Photometric observations of the eclipsing variable CV Carinae on Franklin-Adams plates

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BULLETIN OF THE ASTRONOMICAL INSTITUTES OF THE NETHERLANDS

1939 November 6 Volume IX No. 323

COMMUNICATIONS FROM THE OBSERVATORY AT LEIDEN

Photometric observations of the eclipsing variable CV Carinae on Franklin Adams plates,

by *L. Plaut.*

The star CPD —57°3774 ($9^m{\cdot}6$) = CoD —57°3474 (10^m) has been found to be a variable of the Algol type by HERTZSPRUNG from estimates on Franklin Adams plates with the centre at η Carinae (*B.A.N.* No. 52, 1924). As a result of estimates on 408 plates of this kind HERTZSPRUNG published (*B.A.N.* No. 77, 1925) the following elements: Min. = J.D. 2423900·209 + $14^d{\cdot}4157$ E.

Meanwhile the number of Franklin Adams plates with the centre η Carinae has increased to 922 (see Table 1, *B.A.N.* No. 273, 1935). The following brands have been used: Gevaert Sensima (330 plates), Imperial SS (87), Ilford Zenith (490), Guilleminot La Superguil (15). The plates are of the size 20 × 20 cm. The exposure time was generally 30 minutes; 23 plates have been taken with a coarse grating ($d = l =$ ·95 mm) placed in front of the objective.

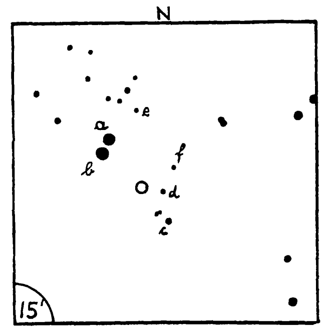
Of this material 888 plates have been measured with the second Schilt photometer of the Leiden Observatory. A diaphragm of 7 mm diameter or ·2 mm as projected on the plate has been used. The six comparison stars used are given in Table 1 and Figure 1. Successively the stars a, c, e, CV Carinae, b, d, f were measured. The galvanometer readings for zero point and plate fog have been controlled after the measurements of every plate. The galvanometer readings have been converted into provisional magnitudes m_{prov} by aid of a table

TABLE 1.

*	CPD	α (1875)	δ (1875)	m_{pg}
	° m	h m s	° ′	m
a	—57 3777 (9·6)	10 41 00	—57 13·1	11·16
b	—57 3778 (9·6)	41 02	13·8	11·27
c	—	40 42	17·2	12·27
d	—	40 44	15·7	12·39
e	—	40 50	11·7	12·60
f	—	40 40	14·7	13·56
v	—57 3774 (9·6)	40 47	15·5	—

like that described by WESSELINK (*B.A.N.* No. 318, 1939, see also *B.A.N.* No. 190, 1930).

FIGURE 1. CV Carinae



For the determination of the photographic magnitudes of the comparison stars (Table 2) the following procedures were used:

1. Comparison with the magnitudes of stars in Selected Area 193. The comparison stars have been connected with Selected Area stars by aid of measurements on one plate with the centre 11^h00^m, — 59°00′ containing both regions and on two pairs of plates of the Crux region (with the Selected Area) and the η Carinae region, which had been taken immediately after each other. The corrections of Table F, *Groningen Publ.* **43**, 1929, have been applied to the magnitudes of *H.A.* **101**. No field correction has been applied, because the distances of CV Carinae and of Selected Area 193 from the centre of the plates are not very different.

2. Grating-plates. On five plates taken with the grating mentioned above all comparison stars and on nine further plates of the same kind the comparison stars a to e have been measured. The theoretical value $^m{\cdot}98$ has been taken for the difference in magnitude between the central and first order images.

3. Star counts. By comparing counts of stars brighter than each comparison star in an area of one square degree around CV Carinae with the number of stars down to a certain magnitude given by VAN RHIJN (*Groningen Publ.* **43**, Table 10, 1929) and by BOK (Diss., Groningen = *Harvard Repr.* No. 77, 1932, Table VIII, field J) respectively, two sets

of magnitudes for the comparison stars have been obtained. The difference between these two sets shows that the distribution of the stars is too irregular in this region for an accurate scale of magnitudes from star counts.

4. Provisional magnitudes. From measures of a series of plates taken with a grating it is seen that the adopted table of provisional magnitudes is valid for the Franklin Adams plates. The means of the m_{prov} of the comparison stars from all plates therefore also give magnitudes for these stars.

5. For both the comparison stars a and b the magnitude $9^m{\cdot}6$ is given in the C.P.D. This magnitude is reduced to $10^m{\cdot}85$ by PANNEKOEK's tables (*Amsterdam Publ.* 2, 70, 1927). Herefrom a value of the zero point for the magnitudes of the comparison stars has been derived.

6. On one plate taken with a grating 20 stars from Table VI of BOK's paper quoted above and the comparison stars have been measured. These measurements give a value for the zero point of the magnitudes of the comparison stars.

Photovisual magnitudes of the comparison stars have been obtained from two plates, one of which had been taken with a grating. The zero point of these magnitudes is obtained from W. CHR. MARTIN's photovisual magnitudes of stars in NGC 3532 (*B.A.N.* No. 244, 1933). The estimated mean error of a single photovisual magnitude (last line of Table 2) is $\pm\,{}^m{\cdot}10$ (except for star f, the magnitude of which is more uncertain). The comparison stars c and d are yellow. As shown in Table 2 these stars are markedly fainter on the Imperial SS plates than on the Gevaert Sensima and Ilford Zenith plates, whereas f is brighter on the first kind of plates. This is accounted for by the fact that the Imperial SS plates are more sensitive for shorter wavelengths than normal photographic plates (see for comparison the sensitivity curves by WESSELINK, *B.A.N.* No. 294, 1937).

The provisional magnitudes m_{prov} of every plate have been converted into definitive magnitudes m by aid of linear relations between the m_{prov} and the adopted magnitudes (Table 2) of the comparison stars. The assumption of linearity between these two scales is verified by the measurements of Selected Area stars and of stars on plates taken with a grating.

On the Imperial SS plates the variable is systematically ${}^m{\cdot}06$ fainter in the maximum and ${}^m{\cdot}08$ brighter in the minimum than on the other plates. These corrections have been applied to reduce these observations to the other ones.

Preliminary phases have been computed from the formula: phase $= {}^{d^{-1}}{\cdot}0693722$ (J.D. — 2420000). The variation in brightness between the phases ${}^p{\cdot}5255$ and ${}^p{\cdot}5335$ on the descending and between ${}^p{\cdot}5975$ and ${}^p{\cdot}6055$ on the ascending branch of the light curve is approximately linear. A decrease or increase respectively of one magnitude takes ·16 days. With this gradient, ${}^{d/m}{\cdot}16$, the epochs of all observations between the phases mentioned above have been reduced to the magnitude $11^m{\cdot}91$. The period as a result of least squares solutions through these epochs is found to be:

Period $= 14^d{\cdot}414871 \pm {}^d{\cdot}000023$ (m.e.) from the descending branch,

Period $= 14^d{\cdot}414935 \pm {}^d{\cdot}000020$ (m.e.) from the ascending branch.

TABLE 2. Magnitudes of comparison stars.

a	b	c	d	e	f	Zero point	Brand of plates	Method
Photographic magnitudes								
m	m	m	m	m	m	m		
— 1·11	— ·92	+ ·22	+ ·34	+ ·35	+ 1·09	12·15	Imperial SS	1, Selected Area 193.
— 1·06	— ·94	+ ·17	+ ·30	+ ·35	+ 1·17	—	,,	4, Mean of m_{prov} of 85 plates.
— 1·08	— ·91	+ ·10	+ ·22	+ ·41	+ 1·25	12·43	Gevaert Sensima	1, Selected Area 193.
— 1·08	— 1·04	+ ·02	+ ·13	+ ·40	+ 1·58	—	,, ,,	2, 1 grating plate.
— 1·05	— ·90	+ ·08	+ ·21	+ ·37	+ 1·28	—	,, ,,	4, Mean of m_{prov} of 318 plates.
— 1·06	— ·98	+ ·10	+ ·22	+ ·40	+ 1·33	12·13	Ilford Zenith	1, Selected Area 193.
— 1·02	— ·96	— ·02	+ ·12	+ ·47	+ 1·43	—	,, ,,	2, 13 grating plates.
— 1·00	— ·80	— ·09	+ ·05	+ ·38	+ 1·45	12·35	,, ,,	3, Star counts, *Publ. Gron.* **43**.
— ·83	— ·69	— ·05	+ ·08	+ ·37	+ 1·09	12·00	,, ,,	3, ,, ,, *H. R.* **77**.
— 1·07	— ·97	+ ·10	+ ·24	+ ·37	+ 1·37	—	,, ,,	4, Mean of m_{prov} of 455 plates.
—	—	—	—	—	—	12·54	,, — ,,	6, 20 stars from *H. R.* **77**.
—	—	—	—	—	—	11·85	—	5, C.P.D. corrected according to *Amst. Publ.* **2**, 70.
Adopted photographic magnitudes								
— 1·08	— ·93	+ ·19	+ ·32	+ ·35	+ 1·13	12·21	Imperial SS	
— 1·05	— ·94	+ ·05	+ ·18	+ ·39	+ 1·35	12·21	Gevaert Sens. and Ilf. Zenith	
Photovisual magnitudes								
— ·57	— ·64	— ·46	— ·42	+ ·58	+ 1·50:	11·70	Eastman spectr. I-G	

A third least squares solution with the epochs of both branches yields the following elements:

$$\text{Min.} = \text{J.D. } 2425759{\cdot}730 + 14^{d}{\cdot}414897\ E$$
$$\pm 8 \qquad\qquad \pm 16 \quad \text{(m.e.)}.$$

The epochs and the O—C's from this last solution are given in Table 3.

