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Photoelectric Observations of the Close Eclipsing Binary System CW Cephei*

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ABSTRACT

Photoelectric observations of the close eclipsing binary system CW Cep, which is well known of its apsidal motion, were made on 20 nights during August and November in 1983 using two 61 cm reflectors at the Sobaeksan Observing Station of Korean National Astronomical Observatory and Ilsan Observing Station of Yonsei University Observatory. Standardized new light curves in *UBV* system are presented with a total of 1,422 individual observations. For the corrections of regional and instrumental differences, same standard stars were observed at the two observatories. Four new times of minimum light were determined with the method of Kwee and van Woerden (1956). With all of the collected times of minima, apsidal motion of this system was checked, but the *O-C* values calculated by the light elements of Nha (1975) and Söderhjelm (1976) did not coincide well with new times of minima. New light elements which satisfy most times of minima better, and are deduced the apsidal period derived by the new light elements turns out to be 43 years, somewhat longer than those of values previously known.

I. INTRODUCTION

Petrie (1949) discovered CW Cephei as a double lined spectroscopic binary of approximately equal intensity, and the orbital elements and the spectral type of this system were given as B3 and B3. In the same year, by examining the photographic plates of Harvard College Observatory, Gaposchkin (Nha 1975) reported the eclipse phenomena of CW Cep with one minimum time. Abrami and Cester (1960) carried out the first intensive photoelectric observations in *V* and *B* during the period of 1955-1956. They published photoelectric light curves and derived the pro-

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visional orbital elements. The importance of CW Cep has been increased by the finding the fact that this system is a member of young III Cep OB association (Blaauw, Hiltner and Johnson 1959), whose expansion age less than about 10^6 years was estimated by Garmany (1973) and the distance modulus was determined to be about $9^{m}.3 \pm 0.1$ according to many investigators (Garrison 1970, Crawford and Barnes 1970, Lacy 1978). Sobieski (Nha 1975) analyzed the partial light curves of CW Cep made using OAO-2 satellite in the far-ultraviolet regions and determined two times of minimum light. The second spectroscopic orbital elements from the high dispersion spectroscopic observations were derived by Popper (1974). He suggested the spectral type of both component of CW Cep as B0.5 and the masses were derived 11.7 M⊙ and 11.0 M⊙ using Nha's value of orbital inclination.

The close eclipsing binary system CW Cep is of particulary interest because of its short period of apsidal motion found by Nha(1975), who made intensive observations of CW Cep during 1965 to 1973. Nha determined the new photometric solution of this system and suggested that CW Cep shows an apsidal motion of period about 39 years which is the shortest known in the northern hemisphere. Applying to the model of Semeniuk and Paczynski (1968) related to the apsidal motion, he deduced the central hydrogen content and thus the evolutionary age of this system to be about 10^7 years. The third photoelectric light curves of CW Cep observed during 1971 and 1972 were obtained by Söderhjelm (1976). These light curves were completed partially, but the new photometric solution were derived from the mostly based on the previously available materials including his own. Later, Cester *et al.*(1978) re-analyzed the light curves published by Abrami and Cester (1960) and by Nha (1975) by means of Wood's WINK computer model for the furnishment of coherent picture of CW Cep, not substantially different from Söderhjelm's view.

Meanwhile the observational data for the times of secondary minimum light observed by Brancewicz and Kreiner (1976) did not agree well with the Nha's value of apsidal motion, and this large difference casted doubts on the apsidal motion of CW Cep. But recent observation of the times of primary minimum light carried out by Kim (1981) showed an excellent agreement to the light elements given by both Nha (1975) and Söderhjelm (1976). In this study, Kim revised the orbital period and constants of apsidal motion, but by a negligible amount.

Like those mentioned above, CW Cep is an important binary system not only a view of its shortest value of apsidal period in the northern hemisphere and the member of III Cep association, but also its high mass that contributes to the mass-luminosity relation. Nevertheless, available light curves for the intensive photometric analysis are limited only to those of Abrami and Cester (1960) and Nha(1975); the former lacks the interacting effects (both in reflection and ellipticity) and the latter the combination of too long period of time (7 years). In addition, the study of apsidal motion is only possible when the number of times of minima have been accumulated in a long time basis.

For these reasons, in this paper we present the standardized new light curves of CW Cep in the *UBV* system made of in a given observing season (only one year in 1983) with four times of minima determined with the method of Kwee and van Woerden (1956). These light curves are compared with those of published ones. To check the apsidal motion of this system, *O-C* residuals are calculated for all of the collected times of minima including ours by both light elements of Nha (1975) and of Söderhjelm (1976) and the results are discussed.

