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COMMUNICATION FROM THE OBSERVATORY AT LEIDEN.

Photovisual observations of V Puppis, by *H. van Gent*.

1. *Introduction.*

The variability of V Puppis (= Lacaille 3105 = 233 G Pup = HD 65818, sp. B1, B3, $07^h55^m.4$ — 48°58′, 1900), was discovered in 1885 by A. Stanley Williams [1]) whilst on a voyage to Australia round the Cape by sailing vessel. The discovery of this fourth magnitude variable from aboard ship was followed by several measures of brightness by means of field glasses, using the star Lacaille 3069 as a comparison star. While the discoverer recognized the star at once as a variable of the eclipsing type, the period was still left indeterminate.

In 1895 E. C. Pickering [2]) found the star to be a spectroscopic binary with double lines on objective prism plates taken by Solon I. Bailey at the Harvard Southern Station, Arequipa, Peru. The maximum separation of the lines is more than 600 km/sec. It is the fourth double line spectroscopic binary known, ζ UMa, β Aur and μ_1 Sco being discovered previous to it. Pickering thought the period to be $3^d.115$.

In the meanwhile Alexander W. Roberts had started a long series of visual photometric observations with his $7\frac{1}{2}$ cm telescope at Lovedale, Cape of Good Hope, already as early as 1891, and continued these for many years. When discussing his 1899—1900 observations [3]) he finds it impossible to satisfy them by Pickering's period and then derives a new one. This latter period, $1^d.454476$, even at present hardly needs any correction at all.

From 371 visual observations (not published in detail) Roberts derives the light curve of the variable and makes a first computation of the principal data of this system, assuming it to consist of two spherical bodies of equal size which present uniformly illuminated discs and which revolve in a circular orbit practically in contact with each other. As the secondary minimum in the light curve is almost exactly in the middle between two consecutive primary minima, and very similar in shape, leaving only some difference in depth arising from difference in surface brightness, the assumption of a circular orbit appears to be very firmly founded.

After a general method for the derivation of the fundamental data in an Algol system from its light curve had been worked out by Russell and Shapley [1]), the latter computed the system's elements [2]) according to this rigorous method, taking into account the elongation of the bodies by tidal distortion and making separate solutions for uniform discs as well as for discs darkened towards the limb. The relative orbit is again considered to be circular; the two bodies are no longer supposed to be in contact with each other, but separated by a distance between their surfaces slightly over $^1/_{10}$ of the orbital radius. The computations are based on Roberts's 371 visual observations mentioned before.

Bailey's spectroscopic observations of the years 1893—1898, supplemented by two spectrograms taken in 1917, have been discussed by Miss A. Maury [3]) who derives a spectroscopic orbit. The material consists of objective prism spectra showing double lines; no comparison spectra being present, only the distance between the lines can be measured and consequently only the relative orbit is derived, the mass ratio remaining unknown. Miss Maury adopts Roberts's period, which fully satisfies the Arequipa radial velocities. Whereas Roberts as well as Shapley from the photometric observations assume zero eccentricity for the orbit, the radial velocities yield the values: $e = .08$, $\omega = 72°$. Taking Shapley's data for size and shape of the two components, this orbital eccentricity would make the system likely to show rotation of the line of apsides.

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[1]) *Mon. Not.* **47,** p. 91; *A.N.* No. 3410, p. 25.
[2]) *H.C.* No. 14.
[3]) *Ap. J.* **13,** p. 181.

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[1]) *Ap. J.* **35,** p. 315; **36,** pp. 54, 239, 385.
[2]) *Contrib. Princeton Obs.* **3,** p. 82.
[3]) *H.A.* **84,** p. 172.

For this reason LUYTEN[1]) has recomputed the spectroscopic orbit from the same material as used by Miss MAURY by the WILSING–RUSSELL method, and finds: $e = {\cdot}088 \pm {\cdot}014$ m.e.; $\omega = 59^\circ \pm 10^\circ$ m.e. In the light curve such values should cause the time of secondary minimum to deviate $^{\mathrm{P}}{\cdot}030$ from the point midway between two consecutive primary minima, this deviation being proportional to $e\cos\omega$. In ROBERTS's light curve, however, no effects from this cause are visible. Therefore further photometric observations were thought to be very desirable and the star was put upon the observing program at Johannesburg.

2. *Plate material.*

The observational material consists of a trial plate of small weight on 1937 January 1 and a series of 85 plates from 1937 February 23 till April 28 on 13 nights, all taken with the Franklin Adams star camera ($a = 25$ cm, $f = 112$ cm) of the Union Observatory, Johannesburg, South Africa. A coarse grating was put in front of the objective in order to obtain the magnitude scale. The dimensions of this grating are $d = l = {\cdot}950$ mm. The star Lacaille 3069 (= 216 G Pup = HD 64740, sp. B3, $07^{\mathrm{h}}50^{\mathrm{m}}{\cdot}2$ $- 49^\circ 21'$, 1900) was used as a comparison star. This is the same star as used by A. STANLEY WILLIAMS when discovering the variability of V Pup. Its brightness is intermediate between that of the variable at maximum and at minimum. As the spectrum of V Pup is B1p no serious errors from difference in colour between variable and comparison star are to be feared. All plates are of the brand *Eisenberger Ultra Rapid hochfarbenempfindlich* and have been exposed through a yellow screen in order to make the photometry in a limited region of the spectrum and to reduce the effect from darkening at the limb. By measuring the distance between the first order grating images the effective wavelength of the exposures on the variable as well as on the comparison star could be derived, the scale of the plate being known. For this purpose three plates have been selected, at maximum, minimum and intermediate brightness of the variable respectively. The result is $\lambda_{\mathrm{eff}} = 5604$ Å. This corresponds very well with the maximum in the spectral sensitivity curves for these plates as derived by WESSELINK[2]). As could be expected, no sensible difference in effective wavelength was found between variable and comparison star, nor between the variable at maximum and at minimum.

The plates are of size 9 × 12 cm. The telescope has been equipped with a plateholder mounted on a double slide. In front of this slide is a fixed screen with a square hole of 2·5 × 2·5 cm. This arrangement allows 12 exposures to be made on a 9 × 12 cm plate in three rows of four without adding sky fog to exposures not yet or already made. The device saves much time which otherwise is lost in changing plates. The exposure time was 55 seconds; 5 seconds were used to change from one exposure to the next one. In this way exposures were made at the rate of one a minute. In the last field exposed an extra exposure was made to prevent errors about the plate's orientation and about the order in which the exposures had been taken.

The distance between the variable and the comparison star is $^{\circ}{\cdot}91903$, or nearly two centimetres on the plate. At this distance the non-uniformity of the plate's sensitivity has already serious effects on the accuracy of the photometry. Therefore, the following procedure was carried out. After 13 exposures had been made in the manner already described, the plateholder was closed and taken off and the plate was turned 180° in the dark room. A new series of 12 exposures was then made on the same plate. In this way each field of 2·5 × 2·5 cm carries a set of 2 exposures in positions reversed with respect to each other. As the telescope was pointed midway between variable and comparison star the images of the variable at the exposure before reversal and the comparison star after reversal are very close together, and vice versa. Consequently each field of 2·5 × 2·5 cm on the plate yields two magnitude differences of images which are in the mean about 1 mm from each other. Effects from changes in sensitivity across the plate are almost completely eliminated in this way.

A drawback is that each magnitude difference obtained results from images not taken simultaneously, so that errors from change in atmospheric conditions may come in. For the two magnitude differences from the two pairs of images in each square field these errors should be of opposite sign and consequently disappear by taking their mean. In this way simultaneity is to a certain extent reintroduced and the full advantages of small mutual distances are enjoyed as well. In two cases the images of two consecutive exposures were superposed, the plate by mistake not having been shifted between them. Nevertheless the mean of the magnitude differences of the set of images was good (errors of $^{\mathrm{m}}{\cdot}04$ and $^{\mathrm{m}}{\cdot}05$ only), showing how well also errors in exposure time are compensated by our procedure.

A choice had to be made between photographing

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[1]) *Minnesota Obs. Publ.* **2**, p. 41.