Some older observations during the minimum or on the two branches are collected in Table 4. The first four are estimates by Prof. HERTZSPRUNG made on Arequipa plates during a stay at Harvard Observatory. The other two are estimates on glass-copies

TABLE 3. Determination of the period.

Plate	J.D. 242....	m	Reduction	J.D. ($m = 11^{m}{\cdot}91$)	O—C
Descending branch		m	d		d
1518	3885·2786	11·92	—·0016	3885·2770	·0000
1519	·3056	12·11	—·0320	·2736	— 34
1823	3986·2034	12·05	—·0224	3986·1810	— 1
2733	4202·4099	11·90	+·0016	4202·4115	+ 73
2734	·4306	12·10	—·0304	·4002	— 40
3328	4649·2438	11·76	+·0240	4649·2678	+ 26
3713	5067·2413	11·55	+·0576	5067·2989	+ 24
3714	·2572	11·71	+·0320	·2892	— 73
3715	·2731	11·73	+·0288	·3019	+ 54
3716	·2890	11·78	+·0208	·3098	+ 133
3717	·3050	12·02	—·0176	·2874	— 91
4075	5384·3736	11·65	+·0416	5384·4152	— 84
4076	·4020	11·81	+·0160	·4180	— 56
5169	5759·1915	11·80	+·0176	5759·2091	— 12
5172	·2670	12·30	—·0624	·2046	— 57
7388	6422·2711	11·66	+·0400	6422·3111	+ 167
7389	·3106	12·08	—·0272	·2834	— 110
7390	·3324	12·05	—·0224	·3100	+ 156
9682	7604·3057	11·87	+·0064	7604·3121	— 17
9683	·3272	11·91	·0000	·3272	+ 134
9889	7633·1967	12·33	—·0672	7633·1295	— 140
9890	·2182	12·41	—·0800	·1382	— 53
Ascending branch					
1527	3886·3161	11·90	—·0016	3886·3145	+ 43
1528	·3431	11·68	—·0368	·3063	— 39
1826	3987·2006	12·02	+·0176	3987·2182	+ 34
3336	4650·3200	11·76	—·0240	4650·2960	— 58
3722	5068·2793	12·32	+·0656	5068·3449	+ 100
5064	5731·3771	12·15	+·0384	5731·4155	— 64
5066	·4228	11·86	—·0080	·4148	— 71
5176	5760·2448	11·99	+·0128	5760·2576	+ 59
5177	·2667	11·80	—·0176	·2491	— 26
5178	·2885	11·66	—·0400	·2485	— 32
7396	6423·2920	12·18	+·0432	6423·3352	— 35
7397	·3515	11·83	—·0032	·3483	+ 96
7398	·3734	11·67	—·0384	·3350	— 37
9314	7533·2634	12·03	+·0192	7533·2826	— 61
9317	·3303	11·64	—·0432	·2871	— 16
9318	·3521	11·58	—·0528	·2993	+ 106

TABLE 4. Older observations.

Plate	J.D.	Phase	Estimate
		P	
AM 2792 Arequipa	2416663·522	·5396	CV Car = g
AM 10492 ,,	20613·559	·5642	CV Car = g
AM 11606 ,,	20959·628	·5720	CV Car = g
AM 12681 ,,	21161·836	·5997	CV Car 2st c
277 Johannesburg	21305·315	·5532	e 4 CV Car 1 f
1204 ,,	23525·259	·5566	e 4 CV Car 1 f

TABLE 5. Individual observations.

J.D. 242....	Phase	m	J.D. 242....	Phase	m
	P	m		P	m
3786·5010	·6797	11·09	3828·4910	·5926	13·04
·5341	·6820	11·08	·5166	·5944	12·93
·5551	·6834	11·23	·5415	·5961	12·61
3787·5264	·7508	11·04	·5654	·5978	12·69
3788·4763	·8167	11·10	3829·4593	·6598	11·16
·4969	·8181	10·98	·4901	·6620	11·11
·5111	·8191	11·10	3830·4794	·7306	11·14
·5296	·8204	11·02	·5050	·7324	11·06
3789·4958	·8874	11·03	·5299	·7341	11·11
·5185	·8890	11·02	·5549	·7358	11·12
·5331	·8900	10·99	3831·5190	·8027	11·11
3790·4744	·9553	11·05	·5439	·8044	11·13
·5450	·9602	11·09	·5696	·8062	11·08
·5649	·9616	10·97	3833·5786	·9456	11·11
3791·5009	·0265	11·08	·6043	·9474	11·15
·5204	·0279	11·08	3840·3070	·4124	11·11
·5673	·0311	11·19	3841·3086	·4818	11·17
3799·4877	·5806	13·21	·3342	·4836	11·09
·5090	·5821	13·27	·3548	·4850	11·17
·5577	·5855	13·13	3842·2858	·5496	13·19
3813·3740	·5439	13·10	·3034	·5508	12·97
·4017	·5459	13·35	·3419	·5535	13·26
·4230	·5473	13·15	·3682	·5553	13·14
·4365	·5483	13·28	3844·2929	·6889	11·15
·4490	·5491	13·22	·3206	·6908	11·08
·4615	·5500	13·14	·3400	·6921	11·12
·4739	·5509	13·25	3845·2825	·7575	11·01
·4864	·5517	13·19	·3088	·7593	11·04
·4989	·5526	13·22	3857·2688	·5890	13·06
·5113	·5535	13·19	·2951	·5909	13·18
·5238	·5543	13·28	·3207	·5926	13·09
·5363	·5552	13·23	·3484	·5946	12·96
3814·3832	·6139	11·39	3858·2410	·6565	11·12
·4130	·6160	11·25	·2534	·6573	11·12
·4400	·6179	11·18	·4877	·6736	11·10
·4670	·6198	11·19	·5126	·6753	11·13
·4933	·6216	11·10	3868·2445	·3504	11·16
·5135	·6230	11·05	3871·2364	·5580	13·14
·5260	·6239	11·06	·2620	·5598	13·15
·5385	·6247	11·18	·2870	·5615	13·15
·5509	·6256	11·10	·3147	·5634	13·17
3815·4336	·6868	11·15	·3389	·5651	13·11
·4622	·6888	11·17	·3631	·5668	13·02
·4814	·6901	11·11	3872·2434	·6279	11·15
3816·3617	·7512	10·99	·2626	·6292	11·15
·3825	·7526	11·08	·3126	·6327	11·26
·4008	·7539	11·13	·3389	·6345	11·12
·4609	·7581	11·13	·3646	·6363	11·18
·4872	·7599	11·10	·3895	·6380	11·15
3817·4035	·8235	11·15	·4137	·6397	11·12
·4333	·8255	11·16	3874·2518	·7672	11·09
·4616	·8275	11·05	·2722	·7686	11·09
·4880	·8293	11·05	·3106	·7713	11·12
·5122	·8310	11·12	·3328	·7728	11·10
3818·5331	·9018	11·28	3876·2518	·9059	11·08
·5587	·9036	11·13	·2775	·9077	11·07
·5840	·9053	11·13	·3024	·9094	11·12
3820·4426	·0343	11·22	·3273	·9112	11·01
3821·3770	·0991	11·17	·3523	·9129	11·14
3828·3345	·5818	13·31	·3772	·9148	11·08
·3615	·5837	12·99	·4021	·9164	11·13
·3871	·5854	13·09	·4271	·9181	11·10
·4134	·5873	13·20	·4520	·9198	10·98
·4390	·5890	13·05	3877·2415	·9746	11·17
·4661	·5909	13·15	·2664	·9763	11·15

TABLE 5 (*continued*).

