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COMMUNICATION FROM THE OBSERVATORY AT LEIDEN

Photographic photometry of the eclipsing variable WW Draconis = Σ 2092 A,

by *L. Plaut*.

From observations on plates taken with the 1-inch Cooke and 16-inch Metcalf cameras of the Harvard College Observatory Miss HARWOOD found that the southern component A of the visual binary Σ 2092 (B.D. + 60° 1691, $8^{m}\cdot2$ = H.D. 150708, G5) is an eclipsing variable and gave a period of $3^{d}\cdot501$ (*Harv. Circ.* No. 194, 1916; *A.N.* **207**, 217, 1918). The magnitude of the combined light of both visual components was found to vary from $8^{m}\cdot5$ to $9^{m}\cdot1$. To this star the name WW Draconis has been given in the 21st "Benennungsliste" (*A.N.* **224**, 129, 1925).

The observations of the position angle and distance of the visual binary Σ 2092 have been collected in Table 1. The fourth and fifth columns give the estimated visual magnitudes of the components, with the exception of the eighth line of these columns, where the photographic magnitudes of the Astrographic Catalogue are given. No relative motion of the two components has been observed. The proper motion of component A is given as follows in B. Boss' General Catalogue:

$$\mu_\alpha = +{}^{s}\cdot0017, \quad \mu_\delta = -\,''\cdot065$$
$$\pm \quad 9, \qquad \pm \quad 4 \quad \text{(m.e.)}$$

It is probable that the two stars form a physical pair.

Since the announcement of the variability of WW Draconis by Miss HARWOOD the following has been published about this star:

GRAFF (*V.J.S.* **63**, 164, 1928) mentions that he has measured the magnitudes of a sequence of comparison stars.

KUKARKIN (*N.N.V.S.* **1**, No. 12, 1929), PARENAGO (*N.N.V.S.* **3**, No. 25-6, 1930), HOFFMEISTER (*Sonneberg Mitt.* No. 20, 18, 1931), KANAMORI (*Kyoto Bull.* No. 247, 1933) and BEYER (*G.u.L.* II, 2, 90, 1934) give notes on small numbers of unpublished visual estimates.

ZVEREV (*N.N.V.S.* **4**, No. 43, 1933 and **5**, No. 52, 1937) found that the period $3^{d}\cdot501$ is erroneous. He derives the new elements: Min. I = J.D. 2427344·447 + $4^{d}\cdot62963$ E, visual maximum brightness $8^{m}\cdot84$, range of the primary minimum = ${}^{m}\cdot74$, of the

TABLE 1.

Double star measurements of Σ 2092 = A.D.S. 10152.

epoch	p	d	m_A	m_B	n	authority
	°	″	m	m		
1831·10	5·9	8·04	7·7	8·8	3*n*	STRUVE, *Mensurae micrometricae*, p. 158 (1837).
1845·60	5·7	8·44	—	—	1*n*	MÄDLER, *Untersuchungen über die Fixsternsysteme*, I, 56 (1847).
1866·20	5·7	7·96	8·0	9·0	3*n*	DEMBOWSKI, *Misure micrometriche*, **2**, 379 (1884).
1872·9	6·0	8·64	8·7	9·3	2	*A. G. Katalog, Helsingfors*, Nr. 8924-5 (1890).
1878·42	5·2	8·18	—	—	1*n*	BURNHAM, *Mem. R.A.S.* **44**, 210 (1879).
1879·29	4·0	8·06	8·3	8·5	1*n*	BURNHAM, *Mem. R.A.S.* **47**, 290 (1882).
1883·22	5·7	8·03	—	—	2	SEAGRAVE, *Sidereal Messenger*, **2**, 275 (1883).
1902·52	7·7	8·15	8·6	9·5	2*n*	*Cat. Astrografico Sez. Vaticana*, App. III, 60° 26322-3, 61° 25985-6 (1926).
1903·57	2·8	8·49	7·8	8·4	3*n*	ESPIN, *M.N.* **64**, 677 (1904).
1905·15	5·0	8·25	—	—	2*n*	BURNHAM, *Double Star Catalogue* II, 724 (1906).
1915·39	3·8	8·26	—	—	3*n*	FRANKS, *M.N.* **76**, 32 (1915).
1923·83	4·6	8·07	—	—	4*n*	PEEK, *M.N.* **87**, 171 (1926).
1937·63	5·11	8·235	—	—	2*pl*	HERTZSPRUNG, *B.A.N.* No. 330 (1940).

secondary = $^{m}\cdot 14$?, duration of the primary minimum $^{P}\cdot 08$, and of totality $^{P}\cdot 02$.