[2]) *B.A.N.* No. 294, p. 127.

the 12 fields on the plate after reversal in the same order as before reversal or in the opposite direction. The first manner has the advantage that the time elapsed between the two exposures is constant, the second that the time halfway between the exposures is the same for all fields.

It should be remembered that the mean of two brightnesses of a variable star at two different times is not equal to its brightness halfway between these times. The difference is in first approximation proportional to the square of the time interval and to the second derivative of the light curve. If it is necessary to correct for this effect it is convenient to have the time interval the same for all pairs of exposures. Therefore the first alternative was chosen. Consequently a normally exposed plate followed the scheme shown in Figure 1. As the time lost for plate reversal was 1 minute, the time between two exposures of a set to be compared was 14 minutes.

FIGURE 1.

13,12 25	11 24	10 23	9 22
5 18	6 19	7 20	8 21
4 17	3 16	2 15	1 14

3. *Measures and reduction.*

The plates have been measured in the old thermopile photometer [1]) at the Leiden Observatory. The diaphragm used has a diameter of 4·15 mm, corresponding to a diameter of ·13 mm for its projected bright image on the plate. At each set of measures the intensity of the lamp was so regulated by a resistance that a constant deflection of the galvanometer was obtained for the plate fog about midway between the two sets of three images to be compared, which is very convenient for the reduction of the measures. Then settings were made on the two sets of images. As each set consists of a central image and two first order grating spectra on opposite sides of it, the mean of the latter two was taken.

The four quantities obtained in this way for each set have been converted into provisional magnitudes by means of a table constructed by A. J. WESSELINK [2]). To these provisional magnitudes the formula $\frac{\Sigma_v - \Sigma_c}{\Delta_v + \Delta_c}$ was applied [1]), Σ_v and Σ_c being the sums of the provisional magnitudes of first order spectrum and central image for variable and comparison star respectively, and Δ_v and Δ_c their differences. This formula is rigorous if the provisional magnitudes obtained by the table are supposed to be a quadratic function of the correct magnitudes.

The validity of this supposition was tested for a few plates by reducing them in three different ways:

1° by the procedure mentioned;

2° by applying the formula $\frac{\Sigma_v - \Sigma_c}{\Delta_v + \Delta_v}$ directly to the galvanometer readings;

3° by drawing first a characteristic curve from the readings on a plate connecting magnitude with galvanometer reading and reducing all readings by means of this curve, the formula mentioned being then applied to the figures obtained.

The result was that the second procedure was likely to give slightly different values; for the other two they were in good accordance. As the third method involved considerably more labour, the first method was chosen.

For five plates, viz. Nos. 13421 till 13425, many of the first order grating spectra were very faint, giving galvanometer readings close to the value for the plate fog. In such a case a small error in the reading from irregular fog or inhomogeneous plate sensitivity causes a large error in the result. Therefore these five plates have been reduced by means of a characteristic curve derived for each plate separately as mentioned under 3°. In order to give smaller weight to the faint first order spectra the magnitude difference was then obtained by dividing the difference of the provisional magnitudes of the central images of variable and comparison star by their mean gradation, the difference in provisional magnitude between central image and first order spectrum being considered as the gradation. In this way the first order spectra contribute to the denominator only, whereas in the formula mentioned before they contribute to both denominator and numerator.

Some exposures have been rejected owing to defective images or disturbing insensitive spots on the plate. In a few fields the reversed image had by accident been put too close to the non-reversed one. In all these cases both exposures, reversed and non-reversed, have been sacrificed.

For all plates the means have been taken of the two magnitude differences resulting from the two

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[1]) For description see *B.A.N.* No. 60.

[2]) A. J. WESSELINK, *Thesis for the doctor's degree*, Leiden, 1937, p. 13. See also *B.A.N.* No. 318.

[1]) E. HERTZSPRUNG, *A.N.* No. 4543, p. 121.

exposures, reversed and non-reversed, in each of the twelve fields on a plate. For exposures 12 and 13 their average difference in brightness with exposure 25 was used. In this way each plate with 25 exposures gave 12 magnitude differences, expressed in the difference between first order spectrum and central image as unit. For a grating the bars of which are of the same width as the spaces between them this difference is theoretically ^{m}·981. Therefore, all magnitude differences have been multiplied by this quantity.

For each plate the mean of its 12 magnitude differences was taken. Again it should be remembered that the mean of these 12 brightnesses may differ from the brightness at the mean of the exposure times. The correction for this effect is small; only in those parts of the light curve that show strong curvature it is worth being applied.

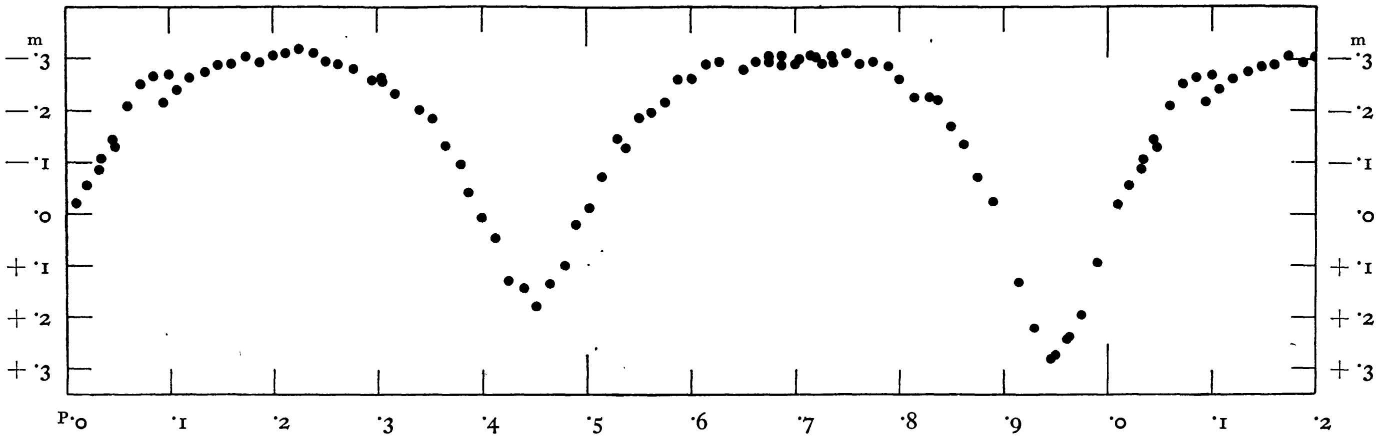
4. *Light curve.*

The time of each exposure has been converted into Julian Day Hel. M. Time Greenwich. Only the mean for each plate has been given in Table 1, 2nd column. For the construction of the light curve PRAGER's period 1^{d}·454488 has been used. The phases, in column 3, have been computed according to the formula: phase = (J.D. — 2420000) × $^{d-1}$·6875278. The difference in brightness between the variable

TABLE 1.

