Notes on eclipsing variable stars estimated on Harvard plates (Errata: 4 V)

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COMMUNICATIONS FROM THE OBSERVATORY AT LEIDEN.

Notes on eclipsing variable stars estimated on Harvard plates, by *Ejnar Hertzsprung.*

During my stay at the Harvard Observatory from October 1926 to May 1927 I made about 12000 estimates of variable stars mainly on plates taken with the 1-inch Cooke lenses. About one half of these estimates were made on δ Cephei stars and the other half on eclipsing variables. The results obtained for the objects of the latter class are presented below. *)

The eclipsing stars examined are given in Table 1.

TABLE 1.

	α(1900)	δ(1900)	period	number of plates
	h m	° ′	d	
X Pct	5 2·7	−53 17	·862	222
RW Dor	5 18·9	−68 20	·143	42
C.P.D. −20°2574	7 28·4	−20 35	·291	445
TU Mon.	7 48·3	− 2 47	5·049	548
RZ Cnc	8 32·9	+32 9	21·643	557
DW Car	10 39·3	−59 31	·664	97 [1])
BL Car	10 41·1	−59 19	3·355	41
BP Car	10 42·9	−59 38	9·645	119
EQ Car	10 43·4	−57 56	25·517	36 [2])
DG Car	11 7·9	−60 42	34·725	150
TT Hya	11 8·3	−25 55	6·953	350
RU Cen	12 4·2	−44 52	64·74	669
C.P.D. −32°4415	17 7·2	−32 44	5·728	1034
UW Ara	17 39·9	−48 42	3·297	794
AB And	23 6·8	+36 21	·332	20

[1]) and 386 additional estimates on Johannesburg plates.
[2]) and 200 additional estimates on Johannesburg plates.

The total number of estimates on Harvard plates used here is 5124 not counting duplicates; 586 additional estimates were made on later Johannesburg plates making a total of 5710 estimates.

In the following J. D. means J. D. hel. M. astr. T. Grw.

*) In addition to the elements mentioned in the preface of "Katalog und Ephem. Veränd. Sterne 1928" improved elements of RZ Cnc and period of RW Dor have been communicated to the quoted publication and published there.

The mean values do not always agree exactly with the figures given here, as the computations have sometimes been made with a decimal more.

On the diagrams each division of the abscissas corresponds to one tenth of the period except in the case of RU Centauri, where one division is equal to one twentieth of the period.

I am indebted to the director of the Harvard Observatory and to the members of the staff for all possible help during my work. After my return to Leiden Mr. W. F. H. WATERFIELD has been kind enough to provide me with some lacking data and to make a few revisions.

X Pictoris

This star was estimated on 223 Harvard plates, viz: 197 AM, 21 AX and 5 B plates. The comparison stars used are

	C. P. D.		
	°	m	s
a	−53 789	9·1	·00
b	792	9·2	·51
c	798	9·6	·93
d	795	9·6	1·35

The period finally adopted is ^{d}·8619003 and the phases were calculated from the formula

$$\text{phase} = 1^{d^{-1}}\cdot 160227\,(\text{J. D.} - 2400000)$$

The earliest minimum observed (1^{s}·68) was on plate B 8833 taken 1892 Nov. 22 or J. D. 2412425·769 with an exposuretime of 49 minutes.

The 223 observations were arranged according to phase and divided into 23 about equal groups. The mean results are given in Table 2 and represented graphically in Figure 1. The period has perhaps to be doubled. There is an uncertain indication of the even minima being deeper than the odd ones by something like ^{s}·3. But it is doubtful, whether the minima (provisionally ^{s}·65 and ^{s}·95) are not too deep to allow for a doubling of the period, even when the system is seen nearly from the edge.

The mean epoch of minimum is J. D. 2420001·84, corresponding to the phase ·674 according to the above formula.

FIGURE 1.

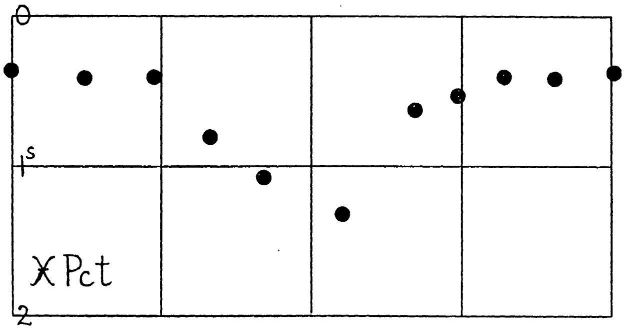


TABLE 2.

X Pictoris

number of plates	phase	bright-ness	number of plates	phase	bright-ness	number of plates	phase	bright-ness
	p	s		p	s		p	s
10	·026	·37	10	·424	·37	8	·771	·54
10	·082	·39	11	·473	·36	10	·803	·40
10	·148	·38	10	·522	·42	10	·837	·42
10	·185	·50	10	·569	·41	10	·876	·39
10	·214	·42	10	·607	·81	10	·919	·42
10	·272	·36	8	·642	1·08	10	·944	·31
10	·350	·41	8	·695	1·32	10	·993	·33
10	·390	·42	8	·743	·63			

R W Doradus

This variable was estimated on 42 old Harvard plates of the B series. The 6 most pronounced minima found on 5 plates of 10 min. each and one plate (the first of the 6) of 34 minutes exposuretime are collected in Table 3 adding the 2 minima given in *B. A. N.* **77** and **88** respectively.

Adopting the counting of epochs as indicated and assigning equal weight to all the 8 minima, the

TABLE 3.

R W Doradus

J. D. M. astr. T. Grw.	*E*	*O—C*
d		d
2411298·835	—87477	+·002
14168·883	—67369	— 4
15621·901	—57189	+ 3
16013·836	—54443	— 4
16489·714	—51109	+ 6
17075·903	—47002	— 5
23784·600	0	+ 5
24172·537	+ 2718	— 4

apparent period is found to be ^{d}·14273194 ± ^{d}·00000006 (m. e.). The values *O—C* are unexpectedly small for the first 6 epochs each depending on a single plate only. The possibility that the mean error of the period has accidentally been found somewhat too small should therefore be considered.

C. P. D. — 20°2574 = H. D. 60265, Sp. F0.

This star was first used as a comparison star for X Puppis, but later rejected as such, because it was suspected of variability. It was estimated on 445 plates but no period found and the object did not seem ripe for publication as a new variable star. Mr. LEON CAMPBELL then kindly took up photometric observations of the star, which soon established the variability and revealed the true character of the variation. LEON CAMPBELL found a lightcurve of the W Ursae majoris class and the period to be ^{d}·58.