II. INSTRUMENTATIONS AND OBSERVATIONS

The observations were made on 20 nights in the period from August 11 to November 28 in 1983 using two 61 cm reflectors, one at the Sobaeksan Observing Station (SOS) of Korean National Astronomical Observatory and the other at the Ilsan Observing Station (IOS) of Yonsei University Observatory. These two observatories are 200 km apart and the former station is located on the top of a mountain 1,390m above sea level. Seventeen nights are observed at the Sobaeksan, and the rest are at the Ilsan's.

The photomultiplier 1P21 refrigerated with dry ice was attached to the Boller and Chivens Cassegrain reflector of SOS, while the Goto Cassegrain reflector of IOS is equipped with unrefrigerated 1P21. The filters used at two observatories were standard *UBV* filter sets similar to those recommended by Johnson (1963). The photocurrent was amplified by means of dc amplifiers of similar circuit and the signals were recorded on a strip chart recorder at each station. The amplifier used at SOS was made and calibrated by Kang (1978) and that of IOS was done by Jeong (1983). Instrumentations used have been extensively described by Han (1984) and Kim (1983).

Two stars HD 218342 and HD 217919 were observed as the comparison and the check star, respectively, which were chosen by Nha (1971) and characteristics of these two stars and CW Cep are given by him. The check star was observed two or three times a night not only for the check the constancy of comparison star's light but also to compare the regional and instrumental differences at the two observatories. (The companion star more than 4 magnitude fainter than CW Cep (Blaauw *et al.* 1959) was not included in the measurements on most observing nights except for a few nights of bad tracking of SOS telescope.)

The observational procedures and data reductions were performed according to Kang (1977) and Nha *et al.*(1981) and calculated with program written by Han (1984) using HP 9825 T microcomputer. Each measurements of CW Cep runned for at least one minute of time are repeated in a sequence of *V-B-U-B-V* and two values of *V* measurements as well as *B*, are combined into a single data point on the basis of time of U measurement for the high confidence of observational data and the colors.

Although small transformation differences at two observatories are expected due to close similarity of CW Cep and comparison star in their colors and spectral types, same standard stars were observed on several nights for the standardization of the data. The transformation coefficients to the standard *UBV* system for the two observatories were determined, and the following equations are deduced.

(i) Sobaeksan Observing Station

$$\Delta V = \Delta v - 0.109\ (\Delta b - \Delta v)$$
$$\Delta B = \Delta v + 0.904\ (\Delta b - \Delta v)$$
$$\Delta U = \Delta v + 0.904\ (\Delta b - \Delta v) + 1.090\ (\Delta u - \Delta b)$$

(ii) Ilsan Observing Station

$$\Delta V = \Delta v - 0.045\ (\Delta b - \Delta v)$$
$$\Delta B = \Delta v + 0.850\ (\Delta b - \Delta v)$$
$$\Delta U = \Delta v + 0.850\ (\Delta b - \Delta v) + 1.108\ (\Delta u - \Delta b)$$

Δs used in the above equations denote the magnitude difference in the sence of Δm (Var.-Comp.) corrected for the atmospheric extinctions. The methods for the data reductions and conversions to the standard *UBV* system are those presented elsewhere (Han 1984).

A total of 1,422 individual observations is obtained in three colors. The phase of each observation given in table I were calculated using the light element given by Nha (1975),

$$\text{Min I.} = \text{JD}2435373.4492 + 2^{\text{d}}.7291396E + 0^{\text{d}}.0256 \sin(0.^{\circ}07018\text{E} - 31.^{\circ}55).$$

Four times of minimum light, three for the primary eclipse and one for the secondary, were observed in this observing season. Two primary minimum times on JD 2,445,665 are the result of simultaneous observations at two observatories; at SOS by Han at IOS by Nha. Table III is the supplementary table to Nha's table for the new times of minimum light since his paper.

Table 1. *UBV* observations of CW Cep

JD Hel. 2445000+	ΔV	ΔB	ΔU	JD Hel. 2445000+	ΔV	ΔB	ΔU	JD Hel. 2445000+	ΔV	ΔB	ΔU
558.1877	0.205	0.180	0.199	558.2720	0.217	0.178	0.187	566.2639	0.197	0.169	0.175
558.1917	0.194	0.170	0.182	558.2778	0.198	0.169	0.180	566.2670	0.197	0.165	0.181
558.1939	0.206	0.183	0.197	558.2870	0.201	0.163	0.168	566.2701	0.206	0.178	0.174
558.2000	0.187	0.171	0.177	558.2891	0.204	0.168	0.176	566.2734	0.198	0.178	0.182
558.2015	0.203	0.170	0.192	558.2944	0.215	0.191	0.200	566.2767	0.196	0.162	0.181
558.2050	0.197	0.173	0.190	558.2965	0.208	0.185	0.192	566.2800	0.200	0.162	0.175
558.2069	0.200	0.169	0.186	566.2504	0.203	0.168	0.175	566.2831	0.202	0.168	0.182
558.2576	0.194	0.179	0.192	566.2541	0.191	0.157	0.172	566.2864	0.198	0.163	0.163
558.2599	0.200	0.167	0.181	566.2575	0.201	0.164	0.171	566.2921	0.186	0.156	0.167
558.2699	0.197	0.166	0.188	566.2609	0.196	0.163	0.172	566.2958	0.199	0.167	0.171