plate	J.D. Hel. M.T. Grw.	phase	observed brightness	hour angle correction	corrected brightness	n	sid. time Johbg.
	d		m	m	m		
13083	8535·3711	·3049	— ·256	— ·004	— ·260	3	05^h27^m
13138	8588·2684	·6733	— ·293	— ·002	— ·295	12	06 28
13139	·2885	·6871	— ·295	— ·001	— ·296	12	06 58
13140	·3130	·7039	— ·300	+ ·001	— ·299	12	07 33
13141	·3373	·7206	— ·304	+ ·003	— ·301	12	08 08
13142	8590·2456	·0327	— ·083	— ·003	— ·086	12	06 04
13143	·2660	·0467	— ·128	— ·002	— ·130	8	06 33
13145	8591·4153	·8369	— ·211	+ ·015	— ·196	11	10 13
13146	·4344	·8500	— ·171	+ ·017	— ·154	10	10 40
13147	·4541	·8635	— ·136	+ ·020	— ·116	12	11 08
13148	·4731	·8766	— ·071	+ ·023	— ·048	12	11 36
13149	·4918	·8895	— ·012	+ ·025	+ ·013	12	12 03
13150	8593·2439	·0941	— ·215	— ·003	— ·218	12	06 13
13151	·2626	·1069	— ·240	— ·001	— ·241	12	06 40
13152	·2812	·1197	— ·262	·000	— ·262	9	07 07
13153	·3043	·1356	— ·276	+ ·002	— ·274	9	07 40
13154	·3229	·1484	— ·288	+ ·003	— ·285	6	08 07
13155	·3411	·1609	— ·291	+ ·006	— ·285	9	08 34
13156	·3603	·1741	— ·304	+ ·008	— ·296	12	09 01
13157	·3797	·1874	— ·293	+ ·010	— ·283	10	09 28
13158	·3980	·2000	— ·305	+ ·013	— ·292	10	09 55
13159	·4164	·2127	— ·310	+ ·016	— ·294	12	10 22
13160	·4351	·2255	— ·318	+ ·018	— ·300	12	10 49
13161	·4538	·2384	— ·310	+ ·021	— ·289	12	11 16
13162	·4725	·2514	— ·293	+ ·023	— ·270	12	11 43
13169	8595·3423	·5368	— ·127	+ ·006	— ·121	12	08 43
13170	·3610	·5496	— ·186	+ ·009	— ·177	12	09 10
13171	·3795	·5624	— ·195	+ ·011	— ·184	9	09 37
13172	·3984	·5754	— ·215	+ ·014	— ·201	12	10 04
13173	·4171	·5882	— ·258	+ ·016	— ·242	12	10 31
13174	·4357	·6010	— ·258	+ ·019	— ·239	11	10 58
13175	·4542	·6137	— ·288	+ ·022	— ·266	10	11 25
13176	·4729	·6266	— ·293	+ ·024	— ·269	11	11 52
13179	8596·4017	·2651	— ·290	+ ·015	— ·275	11	10 13
13180	·4203	·2779	— ·280	+ ·017	— ·263	11	10 40
13181	·4393	·2910	— ·261	+ ·020	— ·241	12	11 07
13182	·4578	·3037	— ·262	+ ·022	— ·240	11	11 34
13183	·4767	·3167	— ·233	+ ·025	— ·208	12	12 01
13279	8623·2691	·7372	— ·294	+ ·007	— ·287	10	08 49
13280	·2885	·7506	— ·310	+ ·009	— ·301	11	09 16
13281	·3066	·7630	— ·289	+ ·012	— ·277	10	09 43
13282	·3256	·7761	— ·296	+ ·014	— ·282	12	10 10
13283	·3443	·7889	— ·283	+ ·017	— ·266	12	10 37
13284	8623·3630	·8018	— ·259	+ ·020	— ·239	12	11^h04^m
13285	·3819	·8148	— ·226	+ ·022	— ·204	11	11 31
13286	·4023	·8288	— ·223	+ ·025	— ·198	11	12 00
13287	8624·2148	·3874	— ·039	+ ·001	— ·038	10	07 34
13288	·2335	·4003	+ ·007	+ ·003	+ ·010	12	08 01
13289	·2522	·4131	+ ·048	+ ·005	+ ·053	12	08 28
13290	·2709	·4260	+ ·129	+ ·007	+ ·136	12	08 55
13291	·2899	·4391	+ ·144	+ ·010	+ ·154	11	09 22
13292	·3080	·4515	+ ·178	+ ·012	+ ·190	11	09 49
13293	·3269	·4645	+ ·134	+ ·015	+ ·149	11	10 16
13294	·3457	·4774	+ ·100	+ ·018	+ ·118	12	10 43
13295	·3642	·4901	+ ·018	+ ·020	+ ·038	11	11 10
13296	·3831	·5031	— ·010	+ ·023	+ ·013	12	11 37
13297	·4018	·5160	— ·071	+ ·026	— ·045	12	12 04
13298	·4209	·5291	— ·146	+ ·029	— ·117	12	12 37
13415	8648·2524	·9139	+ ·132	+ ·014	+ ·146	12	10 04
13416	·2711	·9268	+ ·222	+ ·016	+ ·238	12	10 31
13417	·2906	·9402	+ ·282	+ ·019	+ ·301	12	10 59
13418	·3237	·9630	+ ·239	+ ·024	+ ·263	12	11 47
13421	8651·2126	·9492	+ ·274	+ ·010	+ ·284	11	09 19
13422	·2312	·9620	+ ·241	+ ·012	+ ·253	11	09 46
13423	·2499	·9748	+ ·197	+ ·015	+ ·212	11	10 13
13424	·2745	·9917	+ ·094	+ ·018	+ ·112	11	10 48
13425	·2977	·0077	— ·022	+ ·021	— ·001	11	11 22
13426	·3168	·0208	— ·054	+ ·024	— ·030	11	11 49
13427	·3358	·0339	— ·107	+ ·027	— ·080	9	12 16
13428	·3543	·0466	— ·143	+ ·030	— ·113	11	12 43
13430	8652·2309	·6493	— ·279	+ ·012	— ·267	12	09 49
13431	·2498	·6623	— ·295	+ ·015	— ·280	11	10 16
13432	·2685	·6751	— ·303	+ ·018	— ·285	11	10 43
13433	·2870	·6878	— ·306	+ ·020	— ·286	12	11 10
13434	·3057	·7007	— ·292	+ ·023	— ·269	12	11 37
13435	·3246	·7137	— ·306	+ ·026	— ·280	11	12 04
13436	·3431	·7264	— ·292	+ ·028	— ·264	12	12 31
13437	·3568	·7358	— ·305	+ ·030	— ·275	4	12 51
13440	8653·2364	·3406	— ·202	+ ·013	— ·189	12	10 01
13441	·2551	·3534	— ·183	+ ·016	— ·167	12	10 28
13442	·2738	·3663	— ·131	+ ·019	— ·112	12	10 55
13443	·2922	·3789	— ·095	+ ·021	— ·074	11	11 24
13444	8654·2836	·0606	— ·210	+ ·020	— ·190	12	11 13
13445	·3023	·0734	— ·252	+ ·023	— ·229	12	11 40
13446	·3210	·0863	— ·265	+ ·026	— ·239	12	12 07
13447	·3397	·0991	— ·272	+ ·029	— ·243	12	12 34

FIGURE 2.



and the comparison star has been given in column 4. When plotted against phase we find the light curve as shown in Figure 2.

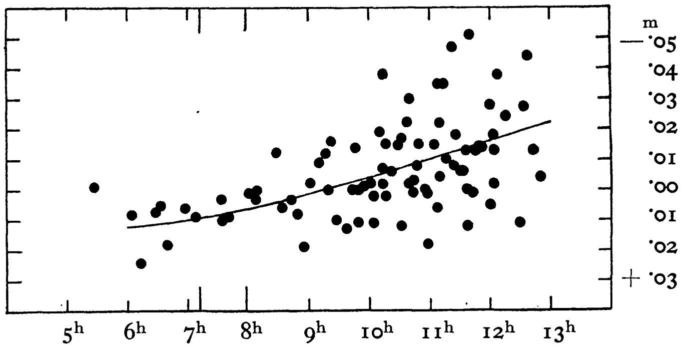
Inspection of the light curve shows that the difference in phase between primary minimum and secondary minimum is very nearly half a period. Consequently the value for $e\cos\omega$ can only be small. The shape of the minima is very symmetrical. There are, however, some discrepancies which occur especially at those places in the light curve where the observations jump from one night to another. The observations of a same night are mostly lying in a row without jump. Further inspection shows that at the end of a series of plates from one night the variable appears to be too bright and at the beginning of a series of another night which follows in phase it mostly appears too faint. This suggests a systematic error depending on the hour angle at which the exposures have been taken. Therefore, the sidereal time of the plates has been given in column 8 of Table 1. The error is far too great to be explained by the ordinary differential atmospheric extinction, although its effect is in the same direction. A bad thing is that, for a long row of observations covering a minimum like the series of twelve plates covering the secondary minimum, the effect tends to produce a spurious asymmetry in the light curve. The complete light curve has been covered by observations only once, so that in the same phase only observations from one hour angle are available. Consequently it is difficult to draw a mean light curve. In the following way this difficulty was more or less overcome. By applying a correction of double the differential extinction at sea level the light curve has been corrected for at least part of the hour angle effect, so that the minima have become more symmetrical. By means of the method exposed in *B.A.N.* No. 147, p.179, the phases of primary and secondary minimum have been determined, the result being:

primary minimum $^{\mathrm{P}}$·94996 ± $^{\mathrm{P}}$·0004
secondary minimum ·45003 ± ·0005

The difference in phase between secondary minimum and the point midway between two consecutive primary minima, which is equal to $\frac{2e\cos\omega}{\pi}$ becomes: $^{\mathrm{P}}$·00007 ± $^{\mathrm{P}}$·0006. As the quantity concerned is much smaller than its mean error, the value for $e\cos\omega$ may be taken as zero. The light curve may be regarded as fully symmetrical and was now reflected about the line of symmetry at phase ·4500. Still the observations taken at great western hour angles showed large deviations. In order not to be disturbed by them when drawing the light curve the observations taken at more than 3^{h} hour angle were temporarily omitted. Then the differences between the uncorrected observations and this light curve have been formed and plotted against the sidereal time as shown in Figure 3.