The comparison stars used on the Harvard plates were

	C. P. D.		H. D.			
		m		m		s
a	— 20°2587	8·5	60342	8·3	B8	·000
x	— 20°2662	8·5	60786	8·7	A0	·278
y	— 20°2666	8·5	60830	8·7	A0	·498
c	— 20°2615	8·9	60495	9·3	B9	1·048

The period finally adopted was ^{d}·58113212 and the phases were calculated from the formula

$$\text{phase} = 1^{d^{-1}}{\cdot}7220132\ (\text{J. D.} - 2420000)$$

The 445 observations were then arranged according to phase and divided into one group of 15 and 43 of 10 observations each. The corresponding mean values are given in Table 4. As no sensible difference between even and odd minima was noted ^{p}·5 was then subtracted from the phases greater than ·5 and after that the 44 groups were arranged again according to phase. Finally the following mean values for 11 larger groups of 45 or 40 observations each were formed, the phases having been doubled according to the formula

$$\text{phase} = 3^{d^{-1}}{\cdot}4440264\ (\text{J. D.} - 2400000)$$

numb. of plates	45	40	40	40	40	40	40	40	40	40	40
phase	^{p}·000	·101	·189	·303	·393	·484	·571	·658	·730	·820	·908
brightness	^{s}·365	·285	·308	·325	·437	·540	·569	·653	·596	·514	·459

According to this the minimum occurs at the phase ·662. The mean epoch of minimum is J. D. 2419455^{d}·618 ± ^{d}·003 (m. e.).

The range is from ^{s}·29 to ^{s}·65 or ^{s}·36, while the mean error of a single estimate is ± ^{s}·144 as derived from the differences between two observations following each other in phase. As the range is only 2·5 times the mean error and the 445 plates used are scattered over about 25 years, it is naturally hard to find a period as short as the present one from this material. But once the period known, a fairly good old epoch of minimum could be derived.

The usual exposuretime of a plate is about an hour. Consequently a considerable part of the light-curve is covered by one exposure.

FIGURE 2.

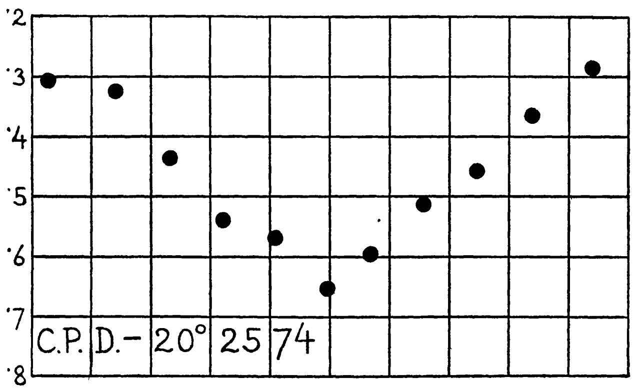


TABLE 4.
C P D — 20°2574

number of plates	phase	brightness	number of plates	phase	brightness
	P	s		P	s
10	·009	·37	10	·488	·40
10	·028	·25	10	·521	·29
10	·050	·36	10	·552	·29
10	·074	·30	10	·572	·24
10	·102	·30	10	·589	·29
10	·136	·40	10	·614	·34
10	·163	·36	10	·643	·29
10	·184	·45	10	·664	·26
10	·201	·42	10	·689	·43
10	·223	·56	10	·712	·44
10	·242	·47	10	·741	·54
10	·267	·56	10	·761	·59
10	·293	·50	10	·778	·61
10	·316	·62	10	·805	·61
10	·330	·66	10	·828	·68
10	·343	·66	10	·844	·60
10	·361	·62	10	·868	·59
10	·387	·57	10	·892	·54
10	·411	·55	10	·912	·46
10	·426	·50	10	·934	·54
10	·450	·48	10	·961	·43
10	·471	·39	15	·989	·39

T U Monocerotis

This variable was estimated on 548 plates of the AC, AM, AY and AX series. The comparison stars used were

	BD		α (1855)	δ (1855)		
	°	m	h m s	° ′	s	m
a	— 2 2342	8·7	7 47 17·7	— 2 34·7	·000	·00
b	— 2 2324	9·0	7 45 13·0	— 2 45·1	·440	·27
c	— 2 2329	9·3	7 45 50·1	— 2 20·9	1·316	1·10
d	— 2 2337	9·3	7 46 53·5	— 2 26·8	1·926	1·69
e	—	—	7 45 55	— 2 39·9	2·458	2·59

The differences in magnitude between the comparison stars have been derived from plates taken by H. VAN GENT using the 34-cm Leiden refractor with a grating before the objective.

The variable was found particularly faint on 15 plates, which are given in Table 5. A least square solution gave the period to be

$$5^{d}{\cdot}049011 \pm {}^{d}{\cdot}000028 \text{ (m. e.)}$$

the mean error of each observed minimum being $\pm\,{}^{d}{\cdot}058$. The phases have been calculated according to the formula

$$\text{phase} = {}^{d^{-1}}{\cdot}1980586\ (\text{J. D.} - 2400000).$$

The 548 estimates were then arranged according to phase and divided into 2 groups of 9 and 53 of 10 observations each. The mean values thus obtained are given in Table 6, where the phase has been counted from minimum, which was found to occur at phase ·480 according to the above formula.

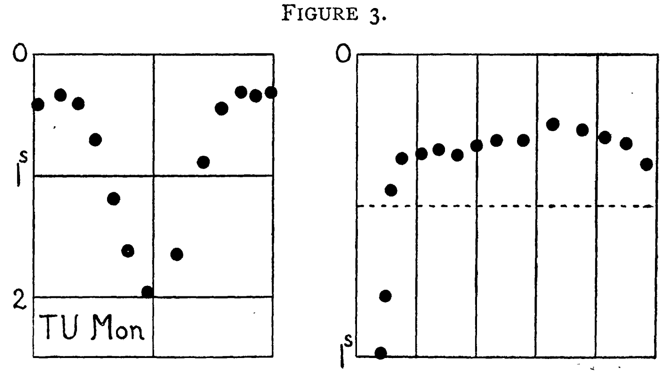
Outside the main eclipse there is a slight indication of change in brightness, showing a minimum at the place of the secondary minimum and a maximum rather nearer to the secondary than to the primary minimum in accordance with a combined ellipticity and reflection effect.

The mean epoch of minimum is J. D. 2420930·57.