Table I. Continued

JD Hel. 2445000+	ΔV	ΔB	ΔU	JD Hel. 2445000+	ΔV	ΔB	ΔU	JD Hel. 2445000+	ΔV	ΔB	ΔU
566.2989	0.194	0.157	0.173	603.0696	0.189	0.166	0.173	617.1857	0.370	0.350	0.353
566.3022	0.200	0.166	0.173	603.0895	0.193	0.158	0.172	617.1943	0.399	0.371	0.386
566.3055	0.202	0.152	0.166	603.1054	0.216	0.174	0.188	617.2011	0.417	0.393	0.401
566.3145	0.204	0.186	0.193	603.1998	0.197	0.184	0.178	617.2113	0.456	0.431	0.449
566.3182	0.195	0.172	0.179	603.2077	0.200	0.171	0.172	617.2193	0.475	0.448	0.467
566.3238	0.197	0.161	0.173	603.2128	0.196	0.170	0.175	617.2276	0.496	0.450	0.495
566.3295	0.193	0.167	0.173	609.0711	0.558	0.544	0.568	617.2348	0.520	0.491	0.515
599.1214	0.189	0.171	0.186	609.0748	0.571	0.552	0.558	617.2395	0.552	0.529	0.563
599.1287	0.210	0.179	0.181	609.0850	0.574	0.540	0.573	617.2506	0.553	0.530	0.550
599.1344	0.211	0.178	0.160	609.0914	0.582	0.551	0.573	617.2582	0.567	0.550	0.577
599.1636	0.215	0.195	0.188	609.0992	0.573	0.550	0.577	617.2649	0.573	0.553	0.577
599.1732	0.186	0.168	0.167	609.1052	0.573	0.537	0.570	617.2816	0.582	0.559	0.572
600.0025	0.198	0.182	0.192	609.1119	0.561	0.531	0.562	617.2884	0.575	0.557	0.573
600.0124	0.195	0.166	0.175	609.1175	0.551	0.523	0.549	617.2959	0.566	0.557	0.569
600.0204	0.194	0.164	0.180	609.1250	0.536	0.515	0.549	617.3029	0.559	0.549	0.557
600.0341	0.199	0.171	0.178	609.1321	0.510	0.485	0.511	617.3103	0.533	0.517	0.529
600.0419	0.199	0.167	0.183	614.0356	0.174	0.158	0.189	617.3344	0.481	0.469	0.496
600.0502	0.198	0.168	0.181	614.0497	0.184	0.171	0.180	617.3426	0.449	0.435	0.462
600.0628	0.199	0.165	0.182	614.0601	0.197	0.171	0.181	617.3511	0.428	0.400	0.419
600.0717	0.200	0.166	0.181	614.0684	0.196	0.177	0.174	617.3607	0.396	0.373	0.345
600.0802	0.201	0.172	0.179	614.0782	0.193	0.160	0.182	630.9806	0.452	0.440	0.458
600.0903	0.195	0.171	0.177	614.0873	0.189	0.161	0.187	630.9909	0.425	0.419	0.441
600.0999	0.197	0.163	0.177	614.0951	0.188	0.167	0.186	631.0008	0.414	0.390	0.381
600.1088	0.199	0.172	0.183	617.0407	0.213	0.159	0.199	631.0196	0.360	0.341	0.338
600.1153	0.199	0.178	0.183	617.0497	0.207	0.185	0.201	631.0300	0.342	0.318	0.314
600.1254	0.200	0.173	0.185	617.0597	0.197	0.174	0.188	631.0386	0.333	0.302	0.356
600.1527	0.196	0.161	0.178	617.0833	0.195	0.168	0.180	631.0471	0.302	0.284	0.276
602.9612	0.186	0.155	0.170	617.0989	0.214	0.190	0.213	631.0559	0.278	0.254	0.266
602.9702	0.190	0.157	0.176	617.1074	0.217	0.202	0.224	631.0658	0.275	0.245	0.246
602.9804	0.187	0.157	0.175	617.1187	0.226	0.207	0.221	631.0738	0.237	0.220	0.209
602.9921	0.169	0.140	0.153	617.1289	0.244	0.218	0.229	631.0822	0.224	0.213	0.204
603.0031	0.184	0.153	0.176	617.1365	0.258	0.235	0.248	631.0901	0.224	0.204	0.230
603.0135	0.183	0.155	0.174	617.1447	0.276	0.251	0.261	631.1022	0.202	0.189	0.196
603.0295	0.203	0.178	0.185	617.1544	0.300	0.278	0.288	631.1107	0.197	0.172	0.189
603.0388	0.192	0.156	0.163	617.1619	0.319	0.303	0.308	631.1186	0.192	0.174	0.191
603.0513	0.194	0.161	0.172	617.1696	0.339	0.318	0.325	631.1253	0.209	0.180	0.188
603.0625	0.188	0.166	0.176	617.1786	0.357	0.338	0.350	631.1327	0.207	0.177	0.184