J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*
	P	m		P	m		P	m		P	m
3877·2914	·9781	11·17	3897·2355	·3616	11·20	3928·2450	·5128	11·12	3944·2028	·6199	11·16
·3163	·9798	11·14	3899·2860	·5039	11·19	·2720	·5147	11·21	·2284	·6217	11·14
·3412	·9815	11·20	·3012	·5049	10·97	·2962	·5164	11·14	·2533	·6234	11·16
·3973	·9854	11·08	3900·2230	·5689	13·22	3929·2249	·5808	13·15	·2789	·6252	11·17
·4493	·9890	11·17	·2507	·5708	13·14	·2506	·5826	13·15	·3039	·6269	11·14
·4749	·9908	11·11	·2784	·5727	13·25	·2769	·5844	12·86	3945·2083	·6896	11·07
·4998	·9925	11·08	·3061	·5746	13·18	·3039	·5863	13·13	·2340	·6914	11·14
3878·2392	·0438	11·20	·3338	·5766	13·15	3930·2464	·6517	11·02	·2589	·6931	11·06
·2686	·0458	10·96	3901·2376	·6393	11·24	·2721	·6535	11·17	·2831	·6948	11·12
·2929	·0475	11·15	3902·3353	·7154	11·09	·2991	·6553	11·18	·3074	·6965	11·05
·3178	·0493	11·18	·3637	·7174	11·13	3931·2492	·7213	11·14	3946·2160	·7595	11·04
·3427	·0510	11·18	·3900	·7192	11·34	·2762	·7231	11·13	·2416	·7613	11·09
·3988	·0549	11·13	·4163	·7210	11·00	·3039	·7250	11·14	·2686	·7632	11·12
·4529	·0586	11·18	3903·2349	·7778	11·04	·3323	·7270	11·14	·2936	·7649	10·92
·4771	·0603	11·19	·2612	·7797	11·18	3932·2346	·7896	11·05	3947·2080	·8284	11·09
·5041	·0622	11·12	·2875	·7815	11·07	·2610	·7914	11·07	3948·2271	·8991	11·02
3879·2320	·1127	11·14	·3146	·7834	11·16	·2866	·7932	11·10	·2402	·9000	11·13
·2569	·1144	11·20	·3409	·7852	11·07	·3129	·7950	11·10	·2534	·9009	10·99
·2818	·1161	11·18	·3855	·7883	11·05	3933·2444	·8597	11·09	·2665	·9018	10·90
·3068	·1179	11·14	·4129	·7902	11·05	·2991	·8635	11·08	3949·1965	·9663	11·14
·3317	·1196	11·14	3904·2419	·8477	11·15	·3247	·8652	11·09	·2069	·9670	11·14
·3566	·1213	11·12	·2682	·8495	11·07	3934·2429	·9289	11·08	3955·1993	·3827	11·02
·3816	·1231	11·06	·2959	·8514	11·01	·2748	·9311	11·15	3956·1986	·4521	11·09
·4335	·1267	11·13	·3222	·8533	11·07	·3039	·9332	11·06	·2256	·4539	11·12
3880·2382	·1825	11·07	·3575	·8557	11·00	·3323	·9351	11·09	3957·2097	·5222	11·37
·2639	·1843	11·15	·3838	·8575	11·04	3935·2444	·9984	11·20	·2443	·5246	11·47
·2930	·1863	11·17	·4095	·8593	11·13	·2845	·0012	11·07	·2720	·5265	11·37
·3234	·1884	11·14	3907·2973	·0596	11·18	·3011	·0023	11·15	3958·2013	·5910	13·11
·3518	·1904	11·13	·3236	·0615	11·18	·3282	·0042	11·13	·2276	·5928	13·21
·3781	·1922	11·09	·3499	·0633	11·07	3936·2229	·0663	11·18	·2532	·5946	12·93
·4342	·1961	11·14	·3776	·0652	11·19	·2603	·0689	11·15	3959·2006	·6603	11·14
·4889	·1999	11·07	3908·2482	·1256	11·12	·2866	·0707	11·16	·2277	·6622	11·13
3881·3131	·2571	11·13	·2772	·1276	11·09	·3143	·0726	11·10	·2533	·6640	11·13
·3429	·2591	11·14	·3517	·1328	11·12	3937·2367	·1366	11·12	3960·2345	·7320	11·08
·3713	·2611	11·12	3910·2323	·2633	11·10	·2658	·1386	11·17	·2601	·7338	11·01
·4308	·2652	11·01	·2593	·2651	11·07	·2928	·1405	11·14	3962·2200	·8698	11·09
·4585	·2671	11·19	·2863	·2670	11·06	·3254	·1428	11·17	·2677	·8731	11·09
·4883	·2692	11·07	·3133	·2689	11·07	3938·2111	·2042	11·11	3963·1978	·9376	11·06
3882·2709	·3235	11·05	3911·2642	·3348	11·09	·2395	·2062	11·12	·2228	·9393	11·19
3883·4635	·4062	11·11	·2926	·3368	11·11	·2679	·2082	11·09	·2463	·9410	11·07
·4925	·4082	11·13	·3196	·3387	10·98	3939·2041	·2731	11·21	3964·2033	·0074	11·14
3884·2412	·4602	11·03	·3473	·3406	11·09	·2312	·2750	11·07	·2275	·0090	11·06
·2994	·4642	11·11	3913·2552	·4730	11·12	·2582	·2769	11·04	·2532	·0108	11·17
·3264	·4661	11·18	·2843	·4750	11·13	·2872	·2789	11·04	3965·2068	·0770	11·07
·3825	·4700	11·17	·3113	·4769	11·15	·3136	·2807	11·06	·2304	·0786	11·13
·4095	·4719	11·18	·3411	·4789	11·12	3940·2056	·3426	11·04	·2539	·0803	11·12
3885·2786	·5322	11·92	3914·3110	·5462	13·37	·2326	·3445	11·04	3966·2047	·1462	11·10
·3056	·5340	12·11	3915·2684	·6126	11·41	·2575	·3462	11·10	·2324	·1481	11·13
·3312	·5358	12·38	·2968	·6146	11·32	·2831	·3480	11·07	·2566	·1498	11·04
·3603	·5378	12·48	·3252	·6166	11·21	·3101	·3498	11·10	3967·2040	·2155	10·82
·3860	·5396	12·61	·3522	·6184	11·11	3941·2208	·4130	11·03	·2290	·2173	11·06
·4123	·5414	12·84	3916·3176	·6854	11·17	·2527	·4152	11·17	·2532	·2189	10·97
·4414	·5434	12·87	·3419	·6871	11·14	·2818	·4172	11·13	3968·2150	·2857	11·13
·4691	·5454	13·22	·3661	·6888	11·10	·3109	·4193	11·08	·2393	·2874	11·14
3886·3161	·6041	11·90	·3903	·6905	11·13	3942·2090	·4813	11·07	3969·2206	·3554	11·09
·3431	·6060	11·68	3918·2788	·8215	11·13	·2353	·4834	11·00	·2469	·3573	11·05
·3687	·6078	11·66	3919·3043	·8926	11·06	·2616	·4852	11·18	3970·2053	·4237	11·07
·4469	·6132	11·29	·3154	·8934	11·03	·2880	·4870	11·09	·2309	·4255	11·05
3887·2558	·6693	11·21	·3265	·8941	11·00	·3212	·4893	11·05	3971·2005	·4928	11·12
·3750	·6776	11·12	·3375	·8949	11·04	3943·2049	·5507	13·20	·2261	·4946	10·97
·4006	·6794	11·18	3926·2145	·3720	11·15	·2312	·5525	13·17	3972·2081	·5627	12·94
·4276	·6812	11·12	3927·2187	·4416	11·07	·2561	·5542	13·24	·2330	·5644	13·30
·4546	·6831	11·08	·2430	·4433	11·12	·2811	·5560	13·21	3973·2240	·6332	11·21
3889·4685	·8228	11·12	3928·2194	·5111	11·09	·3074	·5578	13·11	3974·2080	·7014	11·12

TABLE 5 (*continued*).