The variable is faint and equal to the comparison star *d* on the Franklin-Adams Chart plate No. 100 taken at Johannesburg 1911 April 26.

The estimate on plate AM 8271, taken with an exposuretime of 61 minutes on J. D. 2418557·498 is $^{s}{\cdot}69$, while $1^{s}{\cdot}93$ should be expected according to the phase, which is $^{P}{\cdot}472$, or — ·008 from minimum.

FIGURE 3.



W. F. H. WATERFIELD has kindly revised this estimate, but was not able to change it materially. It has however not been rejected for discordance and is included in the mean value given for phase — ·005 from minimum.

TABLE 5
T U Monocerotis

J. D.	epoch	O—C
		d
2415886·515	0	— ·091
16825·786	186	+ ·065
17880·911	395	— ·054
18688·774	555	— ·032
19723·850	760	— ·004
19723·892	760	+ ·038
19804·637	776	— ·001
19804·716	776	+ ·078
20930·608	999	+ ·041
22293·818	1269	+ ·018
22298·909	1270	+ ·060
24136·705	1634	+ ·016
24146·693	1636	— ·094
24146·809	1636	+ ·022
24469·860	1700	— ·064

TABLE 6.
T U Monocerotis

number of plates	phase counted from minimum	brightness	mean values of 40 plates		number of plates	phase counted from minimum	brightness	mean values of 40 plates	
	P	s	P	s		P	s	P	s
10	— ·005	1·97			10	+ ·225	·28	·233	·285
10	+ ·020	1·65			10	+ ·237	·32		
10	— ·021	1·62			10	— ·245	·22		
10	— ·033	1·19			10	+ ·253	·24		
9	+ ·042	·89			10	— ·272	·32	·277	·284
9	— ·049	·70			10	+ ·280	·31		
10	+ ·056	·45			10	+ ·302	·27		
10	— ·063	·40			10	— ·303	·27		
10	+ ·073	·31	·075	·348	10	— ·326	·25	·326	·232
10	— ·078	·33			10	+ ·332	·21		
10	+ ·086	·35			10	— ·343	·20		
10	— ·097	·42			10	+ ·359	·24		
10	+ ·098	·32	·106	·332	10	— ·370	·27	·374	·254
10	— ·114	·33			10	+ ·381	·23		
10	+ ·114	·27			10	— ·388	·28		
10	— ·124	·36			10	+ ·393	·23		
10	— ·136	·33	·138	·316	10	— ·409	·26	·412	·276
10	+ ·138	·28			10	+ ·415	·30		
10	+ ·153	·30			10	— ·432	·32		
10	— ·154	·38			10	+ ·433	·26		
10	+ ·163	·30	·167	·332	10	+ ·445	·36	·448	·297
10	— ·172	·30			10	— ·453	·28		
10	+ ·180	·35			10	+ ·461	·28		
10	— ·192	·30			10	— ·466	·32		
10	+ ·193	·34	·200	·301	10	+ ·481	·35	·483	·362
10	— ·207	·28			10	— ·489	·42		
10	+ ·210	·28			10	+ ·498	·35		
10	— ·224	·32							

RZ Cancri = H. D. 73343, Sp. Ko

This Algol variable is of special interest because of its "late" spectrum, while the period and form of the lightcurve suggests, that we have here to do with a yellow "giant".

The star was estimated on 557 Harvard plates of the AC and AY series. The comparison stars used were

	B. D.		α (1855)	δ (1855)	
	°	m	h m s	° ′	s
a *)	+ 32 1780	8·9	8 33 55	+ 32 15	·000
b	+ 32 1774	8·8	8 30 39	+ 32 34	·316
c	+ 32 1771	9·0	8 29 55	+ 32 33	·856
d			8 30·5	+ 32 17	1·419
e			8 30·2	+ 32 12	1·719

The phases were computed from the formula

$$\text{phase} = {}^{d^{-1}}\!\cdot 0462043 \; (\text{J. D.} - 2400000)$$

corresponding to a period of $21^d{\cdot}643$. The 557 estimates were then arranged according to phase and divided into 14 groups of 5, 1 of 7 and 48 of 10 observations each. The mean values for these 63 groups are given in Table 7, the phases having been counted from the primary minimum, which occurs at the phase $^{P}{\cdot}135$ according to the above formula.

The primary and secondary minimum are more different than would be expected from the fact that the period was originally thought to be $10^d{\cdot}8$ (*A. N.* **209**, 29). The observations between minima give some evidence of ellipticity.

It seems premature to derive photometric elements of the system as long as the magnitude scale is not known with more accuracy, but at any rate the density is too small for a "dwarf" star of spectrum Ko.

The mean epoch of minimum is J. D. 2418702·480.

A plate of the R Z Cancri region has been taken with the 34-cm Leiden refractor by P. TH. OOSTERHOFF and measured in the microphotometer by H. VAN GENT. Three exposures were made with a grating placed in front of the objective. Adopting the difference in magnitude between the central image and the spectra of the first order to be $^m{\cdot}92$ it was found, that 1^s on my scale of steps is equal to $1^m{\cdot}375$ in the present case.

The constant $e^2 \sin^2 i$ in RUSSELL's formula (*Ap. J.* **36**, 64; 1912) for ellipticity of the stars $(e/l_{\max})^2 = 1 - e^2 \sin^2 i \, \cos^2 \vartheta$, where ϑ is the phaseangle, was found to be about ·214. After having corrected the observed magnitudes for this ellipticity ($e = {\cdot}46$

*) This star and B D + 32°1779 are on the BD. chart placed at a right ascension 1 min. too small.

for $i = 90°$) the depths of the primary and secundary minima were found to be $1^m{\cdot}64$ and $^m{\cdot}26$ respectively. Taking the first as correct, the maximum possible value of the second is $^m{\cdot}22$ or nearly what is really found. The two stars are therefore in this preliminary treatment taken to be of equal size, and the inclination to be 90°. Then the brighter component gives about 78 and the fainter one 22 percent of the total light. At a phase angle of $12^{\circ}{\cdot}2$ the depression in brightness is $^m{\cdot}65$ after correction for ellipticity. This gives the proportion between the radius of each component and the distance between the centers to be ·225. With the period of $21^d{\cdot}643$ this gives the density of the system to be about ·0015 times that of our sun in good accordance with what we know about other yellow giants.

FIGURE 4.