Table I. Continued

JD Hel. 2445000+	ΔV	ΔB	ΔU	JD Hel. 2445000+	ΔV	ΔB	ΔV	JD Hel. 2445000+	ΔV	ΔB	ΔU
631.1400	0.206	0.196	0.173	631.2282	0.207	0.187	0.188	632.1766	0.386	0.364	0.384
631.1471	0.206	0.179	0.182	631.2353	0.198	0.170	0.183	632.1815	0.398	0.381	0.393
631.1553	0.201	0.175	0.180	631.2506	0.203	0.192	0.194	632.1942	0.444	0.424	0.444
631.1632	0.214	0.189	0.194	631.2555	0.200	0.169	0.197	632.1999	0.450	0.441	0.454
631.1698	0.208	0.184	0.182	631.2627	0.196	0.170	0.185	632.2045	0.467	0.452	0.475
631.1776	0.207	0.178	0.170	631.2674	0.188	0.154	0.174	632.2106	0.466	0.445	0.473
631.1852	0.200	0.174	0.164	631.2732	0.191	0.139	0.167	632.2154	0.487	0.447	0.494
631.1925	0.213	0.190	0.192	631.2794	0.205	0.176	0.194	632.2266	0.524	0.502	0.525
631.2016	0.204	0.184	0.168	631.2865	0.200	1.178	0.197	632.2318	0.543	0.506	0.533
631.2108	0.205	0.171	0.172	631.2950	0.209	0.188	0.207	632.2360	0.550	0.521	0.555
631.2103	0.204	0.168	0.181	631.3008	0.209	0.197	0.212	632.2418	0.558	0.542	0.569
631.2267	0.198	0.173	0.183	632.0150	0.201	0.170	0.191	632.2462	0.572	0.545	0.565
631.2442	0.203	0.171	0.168	632.0205	0.202	0.165	0.189	632.2517	0.587	0.555	0.576
631.2631	0.204	0.185	0.178	632.0263	0.205	0.168	0.170	632.2560	0.591	0.566	0.573
631.2624	0.201	0.199	0.195	632.0318	0.209	0.183	0.195	644.9369	0.188	0.163	0.170
631.2699	0.204	0.183	0.184	632.0372	0.202	0.176	0.195	644.9429	0.192	0.169	0.151
631.0801	0.236	0.208	0.224	632.0433	0.209	0.184	0.190	644.9510	0.195	0.176	0.177
631.0898	0.210	0.188	0.201	632.0500	0.210	0.179	0.189	644.9604	0.197	0.165	0.152
631.0969	0.207	0.185	0.205	632.0559	0.205	0.175	0.184	644.9706	0.184	0.159	0.163
631.1034	0.191	0.164	0.170	632.0614	0.203	0.174	0.190	644.9792	0.183	0.176	0.185
631.1102	0.183	0.159	0.164	632.0671	0.210	0.181	0.203	644.9904	0.185	0.167	0.166
631.1169	0.188	0.169	0.175	632.0733	0.202	0.174	0.187	644.9986	0.184	0.167	0.176
631.1243	0.191	0.168	0.179	632.0792	0.207	0.176	0.193	645.0068	0.185	0.168	0.165
631.1335	0.211	0.177	0.186	632.0846	0.208	0.175	0.190	645.0257	0.216	0.178	0.184
631.1382	0.206	0.181	0.174	632.0903	0.227	0.180	0.213	645.0350	0.188	0.170	0.181
631.1456	0.210	0.189	0.186	632.0957	0.227	0.193	0.211	645.0440	0.183	0.164	0.150
631.1513	0.186	0.173	0.178	632.1004	0.223	0.191	0.206	645.0556	0.189	0.151	0.158
631.1786	0.213	0.179	0.196	632.1065	0.233	0.205	0.218	645.0672	0.223	0.207	0.207
631.1864	0.200	0.169	0.181	632.1116	0.241	0.214	0.226	645.0756	0.197	0.179	0.197
631.1914	0.209	0.188	0.193	632.1175	0.257	0.225	0.238	645.0844	0.197	0.176	0.176
631.1984	0.203	0.173	0.190	632.1225	0.269	0.246	0.266	645.0926	0.192	0.160	0.152
631.2035	0.208	0.175	0.196	632.1292	0.285	0.259	0.275	645.1004	0.195	0.152	0.155
631.2113	0.209	0.171	0.183	632.1341	0.283	0.258	0.270	645.0173	0.185	0.151	0.154
631.2155	0.219	0.181	0.195	632.1397	0.301	0.277	0.291	655.1188	0.186	0.156	0.174
631.2230	0.195	0.164	0.181	632.1445	0.308	0.283	0.321	645.1280	0.186	0.161	0.175