As mentioned in the Annual Report of the Mt. Wilson Observatory 1937-8 and in the Draft Report of the I.A.U. 1938, p. 240, observations of the radial velocity are or will be made at the Mt. Wilson Observatory.

Miss HARWOOD and Messrs ZVEREV, JOY, HOFFMEISTER, BEYER and KANAMORI have been so kind to send me their unpublished observations. The dates of eleven minima out of 312 measurements by Miss HARWOOD on Harvard plates, and of two minima out of the visual estimates of HOFFMEISTER and BEYER are given in Table 11.

ZVEREV of the Sternberg Observatory at Moscow made 148 visual estimates, 39 of which were made with a magnification great enough to separate the two components. The magnitudes of the six comparison stars were determined by a comparison with the North Polar Sequence by the aid of a Graff photometer. The amplitude of the primary minimum is $^{m}\cdot 65$, while that of the secondary could not be determined accurately. The minimum epochs deduced from this material together with an additional one found by ZVEREV on an older Moscow plate are given in Table 11.

Photographic observations of WW Draconis have been made with the Leiden photographic refractor (a = 32 cm, f = 524 cm) during three oppositions, viz. from 1934 April 2 to 1936 September 14. In total 5882 photographic exposures (14 by Prof. ZAGAR, 729 by Dr. WESSELINK, 5139 by the writer) have been made on 268 plates in 117 nights. Furthermore 18 photovisual exposures on 6 plates in 5 nights should determine the difference in colour index between the visual components. These exposures were taken on Eisenberger Ultrarapid and Voigtländer Illustra plates combined with a yellow screen OG1 of Schott und Gen. at Jena.

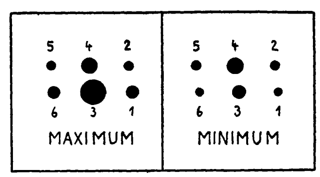
The photographic observations have been made on Guilleminot La Superguil plates, size 9 × 12 cm. These plates are extremely fast but have a large grain and often an irregular plate fog. Unfortunately the plates received before and after July 1935 have a different colour sensitivity. The sensitivity curves for the two different emulsions, called GLS 1934 and GLS 1936, are given by WESSELINK in *B.A.N.* No. 294, 1937. The later plates proved to be sensitized at longer wavelengths.

It was the intention to make two or three series of 10 exposures on each plate. In many cases clouds or moonshine did not allow this. Exposures which have been disturbed by clouds have not been measured. Mostly the exposure time was 75 or 90 seconds. In the case of poor transparency and during minimum longer exposures up to 225 seconds were taken. The total time of exposure is 531285 seconds or a little more than six days. The plates have been taken two millimetres inside the photographic focus. A coarse grating with d = l = 3·8 mm made of stainless steel has been put in front of the objective with the bars perpendicular to the declination circles. A schematic image of exposures at maximum and at minimum is given in Figure 1. The plates have been developed for 8 minutes in Agfa Rodinal 1:20 at a temperature of 18° C.

From the distance of the two first order images the effective wavelength of the exposures has been determined to be 4270 A.

The plates have been measured with the second Schilt photometer of the Leiden Observatory. A diaphragm of 5 mm or ·14 mm as projected on the plate has been used. The B component has been used as the only comparison star. The variable component is photographically brighter than this star in maximum and fainter in minimum. The use of a comparison star which is situated close to the variable has many advantages (compare WESSELINK, *Leiden Ann.* XVII, 3), but in the case of WW Draconis the distance of both stars is only 8″ or ·2 mm on the plate. Systematic errors may be caused by this fact. The images have been measured in the order indicated in Figure 1. The galvanometer readings of the central images and the means of those of the first order images

FIGURE 1.



have been converted into provisional magnitudes by the aid of a table like that described by WESSELINK (*B.A.N.* No. 318, 1939, see also *B.A.N.* No. 190, 1930). To these provisional magnitudes the "parabola" method of HERTZSPRUNG (*A.N.* **190**, 121, 1911) has been applied in order to obtain the difference $m_A - m_B$. Preliminarily a value of 1^{m} has been used for the difference in magnitude between the central and the first order images. The use of this method for this kind of observations is justified by the investigations of WESSELINK (l.c.). Means of about ten values $m_A - m_B$ have been derived from exposures taken after each other on one plate. The use of these means is allowed on account of the practically linear variation in brightness during the time of taking ten exposures. All data concerning such a mean $m_A - m_B$ were written on a card. An example of such a card is given here:

3536b	10	P	75	
8235·6862	·9107	·9261	·4910	
2·53	1·19	15·8	8	14·3
— ·703	± ·044	— ·678		
full moon				