The diagram fully confirms the suspicion that the error depends on the hour angle. A second fact now shows its presence: the dispersion of the observations increases with the hour angle. Computation shows the mean error for plates up to three hours out of the meridian to be ± $^{\mathrm{m}}$·009, and for greater hour

FIGURE 3.



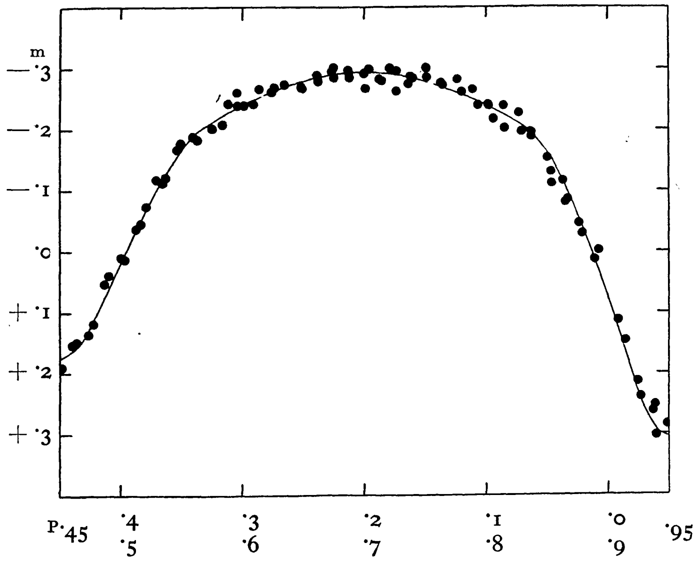
angles ± ^{m}·015, corresponding to a ratio in their weights of approximately three to one.

Means for each hour of sidereal time are shown in the following table:

sidereal time	mean deviation from light curve
h	m
$6\frac{1}{2}$	+·011
$7\frac{1}{2}$	+·008
$8\frac{1}{2}$	+·004
$9\frac{1}{2}$	—·002
$10\frac{1}{2}$	—·007
$11\frac{1}{2}$	—·015
$12\frac{1}{2}$	—·016

A curve has been drawn through the corresponding points in Figure 3. As many more observations have been made after the meridian than before it the effect is not zero at the meridian but +^{m}·006. If the effect is of the nature of a differential extinction it should be zero when comparison star and variable are at equal altitudes above the horizon. This happens at $7^{h}12^{m}$ sidereal time. Therefore all observations have been reduced to $7^{h}12^{m}$ sidereal time by means of the curve mentioned. The resulting light curve is shown in Figure 4. Hour angle correction and corrected brightness are shown in columns 5 and 6 of Table 1.

FIGURE 4.



Although nothing definite can be said about the cause of this hour angle effect the similarity with differential extinction suggests that it may be due to abnormally great extinction by dust in the atmosphere. At the Union Observatory, Johannesburg, for declination —49° at great western hour angles the telescope is pointed across the town, the centre of which is at a distance of about $3\frac{1}{2}$ km, and across the range of gold mines. Both are a source of smoke and dust in the air so that this explanation is not unacceptable.

For accurate photometry the neighbourhood of a big industrial centre seems to be a serious handicap.

5. *Mean errors and weight.*

The mean error of a single plate as found from the symmetrical light curve (Figure 4) is ± ^{m}·0116. The weight of the light curve computed from this value is $86/({}^{m}\cdot0116)^{2} = 640000$ m.$^{-2}$

This result will be flattered if part of the error is of a systematical nature. Therefore different sources of error have been considered, viz. night error, plate error, measuring error and the error in the image.

The mean error ε of the individual measures with respect to the average of a plate was found to be ± ^{m}·043. It is composed of image error and measuring error. By measuring a plate twice the second error was found to be ± ^{m}·014; consequently an error of ± ^{m}·041 is inherent to the image. By studying the systematic deviation of plates of the same night from the light curve, an idea was obtained about the night error and the plate error. The values found are ± ^{m}·0058 and ± ^{m}·0041 respectively. The number of nights being small, not too much importance should be attached to these last two figures. However, a comparison may be given of the values found here and those determined by WESSELINK [1]) in his discussion of 12479 exposures on Σ 485 with the Leiden 34 cm refractor:

	VAN GENT, V Puppis	WESSELINK, Σ 485
	m	m
$\varepsilon_{\text{night}}$	±·0058	±·0053
$\varepsilon_{\text{plate}}$	·0041	·0053
$\varepsilon_{\text{measure}}$	·014	·013
$\varepsilon_{\text{image}}$	·041	·016

The great difference between the values for the accuracy of the image may be satisfactorily explained by the difference between the instruments with which they have been taken. The exposures on V Pup have been obtained with a focal distance of 113 cm through yellow filter on colour sensitive plates, whereas WESSELINK's Σ 485 exposures have been made with a focal distance of 520 cm without filter on ordinary blue sensitive plates. The character of the images is consequently entirely different, those of V Pup being of much smaller diameter and with a steeper gradation.

Taking into account the systematic errors, we

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[1]) L.c., p. 31.

find for the total weight of the observations on V Pup:

$$14 \Big/ \left[({}^{\mathrm{m}}{\cdot}0058)^2 + \frac{({}^{\mathrm{m}}{\cdot}0041)^2}{6{\cdot}5} + \frac{({}^{\mathrm{m}}{\cdot}041)^2 + ({}^{\mathrm{m}}{\cdot}014)^2}{6{\cdot}5 \times 25} \right]$$

$= $ about 250000 m^{-2}.

6. *Period.*

ROBERTS's observations [1]) have been reduced with the reciprocal period already mentioned, viz. $^{\mathrm{d}-1}{\cdot}6875278$, and in the resulting light curve the phase of minimum has been determined in the same way as already described for the 1937 photovisual observations. For both series of observations the corresponding epochs of minimum have been computed. An estimate of the accuracy of these minima was obtained from the accuracy of the points on the respective light curves, viz. $\pm\ {}^{\mathrm{m}}{\cdot}019$ for ROBERTS's and $\pm\ {}^{\mathrm{m}}{\cdot}0116$ for the 1937 Johannesburg curve. Considering the slopes of the descending and ascending branches near the minima, which are the main factor determining the accuracy of these epochs, and considering the number of points upon these branches, the following figures result:

Min. ROBERTS J.D. Hel. M.T. Grw.
$2415021^{\mathrm{d}}{\cdot}2186 \pm {}^{\mathrm{d}}{\cdot}0015$ m.e.
Min. VAN GENT J.D. Hel. M.T. Grw.
$2428648^{\mathrm{d}}{\cdot}3048 \pm {}^{\mathrm{d}}{\cdot}0007$ m.e.