Table I. Continued

JD Hel. 2445000+	ΔV	ΔB	ΔB	JD Hel. 2445000+	ΔV	ΔB	ΔU	HD Hel. 2445000+	ΔV	ΔB	ΔU
645.1381	0.184	0.157	0.187	655.0261	0.185	0.168	0.179	658.1966	0.561	0.539	0.560
645.1452	0.186	0.174	0.190	655.0319	0.181	0.167	0.184	658.2025	0.575	0.545	0.566
645.1527	0.185	0.162	0.170	657.8942	0.225	0.173	0.181	658.2101	0.581	0.543	0.576
645.1607	0.189	0.149	0.155	657.9001	0.197	0.171	0.184	658.2169	0.578	0.553	0.590
645.1700	0.189	0.158	0.166	657.9063	0.186	0.172	0.175	664.9142	0.368	0.329	0.328
651.9480	0.189	0.162	0.170	657.9133	0.207	0.168	0.179	664.9235	0.381	0.355	0.371
651.9573	0.193	0.170	0.184	657.9283	0.203	0.172	0.185	664.9299	0.402	0.377	0.378
651.9711	0.188	0.164	0.175	657.9357	0.204	0.175	0.184	664.9403	0.425	0.413	0.427
651.9789	0.188	0.164	0.172	657.9431	0.202	0.174	0.183	664.9423	0.426	0.410	0.430
651.9896	0.189	0.162	0.164	657.9507	0.200	0.180	0.183	664.9491	0.434	0.400	0.437
651.9987	0.194	0.174	0.188	657.9591	0.198	0.176	0.187	664.9515	0.446	0.413	0.444
652.0052	0.191	0.170	0.179	657.9661	0.200	0.172	0.186	664.9583	0.473	0.459	0.472
652.0134	0.189	0.170	0.179	657.9738	0.198	0.174	0.191	664.9607	0.483	0.466	0.473
652.0531	0.184	0.159	0.174	657.9844	0.201	0.178	0.192	664.9678	0.498	0.468	0.478
652.0638	0.194	0.169	0.193	658.0092	0.200	0.181	0.189	664.9699	0.506	0.476	0.487
652.0709	0.191	0.164	0.176	558.0164	0.205	0.184	0.199	664.9837	0.547	0.514	0.513
652.0827	0.194	0.169	0.177	658.0239	0.204	0.176	0.192	664.9861	0.550	0.518	0.522
652.0890	0.196	0.165	0.177	658.0311	0.208	0.182	0.191	664.9934	0.548	0.527	0.542
652.0954	0.194	0.161	0.168	658.0404	0.212	0.188	0.192	664.9956	0.552	0.530	0.537
652.1017	0.197	0.160	0.173	658.0462	0.217	0.186	0.206	665.0033	0.560	0.542	0.557
652.1163	0.180	0.150	0.154	658.0532	0.222	0.202	0.219	665.0159	0.585	0.569	0.581
652.1245	0.200	0.166	0.176	658.0604	0.230	0.208	0.213	665.0212	0.586	0.573	0.584
652.1312	0.191	0.156	0.169	658.0717	0.250	0.230	0.239	665.0292	0.587	0.569	0.580
652.1395	0.195	0.167	0.185	658.0778	0.270	0.252	0.266	665.0314	0.579	0.570	0.577
652.1567	0.200	0.163	0.179	658.0849	0.282	0.267	0.280	665.0419	0.585	0.560	0.580
652.1826	0.182	0.159	0.170	658.0920	0.297	0.274	0.279	665.0444	0.579	0.542	0.568
652.1900	0.188	0.168	0.173	658.0987	0.317	0.288	0.281	665.0550	0.553	0.534	0.574
652.2057	0.191	0.182	0.177	658.1054	0.323	0.295	0.310	665.0573	0.552	0.525	0.555
652.2123	0.189	0.172	0.167	658.1111	0.342	0.317	0.327	665.0654	0.532	0.510	0.526
654.9647	0.182	0.172	0.171	658.1224	0.373	0.346	0.359	665.0680	0.516	0.493	0.508
654.9741	0.184	0.156	0.178	658.1294	0.393	0.376	0.388	665;0753	0.516	0.485	0.508
654.9829	0.184	0.159	0.182	658.1352	0.409	0.391	0.407	665.0777	0.511	0.478	0.490
654.9905	0.189	0.161	0.171	658.1419	0.426	0.402	0.417	665.0777	0.511	0.478	0.490
654.9996	0.216	0.167	0.184	658.1479	0.444	0.418	0.441	665.0864	0.501	0.466	0.483
655.0117	0.193	0.171	0.182	658.1775	0.529	0.488	0.520	665.0885	0.482	0.450	0.471
655.0202	0.188	0.167	0.182	658.1846	0.557	0.523	0.546	665.9535	0.203	0.178	0.186