J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*
	P	m		P	m		P	m		P	m
3974·2316	·7031	11·02	4177·5477	·8076	11·08	4206·4746	·8144	11·02	4290·2848	·6285	11·12
3975·2074	·7708	10·95	·5712	·8093	11·13	4207·4179	·8798	11·15	4291·2502	·6955	11·20
·2309	·7724	11·06	·5948	·8109	11·05	·4345	·8810	10·98	·2738	·6971	11·17
3976·2052	·8400	11·15	4187·5728	·5031	11·13	4226·2807	·1884	11·09	4292·2475	·7647	11·15
·2281	·8416	11·13	4190·4076	·6998	11·04	4228·2874	·3276	11·08	·2710	·7663	11·13
3977·1997	·9090	11·11	·4304	·7013	11·11	4238·2848	·0211	11·07	·3416	·7712	11·10
·2233	·9106	11·02	4196·3258	·1103	11·15	·3084	·0228	10·99	·3652	·7728	11·00
3978·2059	·9788	10·96	·3554	·1124	10·99	·3253	·0239	10·98	4293·2447	·8338	11·08
·2170	·9795	10·93	·3769	·1139	11·11	4240·4199	·1693	11·07	·2682	·8355	10·98
·2281	·9803	10·98	4198·3251	·2490	11·10	4245·3177	·5090	11·18	·3389	·8404	11·04
3979·2103	·0484	11·09	·3487	·2507	11·06	·3613	·5120	11·17	·3624	·8420	11·04
·2207	·0492	11·19	·3722	·2523	11·10	·3821	·5135	11·16	4294·2482	·9035	11·17
3985·2031	·4642	11·11	·3958	·2539	11·10	4254·4185	·1404	11·09	·2703	·9050	11·04
3986·2034	·5336	11·05	·4193	·2556	11·07	·4344	·1415	11·16	·3382	·9097	11·11
3987·2006	·6028	12·02	·4394	·2570	11·09	4257·2718	·3383	11·13	·3603	·9112	11·06
3988·1985	·6720	11·16	·4532	·2579	11·07	·3099	·3410	11·05	4296·2516	·0424	11·15
3989·1961	·7412	10·98	·4671	·2589	11·02	4258·2593	·4068	11·11	·2741	·0440	11·08
3990·1954	·8105	10·99	·4809	·2598	11·07	4261·2400	·6136	11·24	·2973	·0456	11·21
3991·1938	·8798	11·02	·4948	·2608	11·11	·2636	·6152	11·15	·3209	·0473	11·08
3992·1919	·9490	11·03	·5086	·2618	11·07	4262·2207	·6816	11·11	4297·2558	·1121	11·10
4141·4786	·3054	11·03	·5225	·2627	11·06	·2442	·6832	11·11	·2779	·1136	11·14
·5028	·3071	11·05	·5327	·2634	11·13	·3398	·6899	11·14	·3015	·1153	11·12
·5271	·3088	11·06	4200·3246	·3877	11·12	·3613	·6914	11·08	·3236	·1168	11·12
·5506	·3104	11·11	·3481	·3894	11·06	4263·2096	·7502	11·11	4298·2391	·1803	11·08
·5707	·3118	11·00	·3717	·3910	11·12	·2332	·7519	11·07	4537·3899	·7709	11·02
4168·4700	·1779	11·04	·3952	·3926	11·20	·2505	·7531	11·04	·4148	·7726	10·96
·4818	·1787	11·03	·4188	·3943	11·07	·4063	·7639	11·04	4538·4578	·8449	11·17
·4956	·1797	11·11	·4423	·3959	11·02	·4299	·7655	11·10	·5070	·8483	11·05
·5067	·1804	11·07	4201·3385	·4581	11·12	4264·3260	·8277	11·15	4543·4225	·1893	11·15
4169·3932	·2419	11·13	·3620	·4597	11·14	·3496	·8293	11·06	·4322	·1900	11·06
·4168	·2436	11·12	·3856	·4613	11·03	·4230	·8344	11·15	·4422	·1907	11·14
·4403	·2452	11·12	·4079	·4629	11·09	4266·2391	·9604	11·10	4550·3744	·6716	11·14
·4625	·2467	11·11	·4562	·4662	11·09	4277·2681	·7255	10·88	·3938	·6730	11·13
·4801	·2480	11·07	4202·4099	·5324	11·90	·2785	·7262	11·09	4553·4349	·8839	11·08
·4961	·2491	11·07	·4316	·5339	12·10	·2889	·7270	11·24	·4592	·8856	11·01
·5092	·2500	11·09	4204·3768	·6688	11·09	·2969	·7275	11·04	·4862	·8875	11·05
·5231	·2510	11·07	·3955	·6701	11·03	4280·1947	·9285	11·11	4558·3799	·2270	11·12
·5362	·2519	11·05	·4212	·6719	11·14	4281·2010	·9983	11·13	4559·3218	·2923	11·04
·5490	·2527	11·07	·4447	·6736	11·01	4282·2017	·0678	11·12	·3468	·2941	11·13
4171·4100	·3818	11·03	·4793	·6760	11·07	·2245	·0693	11·16	·3946	·2974	11·08
·4336	·3835	11·08	·5029	·6776	11·14	4284·1962	·2061	11·07	·4195	·2991	11·17
·4571	·3851	11·07	·5264	·6792	11·07	·2820	·2121	10·97	4560·4687	·3719	11·05
·4807	·3868	11·06	·5500	·6809	11·13	4285·2152	·2768	11·09	·4930	·3736	11·13
4172·4222	·4521	11·08	·5735	·6825	11·08	·2436	·2788	11·11	4566·4603	·7875	11·08
·4406	·4533	11·15	·5971	·6841	11·07	·2668	·2804	11·12	·4845	·7892	11·02
·4641	·4550	11·12	4205·3354	·7353	11·19	·2904	·2820	11·13	4586·4617	·1751	11·06
·4884	·4567	11·08	·3589	·7370	11·09	4286·2253	·3469	11·13	·4859	·1768	11·15
·5112	·4582	11·14	·3825	·7386	11·12	·2488	·3485	11·10	4592·3983	·5869	13·03
4173·4168	·5211	11·24	·4060	·7402	11·08	·3195	·3534	11·27	4595·3023	·7884	11·08
4176·4091	·7287	11·12	·4295	·7419	11·10	·3431	·3551	11·11	4627·2368	·0038	11·06
·4326	·7303	11·12	·4531	·7435	11·07	·3666	·3567	11·08	4642·3480	·0521	11·16
·4562	·7319	11·08	·4766	·7451	11·07	4287·2488	·4179	11·12	·3739	·0539	11·12
·4797	·7335	10·95	·4974	·7466	11·10	·2724	·4195	11·12	4648·2403	·4608	11·06
·5033	·7352	11·04	·5182	·7480	11·06	·3430	·4244	11·11	4649·2438	·5305	11·76
·5268	·7368	11·12	·5417	·7497	11·10	·3666	·4261	11·03	4650·3200	·6051	11·76
·5504	·7385	11·13	·5653	·7513	11·12	4288·2461	·4871	11·11	4651·2369	·6687	11·15
·5739	·7401	11·01	·5888	·7529	11·05	·2696	·4887	11·13	4915·3992	·9944	11·12
·5975	·7417	10·97	4206·3098	·8029	11·07	·3402	·4936	11·04	·4269	·9963	11·12
4177·4064	·7978	11·07	·3334	·8046	11·05	·3638	·4952	11·13	4918·4382	·2052	10·98
·4300	·7995	11·14	·3570	·8062	11·01	4289·2599	·5574	13·12	·4652	·2071	11·10
·4535	·8011	11·12	·3805	·8078	11·11	·2835	·5590	13·09	4976·3674	·2239	11·11
·4771	·8027	11·08	·4040	·8095	11·11	·3541	·5639	13·16	5025·4027	·6256	11·17
·5006	·8044	11·12	·4275	·8111	11·02	·3776	·5656	13·14	5038·2404	·5162	11·15
·5242	·8060	11·05	·4511	·8127	11·02	4290·2668	·6273	11·10	·2651	·5179	11·09

TABLE 5 (*continued*).