The number of periods elapsed between is 9369. Consequently the period is [2]):

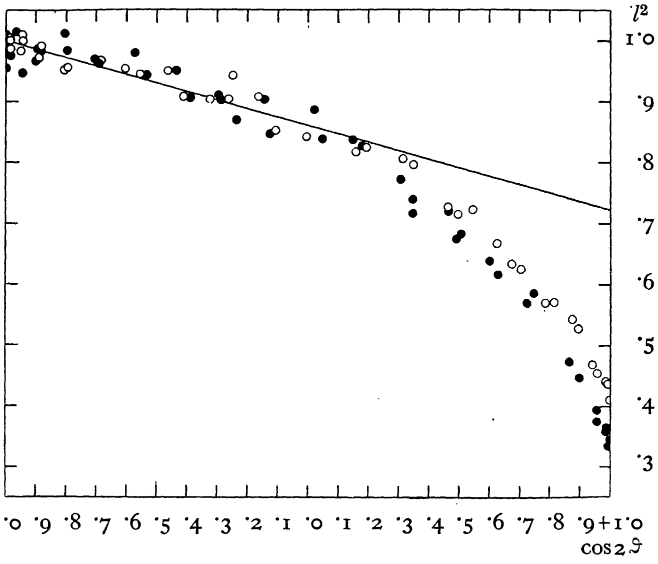
$$1^{\mathrm{d}}{\cdot}4544867 \pm {}^{\mathrm{d}}{\cdot}0000002 \text{ m.e.}$$

The uncertainty of the period is of the order of ·02 seconds.

7. *Determination of the orbital elements.*

As the light curve has considerable weight it was made the basis of a new determination of the fundamental quantities in this eclipsing system. A solution for uniform discs was made, assuming two similar three-axial ellipsoids with their longest axes in a line, as is customary in such cases. The orbit was considered to be circular.

FIGURE 5.



The intensity of light l is connected with the eccentricity ε of the equatorial section in the following way:

$$l^2 = 1 - \varepsilon^2 \sin^2 i \cos^2 \vartheta,$$

where i denotes the orbital inclination and ϑ the system's anomaly, counted from principal minimum. From Table 1 l^2 was computed and plotted against $\cos 2\vartheta = 2\cos^2\vartheta - 1$. The result is shown in Table 2, column 4, and in Figure 5, open circles denoting secondary minimum, dots principal minimum. The relation between the coordinates should be linear outside the eclipses. From inspection of the diagram the eclipse was considered not to start before $\cos 2\vartheta = +\ {\cdot}2$ and a least squares solution was made for a straight line through the points to the left. Its result is:

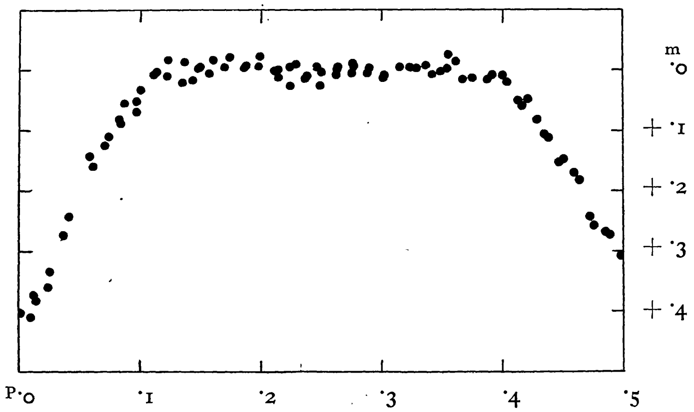
$$l^2 = +{\cdot}8614 - {\cdot}1383 \cos 2\vartheta$$
$$\pm{\cdot}0073 \text{ m.e.}$$

Accordingly: $\varepsilon^2 \sin^2 i = +{\cdot}2766 \pm {\cdot}0146$ m.e.

The light curve was now rectified as shown in column 6 of Table 2 and in Figure 6.

The next quantity to be derived is the ratio of the surface brightnesses $\frac{J_b}{J_f}$. For this purpose the ordinates of the eclipse in Figure 6 have been converted from magnitudes into intensities as shown in column 7 of Table 2. The area in the rectified light curve en-

FIGURE 6.



Rectified light curve.

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[1]) *Ap. J.* **13**, p. 189.

[2]) Although the old observations by STANLEY WILLIAMS actually hit three minima, they could not be used for improving the period, their number being too small.

TABLE 2.

plate	phase from min.	cos 2 ϑ	$l^2_{obs.}$	$l^2_{ell.}$	$m_{obs.}$ minus $m_{ell.}$	obs. loss of light due to eclipse	brightness from maximum obs.	brightness from maximum comp.	O–C
					m		m	m	m
13421	·0008	+ ·9999	·3448	·7232	+ ·402	·3094	+ ·578	·598	—·020
13417	·0098	·9924	·3342	·7242	+ ·420	·3208	+ ·595	·584	+ ·011
13422	·0120	·9887	·3651	·7247	+ ·372	·2901	+ ·547	·578	—·031
13418	·0130	·9867	·3584	·7250	+ ·382	·2966	+ ·557	·574	—·017
13416	·0232	·9578	·3753	·7290	+ ·360	·2822	+ ·532	·530	+ ·002
13423	·0248	·9518	·3937	·7298	+ ·335	·2655	+ ·506	·521	—·015
13415	·0361	·8989	·4446	·7371	+ ·274	·2230	+ ·440	·455	—·015
13424	·0417	·8659	·4734	·7417	+ ·244	·2013	+ ·406	·420	—·014
13425	·0577	·7485	·5829	·7579	+ ·142	·1226	+ ·293	·323	—·030
13149	·0605	·7247	·5681	·7612	+ ·159	·1362	+ ·307	·308	—·001
13426	·0708	·6296	·6149	·7744	+ ·125	·1088	+ ·264	·253	+ ·011
13148	·0734	·6039	·6356	·7779	+ ·110	·0964	+ ·246	·239	+ ·007
13142	·0827	·5069	·6817	·7913	+ ·081	·0719	+ ·208	·197	+ ·011
13427	·0839	·4938	·6742	·7932	+ ·088	·0778	+ ·214	·192	+ ·022
13147	·0865	·4652	·7204	·7971	+ ·055	·0494	+ ·178	·181	—·003
13428	·0966	·3494	·7165	·8131	+ ·068	·0607	+ ·181	·143	+ ·038
13143	·0967	·3482	·7393	·8133	+ ·052	·0468	+ ·164	·143	+ ·021
13146	·1000	·3090	·7727	·8187	+ ·032	·0290	+ ·140	·132	+ ·008
13444	·1106	·1800	·8257	·8365	+ ·007	·0064	+ ·104	·103	+ ·001
13145	·1131	·1490	·8348	·8408	+ ·004	·0037	+ ·098	·097	+ ·001
13286	·1212	·0478	·8379	·8548	+ ·011		+ ·096	·085	+ ·011
13445	·1234	+ ·0201	·8872	·8587	—·018		+ ·065	·082	—·017
13285	·1352	—·1278	·8472	·8791	+ ·020		+ ·090	·070	+ ·020
13446	·1363	·1416	·9036	·8810	—·014		+ ·055	·069	—·014
13150	·1441	·2377	·8694	·8943	+ ·016		+ ·076	·060	+ ·016
13284	·1482	·2874	·9036	·9012	—·002		+ ·055	·056	—·001
13447	·1491	·2982	·9104	·9027	—·004		+ ·051	·056	—·005
13151	·1569	·3902	·9070	·9154	+ ·005		+ ·053	·048	+ ·005
13283	·1611	·4382	·9497	·9220	—·016		+ ·028	·044	—·016
13152	·1697	·5326	·9428	·9351	—·004		+ ·032	·036	—·004
13282	·1739	·5766	·9782	·9412	—·021		+ ·012	·033	—·021
13153	·1856	·6900	·9638	·9569	—·004		+ ·020	·024	—·004
13281	·1870	·7026	·9692	·9586	—·006		+ ·017	·023	—·006
13154	·1984	·7971	·9836	·9717	—·006		+ ·009	·016	—·007
13280	·1994	·8046	1·0130	·9727	—·022		—·007	·015	—·022
13155	·2109	·8817	·9836	·9834	·000		+ ·009	·009	·000
13279	·2128	·8927	·9872	·9849	—·002		+ ·007	·008	—·001
13437	·2142	·9005	·9656	·9860	+ ·012		+ ·019	·008	+ ·011
13436	·2236	·9455	·9462	·9922	+ ·026		+ ·030	·004	+ ·026
13156	·2241	·9475	1·0037	·9925	—·006		—·002	·004	—·006
13141	·2294	·9667	1·0130	·9951	—·010		—·007	·002	—·009
13435	·2363	·9852	·9746	·9977	+ ·013		+ ·014	·001	+ ·013
13157	·2374	—·9875	·9800	·9980	+ ·010		+ ·011	·001	+ ·010