N	A	O	T	
JD	P_1	P_2	P_3	
D	G	St	S	F
Δm_1	m.e.	Δm_2		
remarks				

N = number of the plate and letter of the mean,
A = number of exposures contained in this mean,
O = name of the observer,
T = exposure time in seconds,
JD = heliocentric Julian Day mean astronomical time Greenwich — 2420000,
P_1 = preliminary phase = $^{d-1}$·2160003 (J.D. — 2420000),
P_2 = definitive phase = $^{d-1}$·21600217 (J.D. — 2420000),
P_3 = definitive phase counted from primary minimum,
D = photographic density, defined as the provisional magnitude of the central image of the comparison star,
G = gradation, defined as the mean from both stars of the difference in provisional magnitudes between the central and the first order images (G = 1 if the gradation is the same as that of the table of provisional magnitudes),
St = local sidereal time,
S = sharpness of the images, defined as the sum of three estimates in a scale 1, 2, . . ., 14 of very diffuse to very sharp images obtained by variation of focus,
F = plate fog, defined as the galvanometer reading in cm in measuring the plate fog, with a galvanometer deflection of 25 cm without a plate in the photometer,
Δm_1 = mean of m_A — m_B computed with 1^m preliminary difference in magnitude between the central and the first order images,
m.e. = internal mean error of one exposure as derived from all exposures of a plate,
Δm_2 = definitive difference in magnitude $m_A - m_B$.

It is easy to examine the accidental and systematical errors by filing these cards successively according to the different quantities. In total there are 581 cards. The observations are distributed in phase as follows:

maximum ($P_1 = {}^{P}$·46—^{P}·85, ^{P}·96—^{P}·35): 326 Δm_1's
primary minimum ($P_1 = {}^{P}$·35—^{P}·46) : 170 „
secondary minimum ($P_1 = {}^{P}$·85—^{P}·96) : 85 „

In the further discussion only the means Δm_1 mentioned above will be used and they will be referred to as observations. From the differences in Δm_1 of observations following each other in phase P_1 the following quantities have been derived:

The square of the mean error of one observation
1°. from all differences (practically all are derived from observations in different nights)

for the maximum	$^{m^2}$·000653 = (± ^{m}·026)^2	from 326 differences,
for the primary minimum	·000716 = (± ·027)^2	„ 170 „
for the secondary minimum	·000617 = (± ·025)^2	„ 85 „

2°. from differences between observations during one night

for the maximum	·000170 = (± ·013)^2	„ 247 „

3°. from differences between observations on one plate

for the maximum	·000171 = (± ·013)^2	„ 183 „ .

The error common to all observations of one night or one plate may be called "night error" respectively "plate error". These errors and the internal error have been derived from the above quantities:

the square of the mean night error	$^{m^2}$·000483 = (± ^{m}·022)^2,
„ „ „ „ „ plate „	·000000 = (± ·000)^2,
„ „ „ „ „ internal „	·000170 = (± ·013)^2.

With the aim of determining systematic errors the 326 cards containing observations at maximum have been filed successively according to the quantities JD, D, G, St, S and F. For each separate arrangement of the cards means have been computed of about twenty observations which follow each other respectively in JD, D, etc. The means are given in Tables 2 to 7. The columns of these tables give successively: the means of JD, D, etc.; the mean of Δm_1, called $\overline{\Delta m_1}$; the number n of Δm_1's; the mean "internal mean error" derived from the dispersion of the individual exposures (within one mean Δm_1); the mean error of $\overline{\Delta m_1}$ derived from the dispersion of the Δm_1 within one $\overline{\Delta m_1}$; the mean gradation G; the mean of the definitive magnitudes $\overline{\Delta m_2}$ derived as described below, and the mean error of $\overline{\Delta m_2}$.

In order to obtain some more data about the systematic errors ten series of exposures (at maximum)

TABLE 2.

Dependence of Δm_1 on the Julian Day.

JD	$\overline{\Delta m_1}$	n	m.e.	m.e. $(\overline{\Delta m_1})$	G	$\overline{\Delta m_2}$	m.e. $(\overline{\Delta m_2})$
	m		m	m		m	m
7532	—·870	14	±·043	±·006	1·10	—·831	±·005
7579	·873	16	45	8	1·12	·836	7
7627	·870	17	39	3	1·21	·840	7
7688	·847	22	42	4	1·26	·823	4
7825	·854	13	41	6	1·06	·812	5
7871	·857	28	41	3	1·25	·831	4
7918	·838	30	40	4	1·43	·828	3
8067	·827	8	48	14	1·37	·812	15
8210	·860	36	33	3	1·26	·835	2
8245	·824	32	38	3	1·52	·822	3
8270	·839	31	38	4	1·38	·824	3
8308	·817	31	44	6	1·48	·812	7
8341	·808	27	47	7	1·54	·807	4
8403	·838	21	50	4	1·53	·836	4

TABLE 3.