J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*	J.D. 242....	Phase	*m*
	P	m		P	m		P	m		P	m
5039.1895	.5820	13.22	5570.5631	.4448	11.15	5773.1964	.5020	11.22	6124.2712	.8570	11.09
.2117	.5836	13.19	5571.5044	.5101	11.17	.2182	.5036	11.14	.3564	.8630	11.09
5043.2407	.8631	11.04	5614.4532	.4896	11.13	.2401	.5051	11.19	.3782	.8645	11.03
5067.2239	.5269	11.45	.4754	.4911	11.12	.2622	.5066	11.20	6125.1971	.9213	11.00
.2413	.5281	11.54	5615.3993	.5552	13.19	.2844	.5082	11.12	.2497	.9249	11.06
.2572	.5292	11.71	.4215	.5568	13.13	.3069	.5097	11.20	6126.1943	.9905	11.10
.2731	.5303	11.73	5640.3268	.2845	11.11	.3287	.5112	11.23	.2161	.9919	11.12
.2890	.5314	11.78	5641.4128	.3600	11.04	5774.1888	.5709	13.22	.2826	.9966	11.10
.3050	.5325	12.02	.4827	.3647	11.04	.2331	.5740	13.20	.3044	.9981	11.11
5068.2239	.5962	12.62	.5045	.3662	11.10	.2622	.5760	13.17	.3640	.0022	11.10
.2409	.5974	12.55	.5734	.3710	11.04	.2840	.5775	13.19	.3858	.0037	11.06
.2627	.5989	12.31	5651.5461	.0628	11.13	.3059	.5790	13.24	6129.3515	.2095	11.11
.2793	.6001	12.32	.5678	.0643	11.13	5775.2002	.6411	11.13	.3733	.2110	11.11
5078.2210	.2897	10.97	5652.5452	.1322	11.14	.2304	.6432	11.05	6155.1942	.0023	11.02
.2435	.2913	11.02	.5668	.1336	11.08	.2778	.6464	11.07	.2160	.0038	11.10
.2626	.2926	11.02	5686.2556	.4707	11.13	.2996	.6480	11.16	6269.5954	.9386	11.09
5319.3296	.0161	11.12	.2774	.4722	11.08	.3214	.6495	11.08	6363.4458	.4490	11.07
5320.2556	.0803	11.13	.3013	.4739	11.10	.3437	.6510	11.11	.4680	.4508	11.13
.3705	.0883	11.11	.3234	.4754	11.06	5776.2546	.7142	11.08	6364.4432	.5184	11.20
5327.2657	.5666	13.25	.3453	.4770	11.12	2771	.7158	11.03	.4650	.5200	11.25
.2975	.5689	13.17	.3688	.4786	11.07	.2989	.7173	11.05	6413.2761	.9061	11.09
.3315	.5712	13.21	5709.2568	.0664	11.14	.3207	.7188	11.08	.2979	.9076	11.13
.3557	.5729	13.26	.3025	.0696	11.15	5777.2356	.7823	11.04	6420.4033	.4005	11.02
5328.3329	.6407	11.06	.3483	.0727	11.09	.2761	.7851	11.04	6421.3577	.4667	11.11
.3828	.6441	11.13	.3701	.0742	11.09	.2979	.7866	11.05	6422.2711	.5301	11.66
5329.2727	.7059	11.11	5716.4777	.5673	13.19	5789.1998	.6122	11.40	.3106	.5328	12.08
.3011	.7078	11.11	.5013	.5690	13.22	5791.2048	.7513	11.13	.3324	.5343	12.05
5330.2700	.7751	11.05	5731.2043	.5889	13.11	.2275	.7529	11.09	6423.2705	.5994	12.43
5377.2987	.0376	11.14	.2860	.5946	12.90	5922.5604	.8638	11.05	.2920	.6009	12.18
.3215	.0391	11.16	3553	.5994	12.40	.5822	.8653	10.91	.3515	.6050	11.83
5379.3507	.1799	11.10	.3771	.6009	12.15	5923.5516	.9326	11.04	.3734	.6066	11.67
.3749	.1816	11.02	.4228	.6041	11.86	.5734	.9341	11.16	.5721	.6203	11.08
5380.2454	.2420	11.01	5732.2015	.6581	11.03	5950.4775	.8005	11.04	6449.2939	.4047	11.12
.2697	.2437	11.09	.2552	.6618	11.12	.4991	.8020	10.98	.3170	.4063	11.06
5381.3361	.3177	11.04	5738.1982	.0741	11.14	.5210	.8035	11.06	6476.2872	.2773	11.06
.3597	.3193	11.06	.2734	.0793	11.11	.5428	.8050	11.03	.3088	.2788	11.09
5382.3382	.3865	11.03	.3412	.0841	11.14	.5646	.8066	11.13	6826.3431	.5616	13.21
.3618	.3888	11.06	.3634	.0856	11.06	6007.3567	.7464	11.01	.3656	.5632	13.27
5383.3867	.4599	11.07	5740.2019	.2131	11.09	.3789	.7479	11.08	6828.2846	.6963	11.07
.4096	.4615	11.02	5745.2641	.5643	13.20	6010.5149	.9655	11.15	.3068	.6979	11.09
5384.3736	.5284	11.65	.2863	.5659	13.22	.5367	.9670	11.09	6829.3340	.7691	11.09
.4020	.5303	11.81	5746.2539	.6330	11.11	6030.3871	.3441	11.09	6855.3439	.5735	13.31
5385.3674	.5973	12.72	.2757	.6345	11.11	.4089	.3456	11.08	.3660	.5750	13.23
.3895	.5988	12.43	.2977	.6360	11.16	6036.3425	.7572	11.10	6882.2094	.4372	11.01
5386.3223	.6636	11.05	.3207	.6376	11.18	.3643	.7587	11.09	6883.2219	.5075	11.06
.3452	.6651	11.08	.3425	.6391	11.22	6118.2954	.4425	11.06	.2444	.5090	11.07
5391.3819	.0146	11.05	.3644	.6406	11.19	.3169	.4440	11.12	6884.2262	.5772	13.12
.4062	.0162	11.09	5753.2954	.1215	11.12	6120.2005	.5746	13.13	7426.5683	.2002	11.02
5406.2040	.0428	11.14	5759.1915	.5305	11.80	.2334	.5769	13.30	7427.5530	.2692	11.03
.2268	.0444	11.08	.2670	.5357	12.12	.2552	.5784	13.29	.5745	.2707	11.11
5442.2341	.5423	12.94	5760.1894	.5997	12.30	.2770	.5800	13.26	7533.2634	.6026	12.03
5446.2355	.8199	11.17	.2448	.6036	11.99	.2989	.5815	13.17	.3303	.6072	11.64
5447.2091	.8874	11.04	2667	.6051	11.80	.3203	.5830	12.97	.3521	.6087	11.58
.2313	.8890	11.01	.2885	.6066	11.66	.3421	.5845	13.21	7604.3057	.5310	11.87
5561.5529	.8198	11.13	5761.1957	.6695	11.12	.3640	.5860	13.15	.3272	.5325	11.91
.5750	.8213	11.09	.2914	.6762	11.14	.3858	.5875	13.17	7605.1844	.5919	12.98
5562.5467	.8887	11.01	.3453	.6799	11.05	.4072	.5890	13.19	7618.1983	.4948	11.22
.5689	.8903	11.03	.3674	.6814	11.09	6122.2057	.7138	11.07	7619.1972	.5641	13.18
5564.5468	.0275	11.17	5766.1960	.0164	10.96	.2275	.7153	11.11	7633.1967	.5352	12.33
.5690	.0290	11.05	5772.3259	.4417	10.92	6123.3003	.7897	11.13	.2182	.5367	12.41
5570.5188	.4418	11.09	.3386	.4425	10.94	.3221	.7912	11.14			
.5410	.4433	11.10	.3513	.4434	10.98	6124.2490	.8555	11.09			

of older Franklin Adams plates. The star g is the double star north following c (Figure 1).

Definitive phases have been computed from the formula:

$$\text{Phase} = {}^{\mathrm{d}^{-1}}{\cdot}06937267 \ (\text{J.D.} - 2420000).$$

The individual observations are given in Table 5.

The mean external error of a single observation, computed in the usual manner, is found to be:

± $^{\mathrm{m}}$·062 from all observations,
± ·056 from observations during maximum,
± ·076 from observations during minimum.

The mean "night error", that is the error which is common to all observations of one night, is ± $^{\mathrm{m}}$·026 for observations during maximum. The amount of this "night error" is comparatively small and justifies the use of the same weight for each plate in the determination of the period, even in the case when several plates had been taken in one night. By measuring ten plates six times each the mean measuring error of a single observation has been found to be ± $^{\mathrm{m}}$·024. A comparison of this error and the external error shows that the mean external error ± $^{\mathrm{m}}$·062 is only reduced to ± $^{\mathrm{m}}$·060 by measuring the plates twice.

The phase of the middle of the primary minimum is $^{\mathrm{P}}$·5679 as derived by the method of *B.A.N.* Nos. 147 and 166. Phases reflected with respect to this phase have been computed. Normal points with these phases representing each *n* observations are given in Figure 3 and the first three columns of Table 6. The mean external errors of a single observation on the descending and ascending branches, viz. ± $^{\mathrm{m}}$·068 before and ± $^{\mathrm{m}}$·071 after reflecting the light curve, show that the light curve is symmetrical. The individual observations on the branches are shown in Figure 2.

An idea of the accuracy, which is gained by measuring the plates, may be obtained by a comparison of the external error, the night error and the total weight of these measurements and of the estimates of variable stars on the same plates (*B.A.N.* No. 273, 1935):

	measurements	estimates
external mean error:	± $^{\mathrm{m}}$·062	± $^{\mathrm{m}}$·096
mean night error:	± ·026	± ·040
total weight:	230000$^{\mathrm{m}^{-2}}$	80000$^{\mathrm{m}^{-2}}$

It should be mentioned that for measuring these plates fifteen times the time of estimating is required.