plate	phase from min.	cos 2 ϑ	$l^2_{obs.}$	$l^2_{ell.}$	$m_{obs.}$ minus $m_{ell.}$	obs. loss of light due to eclipse	brightness from maximum obs.	brightness from maximum comp.	O–C
					m		m	m	m
13140	·2461	—·9988	1·0093	·9996	—·005		—·005	·000	—·005
13434	·2493	1·0000	·9550	·9997	+ ·025		+ ·025	·000	+ ·025
13158	·2500	1·0000	·9963	·9997	+ ·002		+ ·002	·000	+ ·002
13433	·2622	·9883	·9854	·9981	+ ·007		+ ·008	·001	+ ·007
13159	·2627	·9873	1·0000	·9980	—·001		·000	·001	—·001
13139	·2629	·9869	1·0037	·9979	—·003		—·002	·001	—·003
13432	·2749	·9514	·9836	·9930	+ ·005		+ ·009	·004	+ ·005
13160	·2755	·9491	1·0111	·9927	—·010		—·006	·004	—·010
13138	·2767	·9443	1·0018	·9920	—·006		—·001	·004	—·005
13431	·2877	·8899	·9746	·9845	+ ·006		+ ·014	·008	+ ·006
13161	·2884	·8858	·9908	·9839	—·004		+ ·005	·009	—·004
13430	·3007	·8039	·9515	·9726	+ ·012		+ ·027	·015	+ ·012
13162	·3017	·7963	·9568	·9716	+ ·008		+ ·024	·016	+ ·008
13179	·3151	·6837	·9656	·9560	—·006		+ ·019	·024	—·005
13176	·3234	·6039	·9550	·9450	—·006		+ ·025	·030	—·005
13180	·3279	·5579	·9445	·9386	—·004		+ ·031	·034	—·003
13175	·3363	·4673	·9497	·9261	—·014		+ ·028	·042	—·014
13181	·3410	·4144	·9070	·9187	+ ·007		+ ·053	·046	+ ·007
13174	·3490	·3209	·9036	·9058	+ ·002		+ ·055	·054	+ ·001
13182	·3537	·2645	·9053	·8980	—·004		+ ·054	·058	—·004
13083	·3549	·2499	·9393	·8960	—·026		+ ·034	·060	—·026
13173	·3618	·1650	·9087	·8843	—·015		+ ·052	·067	—·015
13183	·3667	·1042	·8535	·8759	+ ·014		+ ·086	·072	+ ·014
13172	·3746	—·0051	·8426	·8621	+ ·012		+ ·093	·080	+ ·013
13171	·3876	+ ·1576	·8166	·8396	+ ·015	·0137	+ ·110	·098	+ ·012
13440	·3906	·1947	·8241	·8345	+ ·007	·0064	+ ·105	·104	+ ·001
13170	·4004	·3138	·8061	·8180	+ ·008	·0073	+ ·117	·127	—·010
13441	·4034	·3494	·7914	·8131	+ ·014	·0128	+ ·127	·135	—·008
13169	·4132	·4617	·7271	·7976	+ ·050	·0450	+ ·173	·164	+ ·009
13442	·4163	·4961	·7152	·7928	+ ·056	·0494	+ ·182	·175	+ ·007
13298	·4209	·5454	·7218	·7860	+ ·046	·0415	+ ·177	·190	—·013
13443	·4289	·6267	·6668	·7748	+ ·082	·0727	+ ·220	·220	·000
13297	·4340	·6753	·6321	·7681	+ ·106	·0930	+ ·249	·240	+ ·009
13287	·4374	·7062	·6240	·7638	+ ·110	·0964	+ ·256	·254	+ ·002
13296	·4469	·7855	·5681	·7528	+ ·153	·1314	+ ·307	·295	+ ·012
13288	·4503	·8113	·5712	·7492	+ ·147	·1266	+ ·304	·310	—·006
13295	·4599	·8757	·5425	·7403	+ ·169	·1441	+ ·332	·352	—·020
13289	·4631	·8944	·5277	·7378	+ ·182	·1543	+ ·347	·367	—·020
13294	·4726	·9413	·4682	·7313	+ ·242	·1998	+ ·412	·406	+ ·006
13290	·4760	·9549	·4529	·7294	+ ·258	·2115	+ ·430	·420	+ ·010
13293	·4855	·9834	·4422	·7254	+ ·268	·2187	+ ·443	·449	—·006
13291	·4891	·9906	·4381	·7245	+ ·273	·2223	+ ·448	·458	—·010
13292	·4985	+ ·9998	·4100	·7232	+ ·308	·2470	+ ·484	·469	+ ·015

closed between the intensity at maximum and the eclipse curve was determined for both minima. The ratio between these two areas is the quantity wanted. Its value is:

$$\frac{J_b}{J_f} = 1·36 \pm ·03, \text{ equivalent to } -^{m}·335.$$

It is appropriate to compare this value with the one derived from the spectral types of the two components which are classified by Miss MAURY as B1 and B3 respectively. The ratio of the radiation in a certain wavelength per unit area for the two components is:

$$\frac{10^{\frac{K}{\lambda T_b}} - 1}{10^{\frac{K}{\lambda T_f}} - 1}.$$

Taking $\lambda = 5604$ Å, $K = ·6240$ and interpolating in the temperature scale of RUSSELL, DUGAN and STEWART [1]) we find: $\frac{J_b}{J_f} = 1·34$, in even better agreement with the value derived from the light curve than might be expected.

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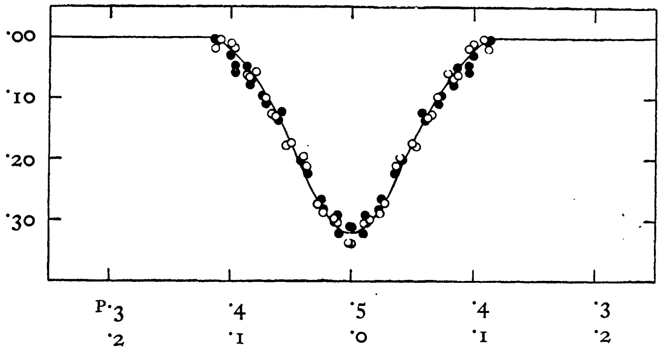
[1]) *Astronomy*, p. 734.

The remaining quantities to be determined from the light curve are $\frac{r_1}{a}$, $\frac{r_2}{a}$ and i.

For this purpose the two minima have been united into a single curve by multiplying the figures for the loss of light due to secondary eclipse from Table 2, column 7, with the value found for $\frac{J_b}{J_f}$. The values so obtained together with the values for the loss of light due to primary eclipse have been plotted against phase, counted either from mid-primary or mid-secondary minimum. The result is shown in Figure 7, dots denoting principal, open circles secondary eclipse. It is seen that there are hardly any systematic differences between the two eclipses, now that the effects of difference in surface brightness have been eliminated.

FIGURE 7.