Dependence of Δm_1 on the photographic density.

D	$\overline{\Delta m_1}$	n	m.e.	m.e. $(\overline{\Delta m_1})$	G	$\overline{\Delta m_2}$	m.e. $(\overline{\Delta m_2})$
	m		m	m		m	m
1·40	—·861	20	±·033	±·004	1·26	—·836	±·004
1·60	·870	20	37	5	1·28	·846	3
1·74	·836	20	41	9	1·36	·820	6
1·85	·850	20	36	5	1·34	·830	5
1·91	·856	20	39	7	1·26	·831	5
1·97	·838	20	39	6	1·38	·824	5
2·04	·849	20	37	8	1·32	·831	5
2·10	·842	20	39	5	1·38	·826	6
2·17	·835	20	43	8	1·34	·817	6
2·25	·835	20	41	5	1·42	·823	4
2·33	·815	20	42	4	1·48	·811	5
2·42	·826	20	43	6	1·38	·812	6
2·49	·840	20	49	9	1·36	·815	7
2·57	·841	20	48	7	1·45	·832	6
2·70	·837	20	44	5	1·33	·819	5
2·94	·849	26	45	3	1·30	·828	3

TABLE 4.

Dependence of Δm_1 on the gradation.

G	$\overline{\Delta m_1}$	n	m.e.	m.e. $(\overline{\Delta m_1})$		$\overline{\Delta m_2}$	m.e. $(\overline{\Delta m_2})$
	m		m	m		m	m
1·00	—·868	20	±·043	±·005		—·822	±·005
1·09	·863	20	43	6		·826	6
1·15	·864	20	45	5		·829	5
1·20	·859	20	39	6		·828	6
1·23	·847	20	40	6		·820	6
1·27	·859	20	41	4		·835	4
1·29	·855	20	34	5		·833	4
1·32	·840	20	36	7		·820	7
1·36	·835	20	36	7		·824	8
1·40	·841	20	44	6		·830	6
1·44	·827	20	43	5		·817	5
1·48	·825	20	49	7		·819	7
1·52	·827	20	46	7		·824	7
1·55	·828	20	41	4		·827	4
1·59	·834	20	39	4		·837	4
1·65	·811	26	40	4		·819	4

TABLE 5.

Dependence of Δm_1 on the sidereal time.

St	$\overline{\Delta m_1}$	n	m.e.	m.e. $(\overline{\Delta m_1})$	G	$\overline{\Delta m_2}$	m.e. $(\overline{\Delta m_2})$
h	m		m	m		m	m
11·10	—·845	20	±·041	±·005	1·26	—·820	±·005
12·06	·847	20	38	6	1·35	·831	4
12·72	·853	20	41	5	1·28	·829	3
13·29	·847	20	44	5	1·30	·828	4
13·75	·835	20	37	6	1·38	·821	6
14·13	·843	20	38	6	1·33	·824	6
14·44	·849	20	38	5	1·34	·832	4
14·80	·848	20	39	6	1·34	·831	4
15·26	·852	20	36	6	1·34	·833	5
15·91	·846	20	37	7	1·39	·828	4
16·64	·833	20	45	9	1·37	·819	7
17·44	·816	20	46	10	1·46	·809	8
18·35	·828	20	44	9	1·39	·810	6
19·24	·838	20	42	6	1·41	·828	6
20·06	·844	20	44	7	1·36	·828	5
21·96	·848	26	47	4	1·32	·828	5

TABLE 6.

Dependence of Δm_1 on the sharpness of the images.

S	$\overline{\Delta m_1}$	n	m.e.	m.e. $(\overline{\Delta m_1})$	G	$\overline{\Delta m_2}$	m.e. $(\overline{\Delta m_2})$
	m		m	m		m	m
6·8	—·820	12	±·044	±·009	1·38	—·806	±·009
9·0	·827	19	34	5	1·42	·816	3
10·0	·829	13	41	7	1·45	·820	6
11·0	·826	21	41	5	1·52	·824	5
12·0	·828	39	39	4	1·40	·816	4
13·0	·846	26	42	5	1·33	·828	4
14·0	·822	33	46	6	1·43	·812	4
15·0	·837	13	42	6	1·45	·828	5
16·0	·853	22	37	4	1·30	·832	4
17·0	·863	20	39	6	1·34	·844	5
18·0	·863	17	42	6	1·40	·849	5
19·5	·846	20	41	6	1·34	·828	5
21·6	·864	16	42	7	1·25	·838	6
23·3	·840	16	42	8	1·22	·812	8
25·9	·866	15	40	4	1·22	·838	8
29·2	·863	11	50	8	1·28	·840	7
33·8	·859	13	46	9	1·04	·815	7

TABLE 7.

