Figures 5(a), 5(b), and 5(c). The complete numeric values for the solution are given in Table 4. Four phases, at orbital quadrature's, of the Roche-lobe model of the binary and for the dark spots, are shown as in Figures 6(a), 6(b), 6(c) and 6(d). Phase zero shows the total eclipse.

8. Conclusion

Thus, the components are apparently F2V and F5V spectral types. Despite the fairly early spectral types, with the primary star nearly A-type, the presence of the large cool magnetic spots on both stars reveal that they have convective atmospheres and thus would be classified as solar type. It is a near contact, totally eclipsing, binary. Thus, the binary will likely soon come into contact through the process of magnetic braking due to solar type winds leaving the stars along the stiff magnetic field lines [10].

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References

- [1] A. V. Khruslov, "New short periodic eclipsing binaries. III," *Peremennye Zvezdy Prilozhenie*, vol. 8, no. 40, 2008.
- [2] D. I. Hoffman, T. E. Harrison, and B. J. McNamara, "Automated variable star classification using the northern sky variability survey," *Astronomical Journal*, vol. 138, no. 2, pp. 466–477, 2009.
- [3] D. J. K. O'Connell, "The so-called periastron effect in close eclipsing binaries," *Riverview College Observatory Publications*, vol. 2, no. 6, pp. 85–100, 1951.
- [4] A. N. Cox, Ed., *Allen's Astrophysical Quantities*, Springer, New York, NY, USA, 4th edition, 2000.
- [5] D. H. Bradstreet and D. P. Steelman, "Binary maker 3.0—an interactive graphics-based light curve synthesis program written in Java," *Bulletin of the American Astronomical Society*, vol. 34, p. 1224, 2002.
- [6] R. E. Wilson and E. J. Devinney, "Realization of accurate close-binary light curves: application to MR Cygni," *Astrophysical Journal*, vol. 166, pp. 605–619, 1971.
- [7] R. E. Wilson, "Accuracy and efficiency in the binary star reflection effect," *Astrophysical Journal Letters*, vol. 356, no. 2, pp. 613–622, 1990.
- [8] R. E. Wilson, "Binary-star light curve models," *Publications of the Astronomical Society of the Pacific*, vol. 106, pp. 921–941, 1994.
- [9] W. V. van Hamme and R. E. Wilson, "Generalized solution for binary star ephemerides and apsidal motion," *Bulletin of the American Astronomical Society*, vol. 30, p. 1402, 1998.
- [10] E. F. Guinan and D. H. Bradstreet, "Kinematic clues to the origin and evolution of low mass contact binaries, formation and evolution of low mass stars," in *Proceedings of the NATO Advanced Study Institute, Held at Viana do Castelo, Portugal, September 21–October 2, 1987*, A. K. Dupree and M. T. V. T. Lago, Eds., vol. 241 of *NATO Advanced Science Institutes (ASI) Series C*, pp. 345–375, Kluwer Academic, Dodrecht, The Netherlands, 1988.