Table I. Continued

JD Hel. 2445000+	ΔV	ΔB	ΔV	JD Hel. 2445000+	ΔV	ΔB	ΔU	HD Hel. 2445000+	ΔV	ΔB	ΔU
665.9599	0.194	0.169	0.179	666.1025	0.209	0.178	0.197	667.0225	0.197	0.165	0.180
665.9658	0.202	0.173	0.185	666.1100	0.206	0.175	0.202	667.0279	0.193	0.162	0.174
665.9720	0.194	0.159	0.177	666.1148	0.211	0.180	0.209	667.0389	0.198	0.167	0.176
665.9773	0.192	0.158	0.167	666.1192	0.206	0.178	0.188	667.0575	0.189	0.158	0.171
665.9884	0.204	0.166	0.180	666.1265	0.206	0.185	0.200	667.0634	0.200	0.168	0.186
665.9939	0.197	0.165	0.179	666.1319	0.195	0.180	0.199	667.0688	0.194	0.159	0.170
665.9998	0.205	0.170	0.182	666.1377	0.190	0.174	0.182	667.0785	0.192	0.165	0.175
666.0120	0.197	0.164	0.169	666.1506	0.204	0.181	0.192	667.0843	0.193	0.166	0.183
666.0169	0.197	0.164	0.171	666.1506	0.204	0.181	0.192	667.0894	0.192	0.164	0.173
666.0220	0.200	0.165	0.173	666.1590	0.209	0.190	0.197	667.0983	0.193	0.164	0.174
666.0273	0.203	0.167	0.174	666.1664	0.201	0.177	0.180	667.1038	0.197	0.165	0.177
666.0366	0.186	0.158	0.166	666.1790	0.176	0.182	0.177	667.1097	0.195	0.163	0.182
666.0422	0.199	0.160	0.163	666.9522	0.189	0.158	0.169	667.1274	0.192	0.163	0.161
666.0480	0.191	0.156	0.170	666.9594	0.187	0.160	0.162	667.1328	0.182	0.159	0.166
666.0605	0.194	0.164	0.176	666.9810	0.191	0.159	0.173	667.1428	0.188	0.165	0.191
666.0666	0.190	0.174	0.193	666.9880	0.185	0.158	0.168	667.1496	0.198	0.162	0.184
666.0721	0.205	0.173	0.190	666.9930	0.190	0.161	0.173	667.1560	0.182	0.154	0.166
666.0781	0.197	0.171	0.204	667.0034	0.197	0.165	0.178	667.1626	0.183	0.160	0.169
666.0904	0.200	0.182	0.187	667.0099	0.192	0.159	0.176	667.1691	0.190	0.167	0.167
666.0966	0.199	0.168	0.174	667.0153	0.197	0.165	0.178	667.1796	0.198	0.179	0.189

III. LIGHT CURVES

The observed new light curves and the color curve of CW Cep together with the ΔV light curve of check star (HD 217919) in the *UBV* system are presented in Figure 1. The phase coverage of these light curves is incomplete, around the ascending shoulder of the primary minimum, $0^p.08 \sim 0^p.17$. Nevertheless, our light curves have better phase coverage than those of Nha (1975) and Söderhjelm (1976). The data of check star was applied for the correction of regional and instrumental difference between two observatories. The probable error for a single observation was calculated from the Δm (Check-Comp.), which turned out to be $\pm 0^m.011$, $\pm 0^m.006$, and $\pm 0^m.007$ for ΔU, ΔB, and ΔV, respectively. Larger scatter at phase $0^p.64 \sim 0^p.71$ in ΔB and ΔV may be resulted from the inaccuracy of observation due to bad sky condition, not responsible to the intrinsic variability of the star. A small amount of shift of the secondary minimum light toward increasing orbital phase is due to the effect of apsidal motion of CW Cep. The color curve of Figure 1 shows no variation and this indicates that CW Cep is consist of two stars having nearly same spectral type as were reported by earlier investigators (Popper 1974, Nha 1975).