Dependence of Δm_1 on the plate fog.

F	$\overline{\Delta m_1}$	n	m.e.	m.e. $(\overline{\Delta m_1})$	G	$\overline{\Delta m_2}$	m.e. $(\overline{\Delta m_2})$
	m		m	m		m	m
7·48	—·856	20	±·044	±·004	1·08	—·816	±·003
9·50	·855	20	48	8	1·24	·827	7
10·36	·839	20	41	8	1·40	·826	5
11·40	·858	20	44	7	1·32	·838	5
12·11	·845	20	48	4	1·41	·833	3
12·62	·834	20	47	8	1·36	·818	7
13·20	·844	20	43	8	1·34	·826	7
13·83	·842	20	40	7	1·28	·819	7
14·22	·859	20	37	5	1·24	·831	5
14·50	·832	20	38	6	1·38	·822	5
14·75	·839	20	43	7	1·36	·819	6
14·93	·820	20	41	7	1·50	·815	5
15·31	·843	20	35	5	1·40	·829	3
15·80	·832	20	33	4	1·46	·824	4
16·30	·839	20	35	5	1·41	·827	5
17·40	·840	26	41	6	1·43	·830	5

TABLE 8.

Further measurements of ten series of observations.

$(\Delta m_1)_S$	$(\Delta m_1)_H$	$(\Delta m_1)_H - (\Delta m_1)_S$	G_S	G_H	G WW Dra	G Comp. B	G a	G b	G c	S	1—6	2—5	1—2 6—5	3—4
m	m	m												
—·939	—·849	+·090	·91	10·15	·92	·89	·89	·90	·94	36	590	591	207	209
·903	·869	+ 34	1·11	11·25	1·11	1·12	1·12	1·10	1·18	31	592	586	207	206
·837	·825	+ 12	1·16	9·60	1·22	1·10	1·14	1·11	1·16	16	591	589	208	212
·847	·870	— 23	1·28	9·30	1·29	1·27	1·21	1·23	1·20	13	589	586	205	202
·801	·781	+ 20	1·32	11·25	1·35	1·29	1·24	1·19	1·26	20	590	588	196	200
·772	·810	— 38	1·37	9·00	1·45	1·29	1·26	1·15	1·41	6	583	594	200	207
·811	·859	— 48	1·45	9·85	1·50	1·40	1·40	1·29	1·42	11	588	582	197	201
·777	·810	— 33	1·52	9·65	1·64	1·40	1·37	1·28	1·61	7	589	589	196	200
·819	·890	— 71	1·60	9·80	1·77	1·43	1·46	1·42	1·70	13	587	592	197	201
·760	·822	— 62	1·72	10·60	1·80	1·64	1·50	1·49	1·69	12	589	598	200	205

covering the whole range of gradation have been measured with the Hartmann photometer. The results are given in Table 8. Columns 1 and 2 give Δm_1 from the Schilt and the Hartmann photometer, column 3 the difference of both measurements, columns 4 and 5 the mean gradation for WW Draconis and component B (the gradation for Hartmann measurements is defined as the difference in wedge reading between the central and the first order images), columns 6 to 10 the Schilt gradation from measurements of different stars, viz. WW Draconis (spectrum G5), component B (colour index $= +{}^{m}{\cdot}68 \pm {}^{m}{\cdot}02$, as found by the aid of photovisual plates), star a = BD + 61°1600, $9^{m}{\cdot}1$ (colour index $= +{}^{m}{\cdot}35 \pm {}^{m}{\cdot}03$), star b = BD + 61°1603, $9^{m}{\cdot}3$ (colour index $= 1^{m}{\cdot}06 \pm {}^{m}{\cdot}03$) and star c = TX Draconis = BD + 60°1688, $7^{m}{\cdot}0$ (spectrum Mb); column 11 gives the sharpness S of the images. The results of measurements with the Toepfer measuring machine of the distances between the different images of the same exposure are given in columns 12 to 15 for the same series of exposures. The columns contain the distances in μ between the images 1—6 (see Figure 1), 2—5, mean of 1—2 and 6—5, and 3—4. The distances 1—6 and 2—5 are proportional to the effective wavelength.

The following features may be derived from Tables 2 to 8:

1. There is a dependence of Δm_1 on the sharpness S of the images. The (absolute) difference in magnitude between both stars is constant for $S > 20$ or sharp images and decreases for smaller S or more diffuse images. In the case of diffuse images especially the central image of the variable (number 3 in Figure 1) becomes so large that it may influence the measurement of neighbouring images, in this case of image 4. Then this image will be measured too bright and the (absolute) difference in magnitude becomes smaller. The influence of the first order images on each other may be supposed to be smaller. If this explanation is right there should be no dependence of Δm on the sharpness of the images if two stars are considered which have a larger distance on the plate.