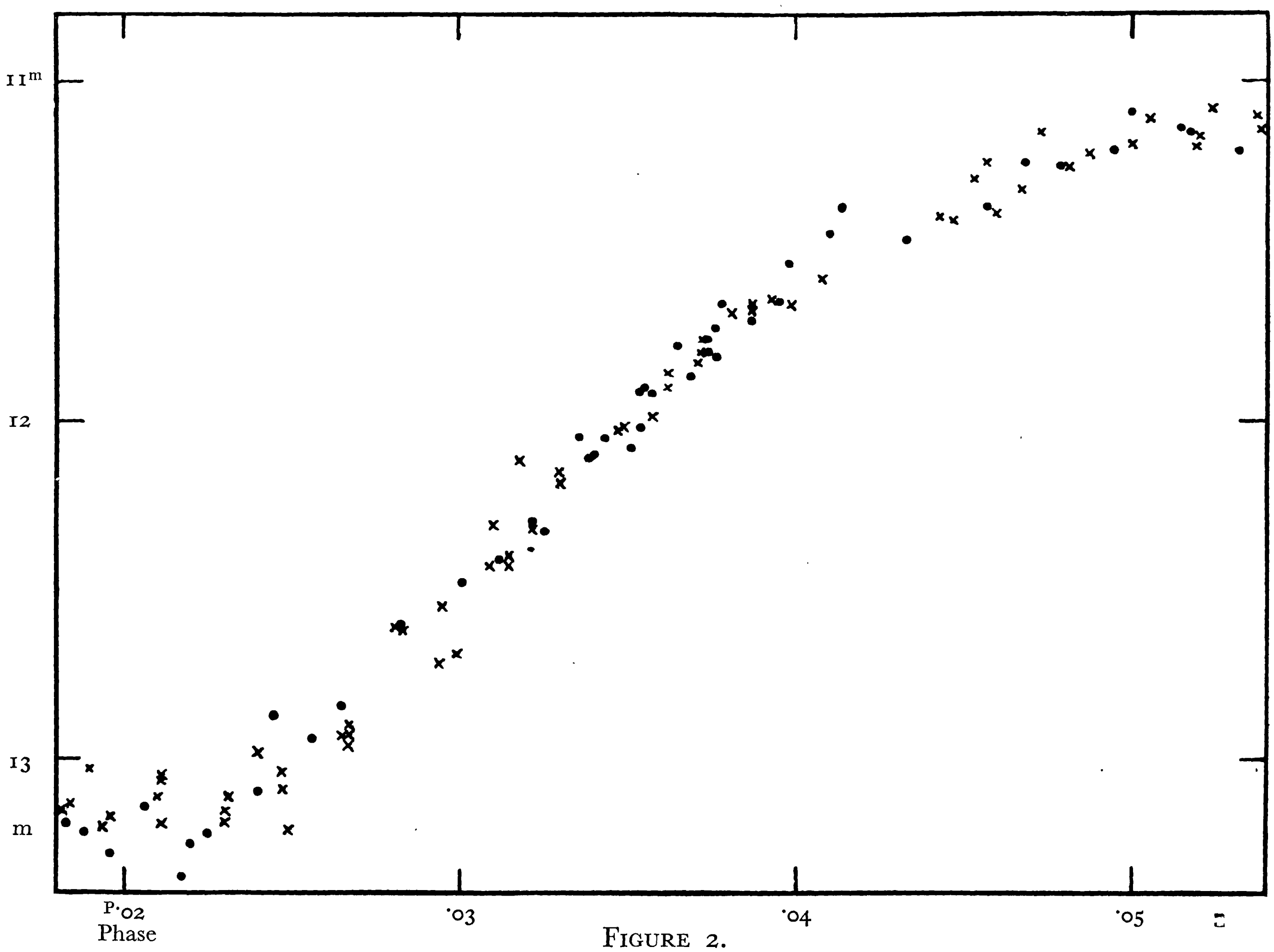


FIGURE 2.
Individual observations. • = descending branch, × = ascending branch.

Determination of the orbital elements.

The method used by VAN GENT (*B.A.N.* No. 215, 1931) has been followed, while the mean errors of the elements have been computed by the method of PANNEKOEK and Miss VAN DIEN (*B.A.N.* No. 297, 1937). The eccentricity of the orbit cannot be determined from the light curve. Preliminarily a circular orbit has been assumed. The two extreme assumptions about limb darkening, the so-called U and D hypotheses, have been made.

Reflection effect.

An approximate elimination of the reflection effect may be made with RUSSELL's formula 47 (*Ap. J.* 36, 68, 1912):

$$l = l_1 + l_2 + (c_2 - c_1) \cos \theta \sin i,$$

where l = the intensity of the whole system,

l_1, l_2 = the mean intensity of component 1, resp. 2,

$l_1 + c_1, l_2 + c_2$ (resp. $l_1 - c_1, l_2 - c_2$) = the intensity of the brighter (resp. fainter) hemisphere of components 1 and 2,

θ = the orbital longitude counted from mid-eclipse,

i = the inclination of the orbit.

In the case of CV Carinae the light curve shows that $c_1 \neq c_2$. A least squares solution of the normal points (Table 6) outside eclipse (phase = $^{P}\cdot0750$ — $^{P}\cdot4250$) yields:

$$l = \cdot9536 - \cdot0107 \cos \theta$$
$$\pm 26 \quad \pm 48 \text{ (m.e.)}$$

(the unit of l is arbitrarily put equal to $11^{m}\cdot033$). The coefficient of $\cos \theta$ has the right sign but is not much greater than twice its mean error. The reflection effect therefore has not been eliminated.

U hypothesis, ellipticity of the components.

The rectification of the light curve on account of the ellipticity of the components is made with the aid of RUSSELL's formulae 40 and 41 (l.c.p. 64): outside eclipse, l^2 = const. $(l - z \cos^2 \theta)$; $z = \varepsilon^2 \sin^2 i$, where ε = the eccentricity of the equatorial section.

A least squares solution yields:

$$l^2 = \cdot9291 \; (l - \cdot075 \cos^2 \theta)$$
$$\pm 73 \quad \pm 20 \text{ (m.e.)}$$

and the light curve is rectified with:

$$l_{\text{rect}} = \frac{l}{\sqrt{1 - \cdot075 \cos^2 \theta}}.$$

Column 4 of Table 6 gives the rectified magnitudes m_U.

U hypothesis, orbital elements.

Suppose:

l = the intensity of the system in units of its intensity at maximum,

k = the ratio of the radii of the components, $k \leq 1$,

a_1, a_2 = the semi axis major of the larger and smaller component in units of the radius of the orbit,

d_1, d_2 = the values of the projections of a_1, a_2 at any instant,

δ = the projected distance of the centres of the two stars,

α = the loss of light in units of the intensity of the eclipsed component.

The following approximate data have been derived from the rectified light curve:

the duration of the primary minimum $D = {}^{P}\cdot100$,

the duration of the constant phase of this minimum $d = {}^{P}\cdot047$,

the intensity of the system during this constant phase l (min. I) = $\cdot150$,

the intensity of the system at the middle of the secondary minimum l (min. II) = $\cdot998$.

A maximum value of k is found from the formula

$$\frac{d}{D} = \frac{1 - k_{\max}}{1 + k_{\max}}, \text{ viz. } k_{\max} = \cdot36.$$

With the assumption of total eclipse at primary minimum (RUSSELL, *Ap. J.* 35, 323-4):

l (min. II) = $1 - k^2 \, l$ (min. I) and $k = \cdot115$,

whereas with annular eclipse:

$$l \text{ (min. II)} = \frac{1 - l \text{ (min. I)}}{k^2} \text{ and } k = \cdot92.$$

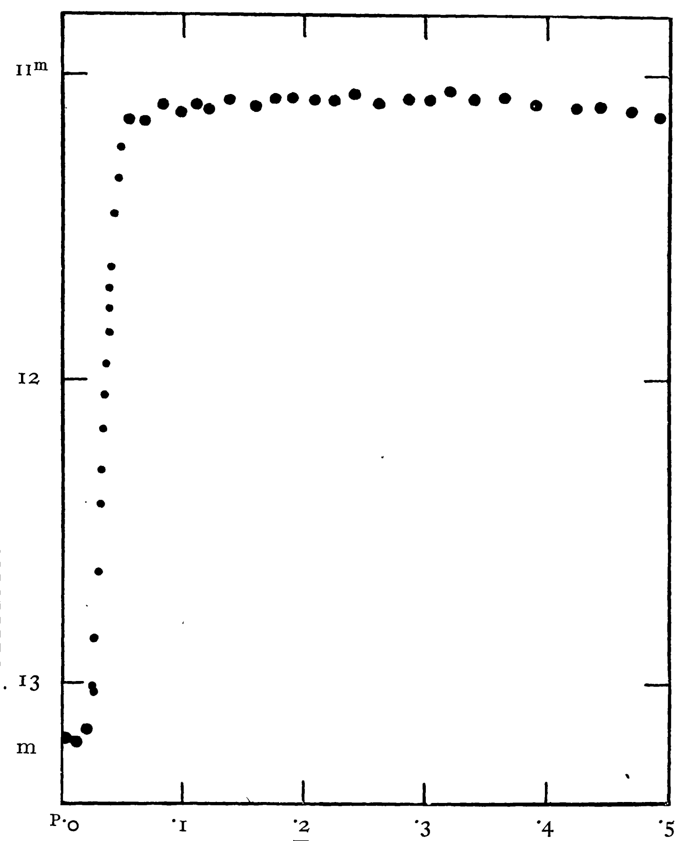


FIGURE 3.
Reflected light curve.