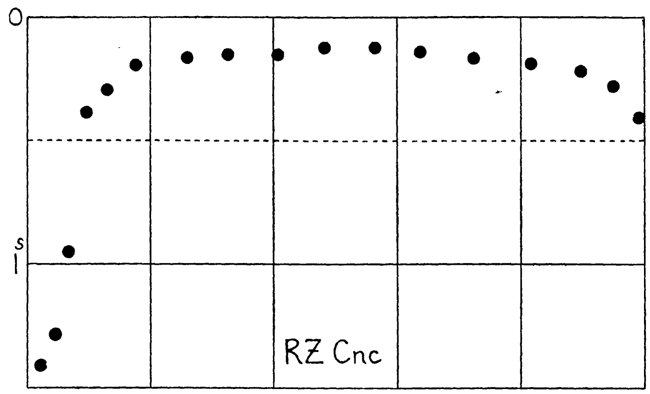


TABLE 7

R Z Cancri

number of plates	phase counted from minimum	brightness	P	s	number of plates	phase counted from minimum	brightness	P	s
	P	s				P	s		
5	— ·001	1·41	·001	1·41	10	— ·239	·11	·241	·122
5	— ·009	1·29	·011	1·28	10	+ ·254	·12		
5	+ ·012	1·28			10	— ·255	·13		
5	— ·021	·97	·023	·95	10	+ ·270	·10		
5	+ ·024	·93			10	— ·272	·09	·282	·121
5	+ ·031	·79			10	+ ·290	·15		
5	— ·033	·61	·034	·69	10	— ·296	·14		
5	+ ·038	·67			10	+ ·304	·12		
5	— ·042	·45			10	— ·311	·17		
5	— ·050	·31	·048	·39	10	+ ·318	·09	·319	·140
5	+ ·050	·41			10	— ·327	·15		
5	— ·058	·37			10	+ ·334	·17		
5	— ·067	·28	·065	·30	10	— ·342	·16		
5	+ ·069	·24			10	— ·356	·22		
10	+ ·074	·18			10	+ ·356	·12	·362	·169
10	— ·083	·22	·088	·195	10	+ ·375	·18		
10	+ ·088	·22			10	— ·378	·17		
10	+ ·106	·16			10	+ ·390	·16		
10	— ·116	·23			10	— ·399	·17		
10	+ ·126	·20	·130	·167	10	+ ·408	·16	·408	·190
10	+ ·140	·13			10	— ·420	·23		
7	— ·142	·08			10	+ ·424	·23		
10	+ ·152	·18			10	+ ·436	·20		
10	— ·154	·15	·163	·152	10	— ·440	·24	·449	·220
10	+ ·173	·14			10	+ ·457	·18		
10	— ·175	·14			10	— ·462	·26		
10	— ·194	·18			10	+ ·473	·28	·474	·28
10	+ ·194	·15	·204	·154	10	— ·476	·28		
10	+ ·207	·14			10	+ ·486	·38	·486	·38
10	+ ·219	·16			10	+ ·494	·42	·495	·41
10	— ·221	·14			10	— ·497	·39		
10	+ ·236	·11							

DW Carinae = B.A.N. 65*m* = C.P.D. — 59°2517

This variable was estimated on 97 Harvard plates (12 A, 50 B, 15 MF and 20 X plates) and on 386 further plates taken with the Franklin-Adams instrument at Johannesburg but not yet used in *B. A. N.* **65**. The comparison stars were the same two as before, viz. C. P. D. — 59° 2509 and 2496.

The phases of the Johannesburg plates were computed from the formula

$$P = 1^{d^{-1}}{\cdot}5063 \text{ (J. D. hel. M. astr. T. Grw.} - 2420000).$$

Mean values for 17 groups according to phase are given in Table 8.

TABLE 8.

D W Carinae (386 Johannesburg plates)

number of plates	phase in fraction of the period	brightness in steps
	P	s
20	·050	·461
20	·109	·558
20	·159	·689
18	·202	·765
18	·237	·761
20	·285	·622
20	·332	·505
20	·382	·414
20	·431	·406
20	·485	·399
30	·577	·393
30	·668	·347
30	·729	·366
30	·792	·345
30	·867	·345
20	·932	·400
20	·994	·430

From these figures the phase of the minimum is found to be ·210. For the preparation of Table 8 originally 39 mean values of 9 or 10 observations following each other in phase were formed. These were now arranged according to the difference in phase from the minimum and divided into the groups given in Table 9. The mean values thus obtained are represented graphically in Figure 5.

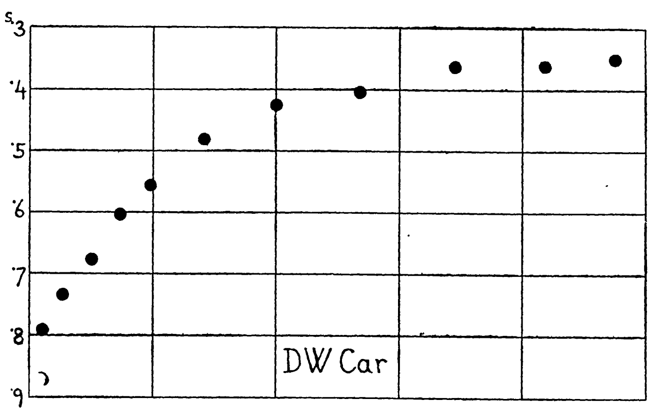
TABLE 9.

D W Carinae (386 Johannesburg plates)

number of plates	difference in phase from minimum	brightness in steps
	P	S
18	± ·010	·792
18	·027	·733
20	·050	·678
20	·073	·603
20	·098	·558
40	·141	·482
50	·200	·426
50	·268	·406
50	·345	·365
50	·419	·362
50	·475	·351

The mean J. D. of the 386 plates is 2424146. The difference in steps between the two comparison stars was here found to be ^{s}·552 and in *B. A. N.* 65 only ^{s}·383. This discrepancy may partly be due to the fact that the stars are more or less involved in nebula, making the estimate of their brightness difficult on plates of longer exposure. The range found here, ^{s}·45, is nearly the same as that derived in *B. A. N.* 65, viz. ^{s}·48 indicating no change in the step value. From the differences in steps between two observations following each other in phase the mean error of a single estimate was found to be ± ^{s}·078.

FIGURE 5.



The epoch of the mean minimum derived from the 386 plates is J. D. hel. M. astr. T. Grw. 2424146·060. On the 97 Harvard plates the variable was found equal to or fainter than C. P. D. — 59°2496 on 12 occasions. These are given in Table 10 together with the minimum taken from *B. A. N.* 65 and the one derived in the present note. Assigning the relative weights as indicated to the different minima a least square solution gave

Min. J. D. hel. M. astr. T. Grw.

$$2421913^d·455 + {}^d·6638752$$
$$\pm\ ·0000008\ \text{(m.e.)}$$

The reciprocal period is $1^{d^{-1}}$·506307 ± $^{d^{-1}}$·000002 (m.e.)