Theoretically three points on a light curve are sufficient to find the values of the three remaining unknowns. For these points the following set has been selected:

phase	loss of light
·0000	·328
·0415	·200
·0810	·075

and with a number of values for $k = \frac{r_{B3}}{r_{B1}}$ corresponding values for a and i have been computed satisfying the first two points. For the third point the values $\frac{\delta}{s_1}$ (projected distance of the centres of the two components in terms of the semi major axis of the equatorial section of the bigger one) have been computed for phase ·0810 and compared with the values derived from the observed loss of light ·075. The following table gives an account of these trial solutions:

k	a	i	α_0	$\left(\frac{\delta}{s_1}\right)_{\text{obs.}} - \left(\frac{\delta}{s_1}\right)_{\text{comp.}}$
·60	2·46	81°·80	·9972	·16
·90	2·73	78·04	·6254	·12
1·00	2·86	78·15	·5689	·12
1/·80	2·57	79·31	·7534	·11
1/·70	2·45	81·02	·9103	·11
1/·66	2·45	82·80	·9937	·13

It was hoped that by varying k the value for $\left(\frac{\delta}{s_1}\right)_{\text{obs.}} - \left(\frac{\delta}{s_1}\right)_{\text{comp.}}$ would pass through zero. As shown by the table, this hope was not fulfilled although the values for α_0, the fraction of the smaller disc eclipsed by the bigger one at mid-eclipse, practically cover the whole possible interval from 1·00 through a minimum to 1·00. It appears that no set of values k, a and i can be found satisfying the three selected points on the light curve. Moreover, a big change in k involves only a small change in $\left(\frac{\delta}{s_1}\right)_{\text{obs.}} - \left(\frac{\delta}{s_1}\right)_{\text{comp.}}$ This raises the suspicion that this type of light curve is not capable of yielding a sharp determination of k, a and i anyhow.

Therefore k was determined in another way. The ratio of the strengths of the brighter B1 spectrum to the fainter B3 spectrum is given by Miss MAURY as $\frac{10}{7}$. This should be equal to $\frac{1}{k^2}\,\frac{J_{B1}}{J_{B3}}$. With the value already found for $\frac{J_{B1}}{J_{B3}}$ the value for k becomes:

$$k = {}\cdot 98.$$

Now that a value for k has been found without using the light curve, only two points upon the latter suffice for determining the two remaining quantities a and i. The two following points have been chosen:

phase	loss of light
·0000	·322
·0610	·135

It will be noted that the value for the loss of light at mid-minimum is less than the one adopted before from a free hand curve through the observed points. A theoretical curve drawn near the middle of the minimum showed it to be much blunter than the free hand curve, with consequent decrease of the depth at mid-minimum.

We thus find: $k = {}\cdot 98$
$a = 2\cdot 6196$
$i = 76°\cdot 89$

With this set of values a theoretical light curve has been computed, which has been compared with the observed points. An account of this comparison is given in Table 2, columns 8, 9 and 10, and in Figures 4 and 7.

The mean error of a single plate with respect to this curve is $\pm\, {}^{m}\!\cdot 013$.

8. *Orbital eccentricity and rotation of periastron.*

In the same way as described under **4** the difference in phase between secondary minimum and the point midway between two consecutive primary minima was determined for ROBERTS's [1] light curve of the year 1900. Together with the spectroscopic orbit derived from the Harvard-Arequipa radial velocities by LUYTEN [2] we now have the following information regarding the position of the periastron, adopting the spectroscopically determined eccentricity throughout:

1896 Harvard-Arequipa radial velocities . . .
$e = \cdot 088 \pm \cdot 014;\ \omega = 59^\circ \pm 10^\circ,$
1900 ROBERTS's visual light curve . . .
$e\cos\omega = +\cdot 0037 \pm \cdot 0033;\ \omega = 88^\circ \pm 2^\circ,$
1937 the author's photovisual light curve . . .
$e\cos\omega = +\cdot 0002 \pm \cdot 0010;\ \omega = 90^\circ \pm 7^\circ.$

From these data an advance of the periastron at the rate of $9^\circ\!\cdot 7$ annually seems possible. It is, however, a suspicious fact that for both photometric determinations ω becomes very nearly 90° with almost exactly one complete rotation of the periastron in between.

As is well known, orbital eccentricity also produces a difference in width between primary and secondary minimum proportional to $e\sin\omega$ [3]. Therefore the magnitude of this effect was computed for the 1937 light curve with LUYTEN's value for e and the values for k, a and i as found in the previous section. The result was that primary minimum should last ${}^{P}\!\cdot 034$ longer than secondary minimum. The light curve in Figure 7 certainly excludes so great a difference, although there is an indication that primary minimum might last longer than secondary minimum by an amount of not more than ${}^{P}\!\cdot 01$, corresponding to an eccentricity of not more than ·026. It should be borne in mind that determination of $e\sin\omega$ from the difference between the widths of the two minima is far inferior to the determination of $e\cos\omega$ from the times of mid-minimum.

The author considers it very probable that the value found spectroscopically for e is too high and mainly due to systematic errors in the radial velocities. Miss MAURY [1] states that the lines in the spectrum of V Pup are wide and hazy and sometimes asymmetrical and liable to cause systematic errors in the measures. Effects of this nature are since long held responsible for the clustering of the values for ω in spectroscopic orbits with moderate eccentricity round $\omega = 90^\circ$ [2]. Therefore in the following section the orbit has been considered to be circular and the question of rotation of periastron was accordingly dropped.

9. *Differential improvement of orbit by least squares.*

As the differences between the observed and the computed light curve show something of a systematic nature, an attempt was made to improve the solution for k, a and i by the method of least squares. The set of values already found for these three unknowns was made the starting point for differential corrections dk, da, di, which are connected with the difference in intensity observed minus computed by the following equations of condition:

$$d\alpha = \frac{\partial\alpha}{\partial k}\cdot dk + \frac{\partial\alpha}{\partial\delta}\,\frac{\sqrt{\cos^2 i + \sin^2 i \sin^2 \vartheta}}{\sqrt{E}}\cdot da - \frac{\partial\alpha}{\partial\delta}\,\frac{a \sin 2i \cos^2\vartheta}{2\sqrt{E}\,\sqrt{\cos^2 i + \sin^2 i \sin^2\vartheta}}\cdot di$$

In this equation α denotes the fraction of the smaller disc obscured by the bigger one, δ the projected distance between the centres of the two components, and $E = 1 - \varepsilon^2 \sin^2 i \cos^2\vartheta = 1 - \cdot 2766 \cos^2\vartheta$.

The 39 plates nearest in phase to principal and secondary minimum have been made the basis of the least squares solution. For each plate the value $d\alpha$ was computed. The values for $\frac{\partial\alpha}{\partial k}$ and $\frac{\partial\alpha}{\partial\delta}$ have been taken from the table $\alpha = f\,(k, \delta)$ computed by M. WEND [3], which is very convenient for this purpose. The normal equations resulting from the 39 equations of condition are:

$$+\,1\cdot 8022\ dk - \cdot 10209\ da - 4\cdot 9597\ di = +\,\cdot 058214$$
$$-\,\cdot 10209\ dk + 1\cdot 657818\ da - 6\cdot 28456\ di = -\,\cdot 0104719$$
$$-\,4\cdot 9597\ dk - 6\cdot 28456\ da + 39\cdot 9091\ di = -\,\cdot 116812$$

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[1] L.c.

[2] L.c.

[3] Cf. UITTERDIJK, *B.A.N.* No. 237.

[1] L.c.

[2] Cf. HELLERICH, *A.N.* **216**, p. 277; STRUVE and POGO, *A.N.* **234**, p. 297.

[3] *Eine Tafel zur Theorie der Bedeckungsveränderlichen*, Dissertation Leipzig, 1931.

From these equations the following corrections to the elements were found:

$$\begin{aligned} dk &= + \cdot 297 \pm \cdot 162 \\ da &= + \cdot 349 \pm \cdot 215 \\ di &= + \cdot 089 \pm \cdot 054 = + 5^{\circ}\cdot 10 \pm 3^{\circ}\cdot 09 \end{aligned}$$

The very great mean errors of these corrections fully confirm the view that a type of light curve as that of V Pup does not permit a sharp determination of k. A new light curve computed with the corrected elements indeed gave a better representation of the observations, but the improvement is small, the mean error decreasing by only 9 percent. After application of the correction dk the new value for k would become: $k = 1{\cdot}28$. With the ratio of the surface brightnesses $\frac{J_{B1}}{J_{B3}} = 1{\cdot}3616$ already found, this new value for k would yield the ratio of the intensities of the two components: $\frac{I_{B3}}{I_{B1}} = \frac{k^2}{1{\cdot}3616} = 1{\cdot}20$, in complete disagreement with the value ·70 found by Miss MAURY from estimates of the relative strengths of the two components, even reversing the position of stronger and weaker component. Such a great deviation from Miss MAURY's value is impossible and nothing seems to be left but admitting that the set of values found under **6** is about the best set of elements satisfying all the observations, including Miss MAURY's observations of the relative strengths of the two spectra.