2. Δm_1 depends linearly on the gradation G. A least squares solution yields:

$$\Delta m_1 = -{}^{m}{\cdot}8424 + {}^{m}{\cdot}085\ (G - 1{\cdot}35)$$
$$\pm 17 \qquad \pm 9 \qquad \text{(m.e.)}$$

The absolute difference in magnitude between both stars increases with decreasing gradation. This effect was also found by WESSELINK (*Leiden Ann.* XVII, 3) from similar observations of SZ Camelopardalis = Σ 485 A. A discussion of observations of SX Aurigae made by OOSTERHOFF and measured by KOOREMAN (*B.A.N.* No. 250, 1933) reveals the same effect. The following values have been found for the coefficient K in the formula

$$\Delta m_2 = \Delta m_1 + K\, \Delta m_1\ (G - \text{const})$$

	K	m.e.	spectra of both stars		mean gradation and dispersion	mean $\lvert\Delta m_1\rvert$
SX Aurigae	— ·31	± ·10	A3	B0	·92 ± ·11	${}^{m}{\cdot}78$
SZ Camelopardalis	— ·080	± ·028	B0	B0	1·05 ± ·13	·12
WW Draconis	— ·101	± ·011	G5	G0:	1·35 ± ·18	·84

3. Relations between the gradation and the other quantities.

a. The gradation of Guilleminot La Superguil plates increased steadily from 1·10 at J.D. 2427500 to 1·55 at J.D. 2428400.

b. Further, least squares solutions yield:

gradation = 1·357—·0130 (sharpness—16)
± 16 ± 22 (m.e.)

WESSELINK (*Dissertation*, Leiden 1938) gave an explanation of this effect and of the effect described above under 2. If the images are sharp many silver grains fall upon each other, while in the case of diffuse images they are spread out so that the density of these images as measured with the Schilt photometer is larger than that of sharp images caused by the same amount of light. This applies only to the central images, because the first order images in any case are more diffuse. Thus the gradation increases for diffuse images and the measured difference in magnitude between two stars decreases. Later WESSELINK did not maintain this explanation (*Leiden Ann.* XVII, 3).

c. Gradation = 1·340 + ·00062 (density—2·00)
± 15 ± 37 (m.e.)

The independence of the gradation on the density (as defined here) shows that the table of provisional magnitudes gives a good approximation of a mean opacity curve.

d. Gradation = 1·403 — ·019 × hour angle
± 22 ± 6 (m.e.)

If real this relation means that the images are sharper at larger distances from the zenith in contradiction to what may be expected.

e. Gradation = 1·328 + ·027 (plate fog—12·5)
± 19 ± 8 (m.e.)

Similar relations have been found by ROSS (*The Physics of the Developed Photographic Image*, p. 118-9, 1924) and by EBERHARD (*Publ. Potsdam*, Nr. 84, 43, 1926).

4. The dependence of Δm_1 on the other quantities may be accounted for by the above dependences of Δm_1 on G and of G on those other quantities.

5. The value of Δm_1 as a result of Hartmann measurements does not depend on G_{Schilt} or on G_{Hartmann}, whereas G_{Hartmann} is larger for sharp than for diffuse images. This latter fact has been mentioned by ROSS (l.c., p. 133).

6. There is no dependence of the gradation on the colour of the star.

7. The effective wavelength is the same for variable and comparison star and does not depend on the sharpness of the images.

8. The distances between the images 1 and 2, 3 and 4, 6 and 5 (see Figure 1) are measured larger in the case of very diffuse images. It cannot be decided whether this is a photographic or a physiological effect.

Preliminarily the difference in magnitude, Δm_1, has been corrected for the dependence on the sharpness S of the images mentioned above under 1. The corrections are given in Table 9. They reduce the observations to the case of sharp images as it ought to be if the explanation of the effect given under 1 is right. A least squares solution of the corrected magnitudes Δm_1 and the gradation gives:

$$\Delta m_1 = -\,^{m}\!\cdot\!8580 + \,^{m}\!\cdot\!060\ (\text{gradation}-1\cdot35)$$
$$\pm 18 \qquad \pm 10 \qquad (\text{m.e.})$$

TABLE 9.

Preliminary correction to Δm_1.