The mean minimum derived from the 251+386=637 Johannesburg plates alone is J. D. 2424019·263.

Though no sensible difference between even and odd minima has been found, the period probably has to be doubled. In that case the spectrum should show double lines of considerable separation.

TABLE 10.

D W Carinae

minimum J. D. hel. M. astr. T. Grw.	relative weight	epoch	O—C
d			d
2412586·640	1	0	—·033
12586·659	1	0	—·014
12594·637	1	12	—·003
13325·557	1	1113	—·009
13325·585	1	1113	+·019
13657·536	1	1613	+·032
13996·758	4	2124	+·014
14107·555	1	2291	—·056
21348·548	1	13198	+·051
23820·770	16	16922	+·001
24146·060	25	17412	—·008
24261·599	1	17586	+·017
24289·516	1	17628	+·052
24293·517	1	17634	+·069

B L Carinae

This star was estimated on 41 Harvard plates, of which it was only found distinctly in minimum on one, viz. A 12985 taken with an exposuretime of 2 hours at J. D. hel. M. astr. T. Grw 2423944·528. The corresponding phase is ·607 according to the ephemeris given in *B. A. N.* 77 in sufficient agreement with the minimum phase, ·597, given there.

B P Carinae

This variable was estimated on 119 Harvard plates of different series mainly to see if the period 9^d·6449, given in *B. A. N.* 77, should not be halved. The fraction of that period, occupied by the eclipse, is unusually small and no decisive observations midway between minima were available.

On one of the 119 plates, viz. X 5551, taken 1924 May 22 with an exposuretime of 90^m the variable is evidently near minimum. Combining this with the 3 other best known minima tabulated below the period is found to be 9^d·64492 ± ^{d}·00003 (m. e.) or the reciprocal period $^{d^{-1}}$·1036816 ± ·0000003·. The mean error as derived from only 4 minima is, of course, uncertain, but it appears reasonable, judging from the shape of the lightcurve.

plate from	minimum at J. D.	epoch	O—C
	d		d
Cape	2412161·399	0	+ ·016
Arequipa	12971·532	84	— ·024
Johannesburg	21401·243	958	+ ·030
„	23841·355	1211	— ·022

The variable was found of normal brightness at J. D. 2412561·500, 13323·615 and 14085·590 with the corresponding phases + ·485, — ·498 and — ·495 respectively counted from minimum. This seems to confirm the long period, but on later plates taken at Johannesburg the variable appears below normal brightness on J. D. 2424280·195, 24550·374 and ·394 with the corresponding phases + ·497, — ·490 and — ·488 respectively. The period of this star has therefore not yet been definitively settled.

E Q Carinae

This star was announced in *B. A. N.* 77 as an eclipsing variable, the true period of which was still uncertain. Additional estimates were made on about 200 later Johannesburg plates making 545 plates in all. As a whole the observations are in favour of a period of 25½ days, the apparent changes during one night being due to observational errors as the object is a very difficult one on most of the Franklin-Adams plates.

The star was estimated on 36 Harvard plates of which it was found in or near minimum on A 2549 (^{s}·65 in the present scale) and A 11153 (^{s}·53) taken with exposuretimes of 60 minutes each at J. D. hel. M. astr. T. Grw. 2414122·502 and 2420603·633 respectively.

From the 8 most pronounced minima given in Table 11 a least square solution gave the period to be 25^{d}·5170 ± ^{d}·0011 (m. e.) and the reciprocal period $^{d^{-1}}$·0391895 ± $^{d^{-1}}$·0000017 (m. e.).

TABLE 11.
E Q Carinae

minimum J. D. hel. M. astr. T. Grw.	epoch	O—C
d		d
2414122·50	0	— ·01
20603·63	254	+ ·13
23818·59	380	+ ·32
23844·29	381	+ ·18
23946·22	385	+ ·27
24176·48	394	— ·33
24201·41	395	+ ·25
24202·41	395	— ·75

FIGURE 6.

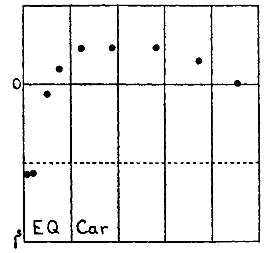
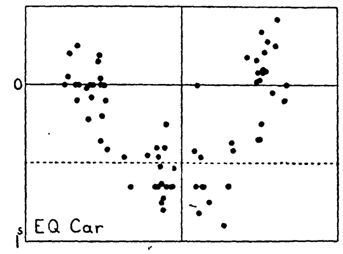


FIGURE 7.



The mean epoch of the minimum as derived from the Johannesburg plates is J. D. hel. M. astr. T. Grw. 2424023·09 corresponding to the phase ·665 as calculated from the formula: phase = $^{d^{-1}}$·03919 (J. D. — 2420000).

Arranging the 545 estimates on Johannesburg plates according to phase and dividing into groups the mean values given in Table 12 were obtained.

TABLE 12.
E Q Carinae

number of plates	phase counted from minimum	brightness in steps
	P	s
10	·006	+ ·572
20	·020	+ ·564
15	·049	+ ·061
50	·075	— ·098
50	·123	— ·227
100	·188	— ·230
100	·285	— ·234
100	·372	— ·148
100	·455	— ·101

These mean values are represented graphically in Figure 6, while the single observations near minimum are shown in Figure 7. The one observation ^{s}·0 at phase ·675 is accidentally in error as it is included between other observations on the same night showing the variable faint. Such an error is not unlikely to occur owing to the difficulty of the estimates in the present case.

The general impression from the above is, that we have here to do with a system consisting of two components of very different size, though the actual speed of the decrease or increase of the brightness near minimum is not determined with any accuracy from the present observations. The depression half a period from the primary minimum looks more like caused by ellipticity than by a secondary minimum, but further observations are needed to decide. The case deserves closer examination with a greater instrument. We should always be on the lookout for an eclipsing binary consisting of a yellow and a white dwarf (as o_2 Eridani BC), which would show extremely steep descending and ascending branches of the light-curve.

D G Carinae

In a letter of February 12, 1925 Professor SHAPLEY writes about this object: "Miss WOODS has examined "234 plates throughout the interval 1889 to 1924. "On two plates only was a perceptible deviation from "constant maximum light observed. The estimate of "normal brightness on several plates, compared with "the sequence 30 Ks, yielded the value 11·3. On "plate B 13861 made J. D. 2413376·517 the magnitude "is 11·8; on A 10928 made on J. D. 2420286·607 the "magnitude is 13·3. The times are geocentric; the "magnitudes are on the present international scale. "The exposures were of ten minutes duration".