TABLE 6. Light curve.

Phase	n	m	m_U	m_D	Phase	n	m	m_U	m_D
P		m	m	m	P		m	m	m
·0017	10	13·168	13·125	13·141	·1694	10	11·086	11·076	11·080
·0041	10	13·222	13·179	13·196	·1754	10	11·065	11·057	11·060
·0066	10	13·167	13·124	13·141	·1807	10	11·079	11·072	11·074
·0098	10	13·185	13·142	13·159	·1841	10	11·069	11·062	11·065
·0126	10	13·197	13·155	13·171	·1892	10	11·079	11·073	11·075
·0145	10	13·200	13·158	13·174	·1959	10	11·079	11·074	11·076
·0167	10	13·108	13·067	13·082	·2016	10	11·069	11·065	11·067
·0190	10	13·166	13·124	13·140	·2064	10	11·062	11·059	11·060
·0220	10	13·179	13·138	13·154	·2141	10	11·111	11·109	11·110
·0243	4	13·010	12·968	12·985	·2196	10	11·084	11·083	11·083
·0254	4	13·030	12·989	13·004	·2229	10	11·079	11·078	11·078
·0270	5	12·848	12·808	12·823	·2291	10	11·081	11·080	11·081
·0291	5	12·638	12·597	12·613	·2350	10	11·081	11·081	11·081
·0309	5	12·412	12·371	12·387	·2393	10	11·081	11·081	11·081
·0320	5	12·304	12·263	12·279	·2462	10	11·033	11·033	11·033
·0332	5	12·164	12·123	12·139	·2539	10	11·102	11·102	11·102
·0346	5	12·056	12·016	12·031	·2606	10	11·082	11·082	11·082
·0355	5	11·948	11·908	11·923	·2706	10	11·095	11·094	11·095
·0366	5	11·848	11·808	11·823	·2787	10	11·076	11·075	11·075
·0374	5	11·770	11·730	11·745	·2866	10	11·072	11·070	11·071
·0382	5	11·704	11·664	11·679	·2911	10	11·093	11·090	11·091
·0394	5	11·632	11·592	11·607	·2968	10	11·050	11·046	11·048
·0422	5	11·454	11·415	11·430	·3028	10	11·092	11·088	11·089
·0455	5	11·340	11·301	11·316	·3089	10	11·097	11·092	11·094
·0474	5	11·242	11·203	11·218	·3148	10	11·060	11·054	11·056
·0508	10	11·151	11·113	11·128	·3194	10	11·048	11·041	11·043
·0549	10	11·140	11·103	11·117	·3234	10	11·058	11·050	11·053
·0579	10	11·148	11·111	11·125	·3315	10	11·079	11·069	11·073
·0612	10	11·124	11·088	11·102	·3396	10	11·100	11·088	11·093
·0660	10	11·164	11·129	11·142	·3463	10	11·068	11·055	11·060
·0719	10	11·164	11·130	11·143	·3561	10	11·034	11·019	11·024
·0766	10	11·081	11·048	11·061	·3631	10	11·077	11·059	11·066
·0825	10	11·101	11·069	11·081	·3712	10	11·096	11·076	11·084
·0883	10	11·117	11·087	11·098	·3797	10	11·118	11·096	11·104
·0932	10	11·122	11·090	11·104	·3881	10	11·072	11·048	11·057
·0979	10	11·117	11·089	11·100	·3971	10	11·098	11·071	11·082
·1028	10	11·129	11·102	11·113	·4134	10	11·078	11·047	11·059
·1065	10	11·067	11·041	11·051	·4242	10	11·127	11·094	11·108
·1098	10	11·120	11·095	11·105	·4304	10	11·121	11·087	11·100
·1133	10	11·099	11·075	11·084	·4357	10	11·100	11·064	11·078
·1162	10	11·136	11·113	11·122	·4441	10	11·102	11·065	11·079
·1212	10	11·116	11·094	11·103	·4511	10	11·113	11·075	11·089
·1242	10	11·081	11·060	11·068	·4567	10	11·082	11·043	11·058
·1275	10	11·084	11·064	11·072	·4702	10	11·150	11·109	11·125
·1370	10	11·070	11·052	11·059	·4798	10	11·111	11·069	11·085
·1475	10	11·083	11·068	11·074	·4868	10	11·140	11·098	11·114
·1528	10	11·125	11·112	11·117	·4936	10	11·129	11·089	11·103
·1594	10	11·095	11·083	11·087	·4979	10	11·145	11·103	11·119
·1640	10	11·078	11·067	11·071					

Thus at primary minimum the eclipse is total. Then according to RUSSELL's formulae 39 and 40 (*Ap. J.* 36, 63-4):

$$d_1^2 = a_1^2\,(1 - z\,\cos^2\theta),$$

$$\delta^2 = \cos^2 i + \sin^2 i \sin^2\theta = a_1^2\,(1 - z\cos^2\theta)\left(\frac{\delta}{d_1}\right)^2,$$

$$\left(\frac{\delta}{d_1}\right)^2 (1 - z\,\cos^2\theta) = \frac{1}{a_1^2} - \frac{1}{a_1^2}\cos^2\theta\,\sin^2 i\,,$$

$$\alpha = \frac{1 - l}{1 - l\ (\text{min. I})}.$$

For the case of the U hypothesis $\dfrac{\delta}{d_1}$ has been tabulated by HETZER (*Beitrag zu* H. N. RUSSELL's *Methode* . . ., Diss., Leipzig 1931) as a function of k and α. The quantities α and $\cos\theta$ are known for each normal point. Suppose $u = \left(\dfrac{\delta}{d_1}\right)^2 (1 - z\cos^2\theta)$; $t = -\cos^2\theta$; $A = \dfrac{1}{a_1^2}$; $B = \dfrac{1}{a_1^2}\sin^2 i$. For a fixed value of k each normal point gives an equation of condition of the usual form $u = A + B\,t$ for the determination of a_1 and i. The normal points used for such least squares solutions are given in Table 7. Column 2 gives the phase counted from mid-eclipse, column 3 the magnitude with the maximum brightness as zero point. These magnitudes have all the same weight, the weights of the u's, however, are not the same. These weights have been determined empirically by

TABLE 7. *U* hypothesis, O—C.

	Phase	$m - m_{max}$	k = ·06	·08	·10	·12	·14	·16	·18	·20	·22
	P	m	m	m	m	m	m	m	m	m	m
1	·0474	·130	+·039	+·035	+·028	+·024	+·018	+·012	+·007	+·001	—·004
2	·0455	·228	+ 57	+ 53	+ 48	+ 43	+ 38	+ 33	+ 28	+ 23	+ 18
3	·0422	·342	— 10	— 13	— 15	— 17	— 20	— 24	— 26	— 28	— 31
4	·0394	·519	— 19	— 19	— 19	— 21	— 22	— 22	— 22	— 22	— 24
5	·0382	·591	— 37	— 36	— 35	— 35	— 35	— 35	— 35	— 34	— 34
6	·0374	·657	— 41	— 41	— 39	— 38	— 38	— 38	— 37	— 35	— 35
7	·0366	·735	— 23	— 24	— 21	— 20	— 19	— 18	— 17	— 16	— 15
8	·0355	·835	— 4	— 1	+ 2	+ 2	+ 4	+ 6	+ 8	+ 10	+ 11
9	·0346	·943	+ 4	+ 6	+ 10	+ 11	+ 14	+ 16	+ 18	+ 21	+ 23
10	·0332	1·050	— 19	— 19	— 11	— 8	— 5	— 4	0	+ 3	+ 5
11	·0320	1·190	+ 6	+ 11	+ 18	+ 18	+ 20	+ 22	+ 25	+ 29	+ 32
12	·0309	1·298	— 4	— 1	+ 7	+ 7	+ 9	+ 10	+ 13	+ 16	+ 18
13	·0291	1·524	+ 42	+ 46	+ 50	+ 48	+ 52	+ 52	+ 54	+ 56	+ 57
14	·0270	1·735	+ 28	+ 26	+ 26	+ 24	+ 23	+ 21	+ 20	+ 19	+ 18
15	·0254	1·916	+ 38	+ 38	+ 37	+ 31	+ 27	+ 24	+ 20	+ 17	+ 13
16	·0243	1·895	— 70	— 72	— 73	— 80	— 84	— 89	— 95	— 99	—103

computing the u's also for $m - m_{max} + {}^{m}{\cdot}010$. They are taken proportional to $(\Delta u)^{-2}$. The weights have been calculated only for k = ·18, but they were used also for all other values of k. The O—C's are given in magnitudes in columns 4 to 12 of Table 7 and in the upper part of Figure 4. There is a systematic difference between the observed and the theoretical light curves, which cannot be avoided by a *U* solution. Column 2 of Table 8 and the dots in Figure 5 give the mean error of a single normal point as derived from the O—C's. A ratio of the radii k = ·12 gives the best agreement. Further Table 8 gives a_1, sin i and i with their mean errors for a fixed value of k. The final results are given in Table 11. The mean error of k has been determined by the method of PANNEKOEK and Miss VAN DIEN (l. c.). The most probable values of the densities have been calculated