S	correction	S	correction
6	—^{m}·047	14	—^{m}·018
7	43	15	15
8	40	16	12
9	36	17	08
10	33	18	04
11	29	19	01
12	26	20–36	00
13	22		

The fact that there remains a dependence on the gradation after the corrections of Table 9 have been applied speaks for WESSELINK's explanation of the gradation effect (see No. 3 above). Further facts supporting this explanation are 1st) the gradation effect found from other observations, where the two stars considered are at a larger distance on the plate, 2nd) the variation of the gradation in the same way for other, single, stars on the plates of WW Draconis, 3rd) the existence of the gradation effect also for very sharp images, and 4th) the independence, as shown below, of the Δm_2, corrected for the gradation effect, on any one of the other quantities. Therefore the preliminary correction for different sharpness has not been applied in the final reduction.

With the assumption of this explanation Δm_1 must be reduced to that gradation for which the difference in magnitude between the central and the first order images has been determined. The fact that this reduction differs from that for the effect of the sharpness of the images is important, because the amplitudes of the light variation as obtained after correction in both manners are different.

The difference in magnitude between the central and the first order images has been determined by HERTZSPRUNG's method (*A.N.* **186**, 177, 1910), which uses exposures taken with and without grating. The results from the different plates are given in Table 10. The material is not extensive enough to show a variation of $m_1 - m_c$ with the gradation. The resulting value is:

$$m_1 - m_c = \,^{m}\!\cdot\!980 \pm \,^{m}\!\cdot\!005\ (\text{m.e.})\ \text{at}\ G = 1\cdot35.$$

The magnitudes Δm_1 therefore have been corrected by the aid of the formula:

$$\Delta m_2 = \Delta m_1\,[\cdot980 + \cdot099\ (\text{gradation}-1\cdot35)]$$
$$\pm 5 \pm \quad 11 \qquad (\text{m.e.})$$

The mean values of Δm_2 have been computed for

TABLE 10.

Difference in magnitude between the central and first order images.

object	n	N	G	S	m_1-m_c	m.e.	weight	exposure time
Photographic plates					m	m		
Praesepe	1	52	1·48	15	·977	±·011	8	300^s
Region of WW Dra	10	42	1·13	13	·973	11	8	75
,, ,, ,,	4	20	1·09	21	·986	30	1	45
,, ,, ,,	4	15	1·48	15	·991	30	1	45
,, ,, ,,	4	28	1·19	33	·968	22	2	45
Messier 39	4	159	1·41	16	·987	8	16	20, 60
,, ,,	4	101	1·25	24	·989	10	10	20
,, ,,	4	59	1·48	18	·967	10	10	20
			1·35		^{m}·980	^{m}·005		
Photovisual plate								
Praesepe	1	36	1·74	36	·968	11	—	600

n = number of exposures with and without grating N = number of stars measured

all the means of observations (all these are maximum observations) given in Tables 2 to 7. Herefrom the following least squares solutions have been derived:

$\Delta m_2 = -$ ^{m}·8268 + ^{m}·0113 (density—2·00)
± 22 ± 53 (m.e.)
$\Delta m_2 = -$ ·8206 — ·0016 × hour angle
± 40 ± 14 (m.e.)
$\Delta m_2 = -$ ·8253 — ·00076 (sharpness—16)
± 31 ± 42 (m.e.)
$\Delta m_2 = -$ ·8249 — ·00017 (plate fog—12·5)
± 17 ± 64 (m.e.)

Further, the mean Δm_2 is — ^{m}·829 ± ^{m}·002 for JD < 8000 and — ^{m}·822 ± ^{m}·002 for JD > 8000. The difference of these values has the opposite sign than would be expected from the higher sensitivity for longer wavelengths of the more recent plates.

There is no dependence of Δm_2 on any of the other quantities. The Δm_2 has been taken as definitive magnitude.

With the definitive magnitudes Δm_2 the different kinds of mean errors have been derived once more as follows:

The square of the mean error of one observation

1°. from all differences

for the maximum $^{m^2}$·000335 = (± ^{m}·018)^2 from 326 differences,
for the primary minimum ·000679 = (± ·026)^2 ,, 170 ,,
for the secondary minimum ·000412 = (± ·020)^2 ,, 85 ,,

and if the definitive phases P_2 (see below, p. 129) are used:

for the primary minimum ·000589 = (± ·024)^2 ,, 168 ,,

2°. from differences between observations during one night

for the maximum ·000143 = (± ·012)^2 ,, 247 ,,

3°. from the differences between observations on one plate

for the maximum ·000136 = (± ·012)^2 ,, 183 ,,

The square of the mean night error $^{m^2}$·000192 = (± ^{m}·014)^2,
the square of the mean plate error ·000007 = (± ·003)^2,
the square of the mean internal error ·000136 = (± ·012)^2.