I examined the star on about 150 Harvard plates of the A M series and found it faint on two, viz. A M 5525 and 10704 taken with exposuretimes of 63 and 30 min. on June 5, 1908 and June 19, 1915 respectively. Together with two minima found on Johannesburg plates, the first of which is given in *B. A. N.* **54**, the 5 most pronounced minima thus obtained are collected in Table 13.

TABLE 13

D G Carinae

J. D.	*E*	*O—C*
d		d
2418098·61	0	— ·14
20286·61	63	+ ·16
20668·49	74	+ ·07
23828·45	165	+ ·02
23967·22	169	— ·11

A least square solution gave the period to be $34^{d}·725$ with an uncertain mean error of $\pm {}^{d}·001$.

The old Harvard plate B 13861, on which the star is half a magnitude fainter than normal, gives *O—C* $= + {}^{d}·41$. On 3 consecutive Johannesburg plates with the mean epoch 2424245·35 the variable is also about half a magnitude fainter than normal, the value of *O—C* being $+ {}^{d}·22$. Supposing these two observations to be at the same phase the period is found to be $10868·83/313 = 34^{d}·7247$.

The exact duration of the minimum cannot yet be indicated, but it does not seem to be longer than ·04 of the period.

T T Hydrae

The phases of the observations given by the discoverer H. E. WOOD in *U. O. C.* **69** have been computed from the formula

$$\text{phase} = \overset{d^{-1}}{·1438138}\ (\text{J.D.hel.M.T.Grw.}—2400000)—·0325$$

According to this the single observations are plotted in Figure 8. It is seen that the star remains in constant minimum for about one thirtieth of the period.

The variable was estimated on about 350 Harvard plates and the period indicated by WOOD confirmed.

The sharpest determination of epochs of minima is obtained by the aid of observations on the descending or ascending branch of the lightcurve. A provisional ephemeris served to show whether an observed intermediate brightness belonged to one or other of the two branches. The corresponding reduction to central minimum was then read off from Figure 8. In this way the 6 first epochs of minimum contained in Table 14 were found. The last minimum with relative weight 16 is derived from WOOD's observations.

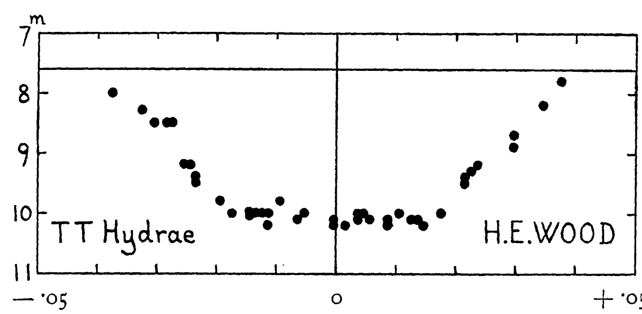
TABLE 14.

T T Hydrae

observed magnitude on Woods scale	date J. D. hel. M. T. Grw.	reduction to central minimum	central minimum J. D. hel. M. T. Grw.	*E*	relative weight	*O—C*
d	d	d	d			d
9·11	2413378·505	+ ·177	2413378·682	—1616	1	— ·010
8·42	16653·522	+ ·218	16653·740	—1145	1	— ·004
8·36	18447·502	+ ·222	18447·724	— 887	1	+ ·002
8·69	18447·552	+ ·202	18447·754	— 887	1	+ ·032
8·77	19532·645	— ·196	19532·449	— 731	1	— ·003
8·31	20957·659	+ ·225	20957·884	— 526	1	— ·015
—	—	—	24615·388	0	16	·000

A least square solution gave the period to be $6^{d}·953401 \pm {}^{d}·000008$ (m.e.).

FIGURE 8.



R U Centauri

The variability of this star was discovered by Kapteyn on C P D plates and confirmed by others, but so far no period had been found. The value $32^{d}·37$ was communicated in *H. C.* **313** and the "Katalog u. Eph. ver. Sterne" without reservation, though it had been indicated by the writer as only unsatisfactorily representing the observations.

The star was estimated on 669 Harvard plates viz. 620 of the A M and 49 of the A X series. The comparison stars used are

	C. P. D.	m	s
a	— 44°5850	9·0	·000
b	5878	9·2	·459
c	5867	9·4	·807
d	5864	9·5	1·167

C P D — 44°5849, $10^{m}\cdot3$ is close to the star *a* and may have influenced its apparent brightness.

The phases were calculated according to the formula

$$\text{phase} = {}^{d\,-1}\cdot030893\ (\text{J. D.} - 2400000)$$

As there proved to be a marked difference in the depth between even and odd minima, they have been considered separately. That is to say that the observations were arranged according to phase 0 to 2·0 and then divided into 33 groups. The mean values thus obtained are given in Table 15 and graphically represented in Figure 9. It is seen that the lightcurve is practically symmetrical and of the characteristic β Lyrae form. This is of particular interest in view of the comparatively long period of $64^{d}\cdot74$. The corresponding density of two equal globular stars in touch with each other is ·000012 times that of the sun. According to *H. C.* **313** the spectrum lies between G 2 and K 2.

The depths of the primary and secondary minima are $1^{s}\cdot05$ and $^{s}\cdot65$ respectively. If my scale in steps is in this case not materially different from the usual one it means that the depth of the secondary minimum is not far from its maximum possible value, the depth of the primary minimum being taken as given. It should however be remembered that ellipticity of the components and reflection effect both tend to increase the range.

The mean error of one observation as derived from the difference between two estimates following each other in phase comes out $\pm\,^{s}\cdot23$ or about double the usual value. This may be partly due to a small step value, but considerable differences between observations at nearly the same calculated phase are noticeably frequent. Probably a few errors are still involved, but they would hardly be sufficient to explain the bulk of the poor agreements. From 93 differences between estimates made on 2 plates taken on the same night the mean error of one observation was found to be $\pm\,^{s}\cdot13$ in fair agreement with the m. e. found in the case of other variables.

FIGURE 9.