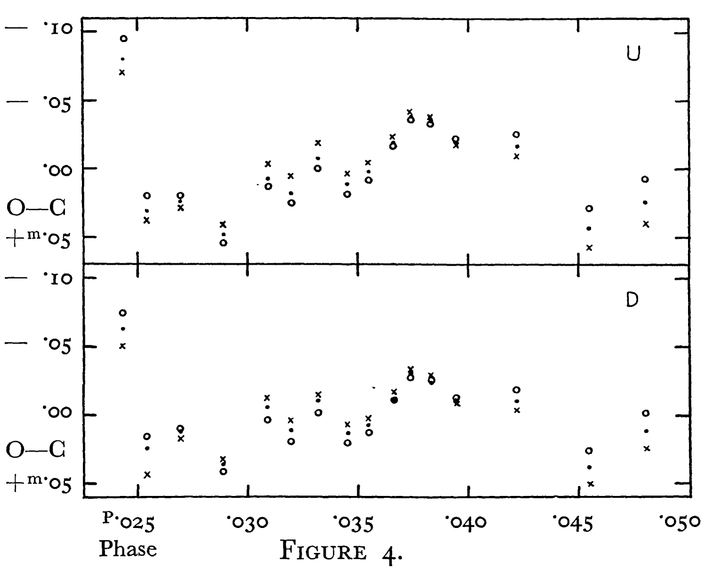


FIGURE 4.

O—C's of the normal points.

U { × k = ·06, • ·12, o ·18 } *D* { × k = ·22, • ·28, o ·34 }

from the formulae by HOLMBERG (*Lund Medd.* No. 71, 1937).

D hypothesis, ellipticity of the components.

According to RUSSELL (*Ap. J.* 36, 400): outside eclipse, l = const. $(1 - Z \cos^2 \theta)$;

$$Z = \left(\frac{4}{5}\varepsilon^2 + \frac{16}{175}\varepsilon^4 + \ldots\right)\sin^2 i;\ z = \frac{5}{4}Z - \frac{5}{28}Z^2 + \ldots$$

A least squares solution gives:

$$l = {\cdot}9638\ (1 - {\cdot}038 \cos^2 \theta);\ z = {\cdot}047$$
$$\pm 39 \qquad \pm 10 \qquad\qquad \pm 13\ \text{(m.e.)}.$$

The rectified magnitudes m_D are given in Table 6, column 5.

D hypothesis, orbital elements.

The elements k, a_1 and i have been determined in the same way as for the *U* hypothesis. New tables for $\frac{\delta}{d_1}$ as a function of α and k have been calculated by numerical integration. These tables have been used for k = ·18, ·20 to ·30; however, for k = ·32, ·34 and ·36 the new tables by ZESSEWITSCH (*Poulkovo Circ.* No. 24, 41, 1938), which were received just while these calculations were made, have been used. The weights have been computed only for k = ·20. The results are given in Tables 9 and 10, the O—C's of the least squares solutions also in Figure 4, lower

TABLE 8. *U* hypothesis, results.

k	m.e. of a single normal point	a_1		sin i		i	
	m					°	°
·06	±·0360	·552	±·004	·8902	±·0020	62·9	±·2·
·08	·0359	·470	4	·9184	17	66·7	·2·
·10	·0352	·432	4	·9367	14	69·5	·2
·12	·0349	·402	4	·9498	12	71·8	·2
·14	·0353	·379	3	·9595	11	73·6	·2
·16	·0357	·359	3	·9669	10	75·2	·2
·18	·0366	·343	3	·9729	9	76·6	·2
·20	·0375	·329	3	·9777	8	77·9	·2
·22	·0386	·317	3	·9818	7	79·1	·2

TABLE 9. *D* hypothesis, O—C.

	Phase	$m - m_{max}$	k = ·18	·20	·22	·24	·26	·28	·30	·32	·34	·36
	P	m	m	m	m	m	m	m	m	m	m	m
1	·0474	·140	+·033	+·028	+·024	+·020	+·015	+·011	+·007	+·002	—·002	—·006
2	·0455	·238	+ 58	+ 54	+ 50	+ 48	+ 42	+ 38	+ 34	+ 30	+ 26	+ 22
3	·0422	·352	+ 1	— 2	— 4	— 6	— 9	— 11	— 14	— 16	— 19	— 21
4	·0394	·529	— 7	— 9	— 9	— 10	— 10	— 11	— 12	— 13	— 13	— 14
5	·0382	·601	— 27	— 27	— 29	— 27	— 26	— 26	— 26	— 26	— 26	— 25
6	·0374	·667	— 34	— 33	— 33	— 32	— 31	— 31	— 30	— 29	— 28	— 28
7	·0366	·745	— 19	— 18	— 16	— 15	— 15	— 14	— 13	— 12	— 11	— 11
8	·0355	·845	— 1	0	+ 3	+ 4	+ 6	+ 7	+ 9	+ 11	+ 13	+ 14
9	·0346	·953	+ 3	+ 4	+ 7	+ 9	+ 12	+ 13	+ 15	+ 17	+ 20	+ 22
10	·0332	1·061	— 22	— 20	— 15	— 15	— 12	— 11	— 7	— 5	— 2	0
11	·0320	1·201	— 1	+ 1	+ 4	+ 6	+ 8	+ 11	+ 13	+ 17	+ 19	+ 22
12	·0309	1·309	— 14	— 13	— 12	— 9	— 7	— 6	— 3	0	+ 3	+ 5
13	·0291	1·535	+ 31	+ 32	+ 33	+ 34	+ 35	+ 36	+ 37	+ 39	+ 41	+ 41
14	·0270	1·745	+ 19	+ 18	+ 17	+ 16	+ 15	+ 12	+ 12	+ 11	+ 10	+ 8
15	·0254	1·926	+ 51	+ 47	+ 44	+ 41	+ 38	+ 34	+ 32	+ 29	+ 26	+ 22
16	·0243	1·907	— 45	— 48	— 52	— 55	— 60	— 63	— 67	— 71	— 75	— 80

part, and the mean error of a single normal point in Figure 5 (crosses). The best agreement between the observed and the theoretical light curve is obtained with k = ·28. Though this agreement is slightly better than that with the U hypothesis, no conclusion can be made about the limb darkening. The final results are collected in Table 11.

Orbital eccentricity.

With the aim to obtain some idea about the influence of an eccentricity, assumed beforehand, the orbital elements have been computed (only for the U hypothesis) for an assumed eccentricity e = ·2 and the two cases that the brighter star is either at periastron or at apastron at primary minimum.

TABLE 10. *D* hypothesis, results.

k	m.e. of a single normal point	a_1	sin i	i
	m			° °
·18	±·0309	·352 ±·003	·9678 ±·0009	75·4 ±·2
·20	·0297	·337 3	·9731 8	76·7 ·2
·22	·0291	·324 3	·9776 7	77·9 ·2
·24	·0285	·313 2	·9813 6	78·9 ·2
·26	·0280	·303 2	·9845 6	79·9 ·2
·28	·0276	·295 2	·9873 5	80·9 ·2
·30	·0278	·287 2	·9897 5	81·8 ·2
·32	·0283	·280 2	·9918 5	82·7 ·2
·34	·0291	·273 2	·9937 5	83·6 ·2
·36	·0299	·267 2	·9954 4	84·5 ·2

TABLE 11.

Elements	Min. I = 2425759·730 + 14^d·414897 . E			
Maximum brightness	m_{max}	=	11^m·08	
Range of the primary minimum	A_1	=	2^m·10	
Range of the secondary minimum	A_2	=	0^m·06	
			U hypothesis	*D* hypothesis
Rectified range of the primary minimum	A_1	=	2^m·06	2^m·07
Duration of the eclipse	D	=	^{P}·103	^{P}·104
Duration of the totality	d	=	^{P}·045	^{P}·043
Intensity of the brighter smaller component in units of the whole intensity	L_2	=	·850	·852
Ratio of the mean surface intensities	γ	=	1 : 390	1 : 73
			m.e.	m.e.
Ratio of radii	k	=	·12 ±·05	·28 ±·04
Ellipticity of the components	ε	=	·29 ±·04	·22 ±·04
Semi axis major of the larger component in units of the orbital radius	a_1	=	·40 ±·05	·29 ±·03
Semi axis major of the smaller component in units of the orbital radius	a_2	=	·05 ±·02	·08 ±·01
Most probable value of the density of the larger component	ρ_1	=	·0001	·0002
Most probable value of the density of the smaller component	ρ_2	=	·02	·02
Assumed orbital eccentricity	e	=	·00	·00
Inclination of the orbit	i	=	72° ± 4°	81° ±2°