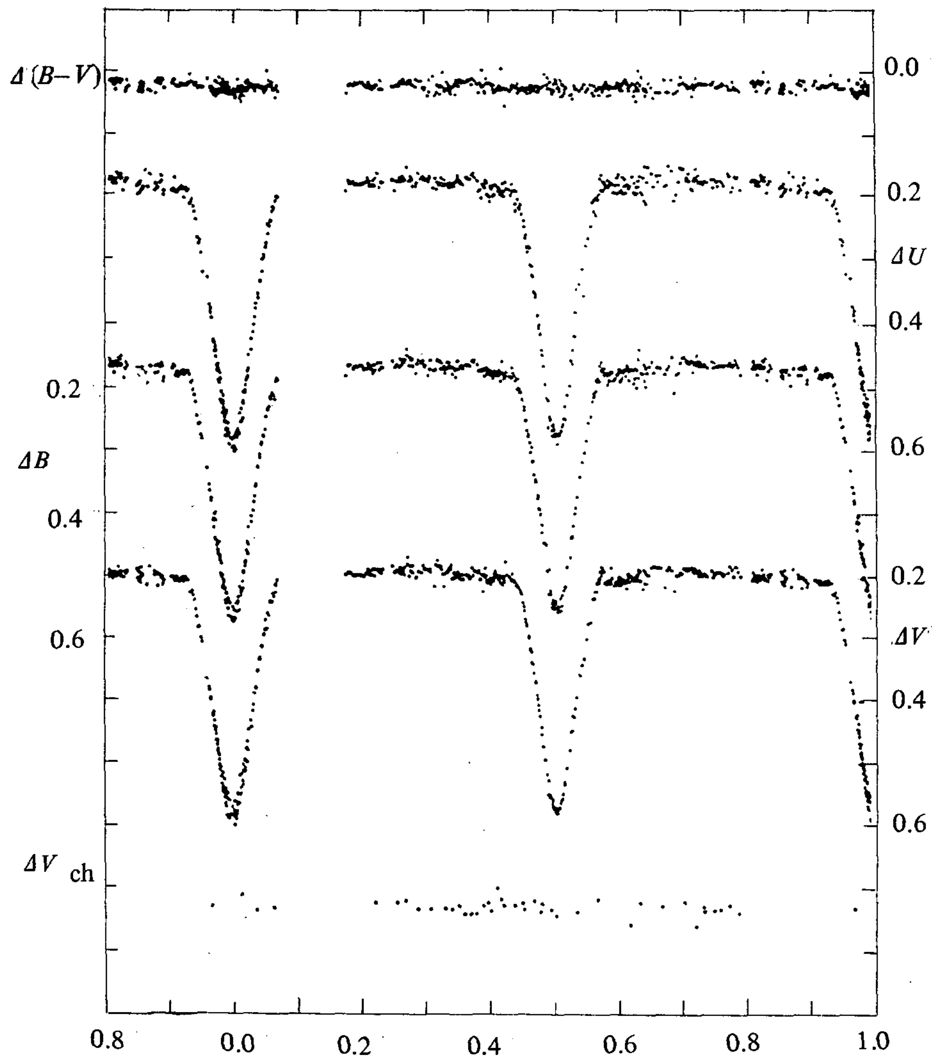

Fig. 1. Observed light curves and color curves of CW Cep in *UBV* system. Magnitude differences in the sense of Δm (Check-Comp.) are also shown. The orbital phases for this light curves were calculated using the light elements given by Nha (1975).

IV. PERIOD STUDY

In this study, three times of primary minimum light and one time of secondary minimum light were observed. Among them, the primary minimum on JD 2,445,665 was observed simultaneously at the two observatories. Using the method of Kwee and van Woerden (1956), we derived 12 times of minima in three colors and they are listed in Table II. The third column of Table II represents the weighted averages of U, B, and V.

Table II. New times of minimum light

JD Hel. 2445600+	Filter	Averaged JD Hel. 2445600+	Note
13.1686 ± 0.0006	V		
13.1685 ± 0.0008	B	13.1685	Min. I
13.1684 ± 0.0010	U	±7	
17.2759 ± 0.0009	V		
17.2789 ± 0.0015	B	17.2771	Min. II
17.2774 ± 0.0011	U	±12	
65.0206 ± 0.0010	V		
65.0236 ± 0.0010	B	65.0220	Min. I
65.0218 ± 0.0011	U	±10	
65.0241 ± 0.0018	V		
65.0242 ± 0.0006	B	65.0253	Min. I
65.0276 ± 0.0011	U	±12	

Table III. Collected times of minimum light since Nha's table

JD Hel. 2440000 +	E	$O-C_1$	$O-C_2$	$O-C_3$	Note
0984.5865	2056	0.0263	0.0251	0.1265	Pe, 1
2653.4974	2667.5	−0.0217	−0.0232	−0.0208	Pe, 2
4909.0564	3494	−0.0066	−0.0084	−0.0047	Pe, 3
5613.1685	3752	−0.0125	−0.0144	−0.0047	Pe, 4
5617.2771	3753.5	0.0024	0.0005	0.0045	Pe, 5
5665.0220	3771	−0.0126	−0.0145	−0.0105	Pe, 5
5665.0253	3771	−0.0093	−0.0122	−0.0072	Pe, 6