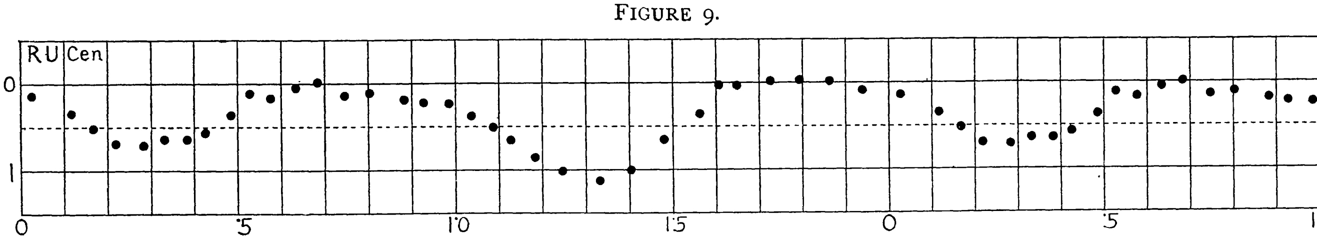


TABLE 15.

RU Centauri

number of plates	phase	brightness	number of plates	phase	brightness
	P	s		P	s
20	·026	·142	20	·985	·232
20	·116	·345	20	1·036	·376
20	·167	·516	20	1·085	·510
20	·219	·696	20	1·126	·652
20	·283	·706	20	1·184	·855
20	·331	·643	20	1·247	1·022
20	·380	·645	21	1·330	1·131
20	·425	·563	20	1·402	1·002
19	·485	·361	20	1·480	·650
20	·528	·117	20	1·561	·352
20	·576	·169	20	1·606	·023
20	·634	·050	20	1·649	·026
20	·684	— ·010	20	1·726	— ·022
20	·747	·148	20	1·792	— ·030
20	·803	·105	20	1·862	— ·020
20	·882	·193	29	1·940	·090
20	·927	·222			

Considering the lightcurve as symmetrical, the phases of the primary and secondary minima are found to be 1·296 and ·296 respectively. The final formula for the primary minimum derived from the present observations is

$$\text{Min.} = \text{J. D. } 2419863^{d}\cdot66 + 64^{d}\cdot74 \times E.$$

There is some indication that the maximum following the primary minimum is higher than the preceding one, the difference $^{s}\cdot13 - {}^{s}\cdot02 = {}^{s}\cdot11$ being about 3 times its mean error, but more accurate observations are needed to settle the question.

C. P. D. — 32°4415 = H. D. 155550, Sp. B9

The variability of this star was discovered in the blinkmicroscope at Johannesburg on plates taken with the Franklin-Adams instrument.

The variable was estimated on 1034 Harvard plates of the AM and AC series. The comparison stars are

	C. P. D.		H. D.			
		m		m		s
b	— 32°4428	8·1	155851	8·0	Bo_p	·00
c	— 32°4371	8·4	155014	8·5	B9	·30
d	— 32°4383	8·6	155162	8·8	A5	·68

The period was derived according to least squares from the 14 minima given in Table 16 and found to be $5^{d}{\cdot}7279 \pm {}^{d}{\cdot}0003$ (m. e.). The phases were calculated according to the formula

$$\text{phase} = {}^{d^{-1}}{\cdot}174584 \text{ (J. D. } - 2400000)$$

The estimates were then arranged according to phase and divided into 2 groups of 12 and 101 of 10 observations each. The mean values for each group are given in Table 17 counting the phases from the minimum, which was found to occur at the phase ·092 according to the above formula.

FIGURE 10.

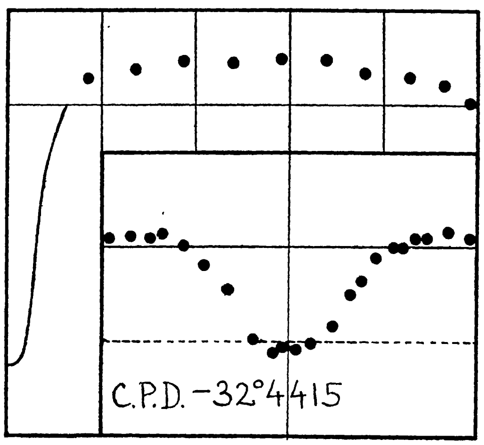


TABLE 16.
C P D — 32°4415

minimum J. D.	epoch	*O—C*
d		d
2414904·571	0	+ ·044
15912·612	176	— 26
16668·725	308	+ 4
16691·624	312	— 9
16960·807	359	— 37
17384·728	433	+ 19
17493·510	452	— 29
18501·597	628	— 53
18501·644	628	— 6
19303·537	768	— 19
20712·581	1014	— 39
21050·640	1073	+ 74
21159·498	1092	+ ·102
23639·513	1525	— 65

The range is from — $^{s}{\cdot}09$ to + $^{s}{\cdot}54$ or $^{s}{\cdot}63$ and the minimum occupies ·12 of the period. It may be constant for a fraction of ·01 or ·02 of the period. The observations outside the primary minimum give slight evidence of a secondary minimum and perhaps a small ellipticity.

The mean epoch of minimum is J. D. 2420277·30.

TABLE 17
C P D — 32°4415

number of plates	phase counted from minimum	brightness	mean values of larger groups	number of plates	phase counted from minimum	brightness	mean values of larger groups
	p	s	p s		p	s	p s
10	+·003	·54		10	+·259	—·11	
10	—·004	·53		10	—·264	—·06	
10	—·009	·56		10	+·271	—·12	
10	+·011	·52		10	—·274	—·10	
10	—·019	·50		10	+·282	—·12	
10	+·024	·42		10	—·286	—·09	
10	+·032	·25		10	+·290	—·11	
10	—·032	·24		10	—·295	—·10	·291 —·097
10	+·038	·19		10	+·296	—·09	
10	—·046	·10		10	+·302	—·10	
10	+·046	·07		10	—·308	—·07	
10	+·055	·00		10	+·309	—·07	
10	—·056	—·00		10	+·319	—·14	
10	+·060	·01		10	—·321	—·08	
10	+·066	—·04		10	+·330	—·09	
10	—·068	—·06		10	—·332	—·08	
10	+·074	—·05		10	— ·339	—·07	
10	— ·074	—·04		10	+·342	—·15	·339 —·094
10	—·085	—·05	·086 —·054	10	—·346	—·06	
10	+·085	—·08		10	+·352	—·07	
10	+·096	—·05		10	—·352	—·11	
12	—·097	—·04		10	+·359	—·10	
10	+·103	—·07		10	—·362	—·08	
12	—·109	—·06		10	+·366	—·06	
10	+·110	—·09		10	—·373	—·06	
10	—·119	—·06		10	+·374	—·06	
10	+·126	—·06		10	—·380	—·08	
10	—·128	—·07		10	+·382	—·06	·380 —·062
10	+·137	—·04		10	—·387	—·05	
10	—·138	—·06	·136 —·074	10	+·390	—·08	
10	+·146	—·10		10	+·394	—·04	
10	—·147	—·12		10	—·395	—·04	
10	+·156	—·05		10	+·402	—·07	
10	—·156	—·10		10	—·404	—·08	
10	—·168	—·07		10	+·413	—·08	
10	+·168	—·12		10	— ·415	—·09	
10	+·178	—·10		10	—·425	—·05	
10	—·178	—·09		10	+·427	—·04	·426 —·059
10	—·184	—·12		10	—·437	—·04	
10	+·188	—·08	·187 —·092	10	+·443	—·06	
10	—·193	—·12		10	—·445	—·06	
10	+·198	—·09		10	+·452	—·02	
10	—·200	—·06		10	—·453	—·04	
10	—·210	—·08		10	+·459	—·03	·464 —·041
10	+·216	—·15		10	—·464	—·06	
10	—·221	—·05		10	—·470	·01	
10	+·225	—·09		10	+·472	—·08	
10	—·229	—·02		10	+·484	—·04	
10	+·236	—·08		10	—·485	—·02	
10	—·240	—·09	·239 —·085	10	+·493	·04	·490 —·004
10	+·249	—·09		10	—·499	·01	
10	—·254	—·11					