Although in this case the least squares solution has apparently not brought us any further as to orbit improvement, one thing is gained by it: a quantitative determination of the uncertainty in the elements.

10. *Reflection and darkening towards the limb.*

If we apply EDDINGTON's formula 1) to both components, the effect of reflection on the luminosity of an eclipsing variable may be expressed by

$$(b_1 - b_2) \cos \psi + \frac{16}{9\pi^2} (b_1 + b_2) \cos 2\psi,$$

in which formula the phase angle ψ is connected to the anomaly ϑ by: $\cos \psi = \sin i \cos \vartheta$.

The effect of the first term is that the maxima are made asymmetrical, except when $b_1 = b_2$. The second term does not disturb the maximum's symmetry but makes it flatter, in this way working in opposite direction to the effect from tidal elongation of the components. Consequently the value for $\varepsilon^2 \sin^2 i$ determined by the usual procedure under **5** will need a positive correction. The amount of this correction is $\cdot 36\ (b_1 + b_2)$. Inspection of the light curves in Figures 4 and 6 shows the maxima to have little or no asymmetry, so that not much reflection effect can be expected. With the values found for k, a, i and $\frac{J_1}{J_2}$ EDDINGTON's formula would predict a value $b_1 - b_2 = + \cdot 0078$. The residuals of column 10, Table 2, outside eclipse, have been analysed for presence of a term $(b_1 - b_2) \cos \psi$. The value found was:

$$b_1 - b_2 = + \cdot 0005 \pm \cdot 0030.$$

As $\frac{b_1}{b_2} = \frac{J_1}{J_2} = 1{\cdot}3616$, the coefficient of the term with $\cos 2\psi$ becomes: $+ \cdot 0012 \pm \cdot 007$. This correction is too small and too unreliable to consider it for improvement of the value found for $\varepsilon^2 \sin^2 i$. Consequently the reflection has been completely disregarded.

Nor is the case of V Pup favorable for showing effects from darkening at the limb. According to MILNE 1) the darkening is a function of λT. Taking the temperature of V Pup as 20000° and that of the sun as 5600°, we find that the darkening in V Pup for the wavelength used, viz. 5604 Å, should be the same as in the sun for wavelength 20000 Å. This is already outside the range of wavelengths that has been chosen by MOLL, BURGER and VAN DER BILT 2) for measuring the intensity of radiation across the sun's disc. The effect of darkening towards the limb upon the computed brightnesses found from the same elements by extrapolation from the figures obtained by MOLL, BURGER and VAN DER BILT is only small. The brightness during eclipse is slightly increased near the beginning and end, and decreased near mid-eclipse as compared with the non-darkened curve.

For the inverse problem, i.e. to find the law of darkening, c.q. the coefficient of darkening if the cosine law is accepted, the present light curve is insufficient. As has been remarked by PANNEKOEK and Miss VAN DIEN 3) the major part of the effect of darkening upon the light curve is taken up by small adjustments of k, a and i. In order to find the darkening much more accurate observations are required, preferably simultaneously in different wavelengths 4) so that the effect may be found differentially. Even so V Pup will not be a favorable case; a variable like Castor C with about equal components of small size with respect to the orbit and of low temperature is much better suited to show effects from darkening.

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1) *Mon. Not.* **86**, p. 322.

1) *Phil. Trans. A.* **223**, p. 201.

2) *B.A.N.* No. 91.

3) *B.A.N.* No. 297.

4) Cf. KRAT, *Zs. f. Ap.* **11**, p. 71; ROSENBERG, *Ap. J.* **83**, p. 67; HELLERICH, *Bergedorf Mitt.* **7**, p. 179.

11. *Dynamical parallax and absolute dimensions.*

As is well known the mass-luminosity relation permits the calculation of the absolute magnitude of an eclipsing binary from its light curve and the spectral type of one component [1]. The procedure consists in computing the surface brightnesses of both components with the aid of the spectral type of one of them and the ratio of the surface brightnesses as derived from the light curve, and then selecting the dimensions of the system in such a way that the absolute luminosities resulting from size and surface brightness, and the total mass calculated by KEPLER's third law from orbital radius and period fit the mass-luminosity relation. Comparison between the absolute magnitudes thus found for both components and their apparent magnitudes will yield the parallax.

Neglecting the absorption, we find in this way for V Puppis:

$$p = +\,''{\cdot}0028,$$

corresponding to:

a = ·0744 astronomical units
Mass B1 component = 15·3 ⊙
Mass B3 component = 11·1 ⊙
M_{vis} B1 component = −2·67
M_{vis} B3 component = −2·29

With the aid of the spectroscopic observations a direct and much more reliable determination of orbital radius and masses was made, its result being:

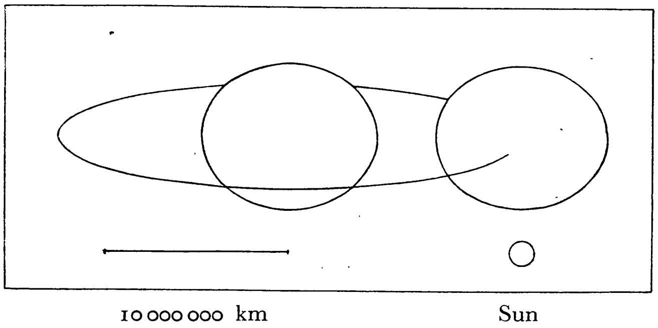
a = ·0830 astronomical units
Mass B1 component = 21·18 ⊙
Mass B3 component = 14·91 ⊙

The corresponding absolute magnitudes can now be derived either by means of the mass-luminosity relation [2] or by means of the relation between spectral type and surface brightness, the result for the brighter component being $-\,3^{M}{\cdot}31$ and $-\,2^{M}{\cdot}91$ respectively or $^{M}{\cdot}64$ and $^{M}{\cdot}24$ brighter than as determined before.

The data obtained for V Puppis may now be summed up in the following list. For the absolute magnitudes and the parallax the mean was taken of the two sets of results obtained with the use of the spectroscopic data.

Epoch of principal minimum	J.D. $2428648^{d}{\cdot}3048$	$\pm\,^{d}{\cdot}0007$
Period	1·4544867	± ·0000002
Brightness at maximum	$4^{m}{\cdot}44$	
Brightness at principal minimum	$5^{m}{\cdot}04$	
Brightness at secondary minimum	$4^{m}{\cdot}91$	
Ratio of surface brightnesses $\frac{J_{B1}}{J_{B3}}$	1·36	± ·03
Ellipticity constant $\varepsilon^2 \sin^2 i$	·2766	± ·0146
Ratio of radii k	·98	
Light of brighter component	·59	
Inclination of orbit i	76°·89	
Oblateness of equatorial section $\sqrt{1-\varepsilon^2}$	·83	
Oblateness of meridional section	·78	
Orbital radius a	12 400 000 km =	17·84 $r_\odot$
Longest radius of B1 component	4 735 000 km =	6·81 $r_\odot$
Longest radius of B3 component	4 640 000 km =	6·67 $r_\odot$
Mass of B1 component	21·18 ⊙	
Mass of B3 component	14·91 ⊙	
Density of B1 component	·105 $\rho_\odot$	
Density of B3 component	·079 $\rho_\odot$	
Mean absolute magnitude of B1 component	− 3·11	
Mean absolute magnitude of B3 component	− 2·73	
Dynamical parallax	″·0023	

FIGURE 8.



A drawing of the system is given in Figure 8.

I am indebted to the late Mr. A. STANLEY WILLIAMS for information about the discovery of variability and early observations of V Pup; to Prof. R. PRAGER for kindly sending me a résumé of the literature on V Pup in advance of publication in the next volume of *Geschichte und Literatur des Lichtwechsels der veränderlichen Sterne* and to Mr. F. DE HAAS for preparing the drawings for the diagrams in this paper.

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[1] Cf. S. GAPOSCHKIN, *Harv. Repr.* No. 151.
[2] Cf. G. DURAND, *Bull. Astr.* **11**, p. 137.