1. Söderhjelm (Kim 1981)
2. Brancewicz and Kreiner (1976)
3. Kim (1981)
4. Kim (this paper)
5. Han (this paper)
6. Nha (this paper)

Collected times of minima after the Nha's table are presented in Table III. The first column of Table III represents the observed times of minimum light, and the number of cycles counted with the ephemeris of Abrami and Cester (1960) are shown in column 2. To check the apsidal motion of CW Cep, the O-C residuals computed with the linear terms of light elements of Nha (1975) and Söderhjelm (1976) are given in columns 3 and 4, respectively. We found both O-C_1 and O-C_2 values did not successfully represent the sine terms of neither ephemeris of Nha nor Soderhjelm. A graphcal method was applied to search a better light elements of CW Cep for all minimum times in Nha's table and Table III of this paper. Most of times of minima observed by Nha and this paper have been weighted according to the number and the quality of observations, and the weighted average is given to the individuals. The new light elements derived in this study are:

$$\text{Min I} = \text{JD}2435373.4512 + 2^{\mathrm{d}}.7291385E + 0^{\mathrm{d}}.0256 \sin(0^{\circ}.0624E - 31^{\circ}.55)$$

In column 5 of Table III O-C_3 values are computed with our new light elements, and with these O-C_3 an O-C diagram is constructed and shown in Figure 2. The apsidal motion of CW Cep is now clearly appeared in Figure 2, but recent secondary minimum light still shows significant differences from the calculated value. Further observations of secondary minimum light

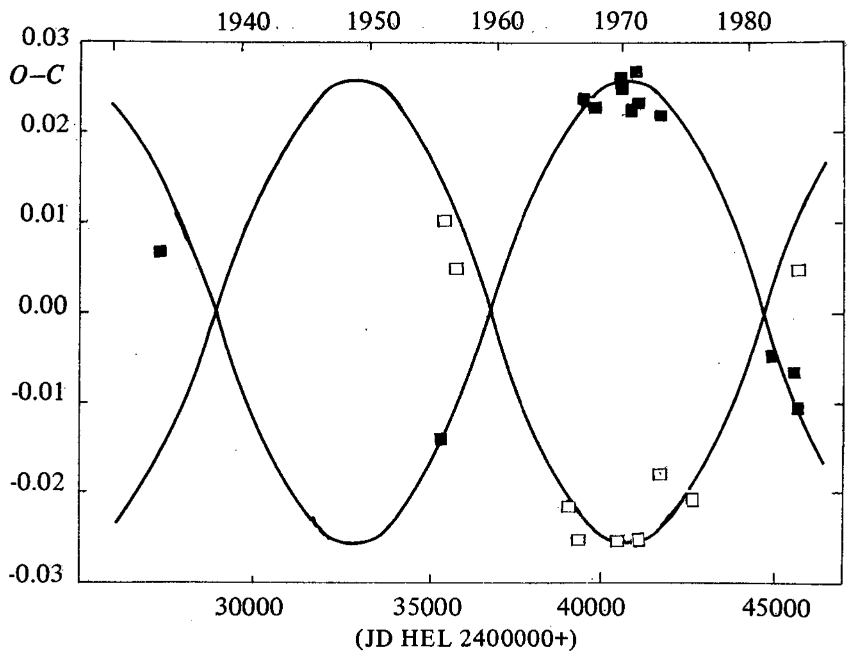

Fig. 2. The O-C diagram of CW Cep obtained by using the new light elements in this study. Filled squares represent primary minima and open squares are secondary minima. The continuous curves represent the sine terms of new light elements.

would be extremely important for the determination of accurate apsidal period. The apsidal period derived by new light element is 43.1 years, which is little longer than those of Nha(1975) and Kim (1981).

V. SUMMARY

The eclipsing binary system CW Cep is particulary interesting because of its high mass and short period of apsidal motion. This system has been studied for many years not only for the internal structure of stars related with its density distribution but also providing a sensitive test of different opacity theories and mass-luminosity relation.

Our *UBV* light curves are made in the standardized differential magnitude system. Although these light curves seem to be superior in the phase coverage than those of known previously, the lacking phase must be reinforced in next observing season for the complete light curve. Nevertheless, these light curves were obtained in a single observational season in 1983, and thus no orbital phase corrections due to the apsidal motion are needed for the light curve analysis.

Three times of primary minima and one time of secondary minimum light were obtained. With all collected times of minima including ours, new light elements are derived. With these light elements both the orbital period and the apsidal motion period are improved in some extent.

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