U W Arae

This variable was estimated on 756 Harvard plates of the A M and A X series and on 38 of the B series. Three comparison stars were used:

C. P. D.

		m	s
a	−48°9403	9·0	·000
b	9491 ?	9·0 ?	·453
c	9486	9·4	1·003

The identification of the second comparison star, which is not marked on my map of the region, is uncertain.

Of the 38 B-plates the variable was found faint on two, viz. B 11420, exp. time 10 min., J. D. 2412994·703, 1^s·00 and B 13994, exp. time 10 min. J. D. 2413383·779, ^{s}·80.

The phases were calculated from the formula

$$\text{phase} = {}^{d^{-1}}\!\cdot 3032926 \; (\text{J. D.} - 2400000),$$

the corresponding period being 3^d·297146. The 756 estimates on A M and A X plates were then arranged according to phase and divided into 2 groups of 8 and 74 of 10 observations each. The mean values found in this way are given in Table 18, where the phases are counted from the main minimum, which was found to occur at phase ^{p}·186 according to the formula given above. The mean epoch of minimum from the A M and A X plates is J. D. 2419760·410.

The minimum occupies about ·11 of the period and the total range is ^{s}·95. The estimates made outside the primary minimum give an uncertain indication of reflection effect and secondary minimum.

FIGURE 11.

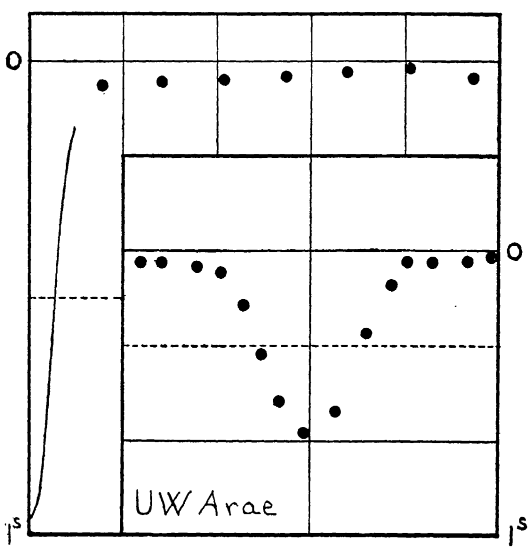


TABLE 18.

U W Arae

number of plates	phase counted from minimum	brightness	mean values of larger groups		number of plates	phase counted from minimum	brightness	mean values of larger groups	
	p	s	p	s		p	s	p	s
10	− ·003	·96			10	− ·251	− ·00		
10	+ ·013	·85			10	+ ·264	·04		
10	− ·016	·79			10	− ·267	·04		
10	− ·026	·54			10	+ ·281	·02	·274	·033
10	+ ·030	·44			10	− ·289	·06		
10	− ·036	·28			10	+ ·294	·06		
10	+ ·043	·18			10	+ ·304	·00		
10	− ·048	·12			10	− ·308	·02		
10	+ ·052	·05			10	+ ·312	·04		
10	− ·060	·09			10	− ·316	·02		
10	+ ·065	·06			10	+ ·320	·05		
10	− ·078	·06	·079	·052	10	− ·325	·02		
10	+ ·083	·05			10	+ ·333	− ·00	·337	·023
10	− ·090	·06			10	− ·341	·01		
10	+ ·097	·03			10	+ ·343	·01		
10	− ·105	·01			10	− ·356	·06		
10	+ ·108	·04			10	+ ·356	− ·01		
10	+ ·117	·04			10	− ·368	·02		
10	− ·126	·05			10	+ ·374	·04		
10	+ ·129	·01			10	− ·380	·05		
10	− ·141	·03	·142	·044	10	− ·389	·01		
10	+ ·144	·04			10	+ ·394	− ·01		
10	− ·157	·08			10	− ·403	·03	·405	·016
10	+ ·158	·03			10	+ ·408	·01		
10	− ·169	·05			10	+ ·419	·00		
10	+ ·172	·06			10	− ·419	− ·02		
10	− ·180	·05			10	+ ·434	·03		
10	+ ·186	·06			10	− ·436	− ·00		
8	− ·191	·02			10	+ ·445	·04		
10	+ ·196	·06			10	− ·450	·02		
8	− ·200	·02	·207	·040	10	− ·458	·02		
10	− ·212	·03			10	+ ·458	·10		
10	+ ·213	·07			10	− ·467	·04	·471	·038
10	− ·223	·04			10	+ ·470	·04		
10	+ ·228	− ·01			10	− ·481	·06		
10	− ·233	·04			10	+ ·486	·02		
10	+ ·238	·06			10	− ·494	·02		
10	+ ·248	·02			10	+ ·497	·03		

A B Andromedae

The star was estimated on 20 old A C plates and found faint on 3 occasions, viz. J. D. 2415775·514, 6108·564 and 6427·698. Using the ephemeris min. J. D. 2424760·360 + ·16595 E, given by GUTHNICK and PRAGER (*A. N.* 5496), the phases for these 3 minima come out − 54141^p·886, − 52134^p·956 and − 50211^p·883 respectively. Supposing the counting of epoches given by these figures to be correct, the apparent period is ^{d}·1659497.