After correcting the magnitudes for the gradation effect the night error decreased. The fact that this error, however, remains fairly large may be due to the small distance of the two stars on the plate. The real nature of the systematic errors and of the night error may possibly be found from observations of the difference in magnitude between the components of double stars of various kinds, made under various conditions. Such kind of observations are now being carried out at the Leiden Observatory.

The ten series of exposures of Table 8 have been measured twice with both photometers. From these measurements the following quantities have been derived:

	Schilt photometer	Hartmann photometer
the square of the mean measuring error	$^{m^2}$·000225 = (± ^{m}·015)^2	$^{m^2}$·003600 = (± ^{m}·060)^2
the square of the mean error inherent to the image	·001521 = (± ·039)^2	·003250 = (± ·057)^2
the square of the mean internal error	·001746 = (± ·042)^2	·006850 = (± ·083)^2

The number of differences used is 107. These errors refer to individual exposures.

From the internal agreement of the exposures contained in one mean the square of the mean internal error of one exposure is found:

for the maximum	$^{m^2}\cdot001656 = (\pm\ ^{m}\cdot041)^2$	from 3260	differences,
for the primary minimum	$\cdot001892 = (\pm\ \cdot043)^2$	,, 1700	,,
for the secondary minimum	$\cdot001440 = (\pm\ \cdot038)^2$	,, 850	,,
mean	$\cdot001693 = (\pm\ \cdot041)^2$		

The dependence of the internal mean error and of the dispersion of Δm_1 or Δm_2 on the various quantities JD, D, etc. can be seen from Tables 2 to 7.

With the assumption that the means Δm_2 are independent from each other the total weight of the observations would be $1450000^{m^{-2}}$. If the systematic errors are taken into account this value is reduced to $510000^{m^{-2}}$.

The improvement of the period has been made in the usual manner. The phase of the primary minimum has been derived by the method described in *B.A.N.* Nos. 147 and 166. Normal points between the phases $P_1 = {}^{P}\cdot35$ and ${}^{P}\cdot46$ have been used representing each 5 values of Δm_2 which follow each other in the preliminary phase P_1. It may be remembered that each value Δm_2 is the mean of about ten exposures.

The normal points outside the primary minimum have not been used, because they show small fluctuations in brightness, which may be caused by systematic errors. A second determination of the minimum phase has been made by aid of the observations on the two branches of the minimum, viz. those with $P_1 = {}^{P}\cdot3690$—${}^{P}\cdot3890$ and ${}^{P}\cdot4160$—${}^{P}\cdot4360$. The light variation within these phases was assumed to be linear. From least squares solutions the phases corresponding to $\Delta m_2 = -{}^{m}\cdot200$ on both branches have been derived. The mean of these two phases gives the minimum phase. The result is the same for both methods:

$$P_1\ (\text{min I}) = {}^{P}\cdot4023 \pm {}^{P}\cdot0002\ (\text{m.e.}).$$

For the observations of the primary minimum phases P'_1 reflected with respect to the middle of this minimum ($P'_1 = |P_1 - {}^{P}\cdot4023|$) have been computed. A light curve has been drawn through normal points representing 10 Δm_2's which follow each other in P'_1. By the aid of this curve the times of observation have been reduced to the middle of the minimum. Means have been computed of the minimum epochs derived from observations during one night. The weights of these means are given by

$$p_1 \sim \frac{1}{(\text{night error})^2 + \frac{1}{n}(\text{internal error})^2} = \frac{1}{{}^{m^2}\cdot000192 + \frac{1}{n}\ {}^{m^2}\cdot000143}$$

Here n is the number of epochs from one night. The plate error has been neglected. These weights (see column 3 of Table 11) have been used although they do not differ very much from each other.

Least squares solutions of the minimum epochs yield the following results:

$$\begin{aligned}
\text{Min I} &= \text{J.D. } 2427918\cdot5171 + 4^{d}\cdot629576\ \text{E} \quad \text{for the descending branch,}\\
&\qquad\qquad \pm 7 \qquad\qquad \pm 13 \qquad \text{(m.e.)}\\
\text{Min I} &= \text{J.D. } 2427983\cdot3334 + 4\ \cdot629579\ \text{E} \quad \text{for the ascending branch,}\\
&\qquad\qquad \pm 7 \qquad\qquad \pm 16 \qquad \text{(m.e.)}\\
\text{Min I} &= \text{J.D. } 2428020\cdot3693 + 4\ \cdot629583\ \text{E} \quad \text{for both branches together.}\\
&\qquad\qquad \pm 5 \qquad\qquad \pm 12 \qquad \text{(m.e.)}
\end{aligned}$$

Table 11 gives the epochs of minimum including those obtained by other observers. The minimum epochs from ZVEREV's observations have been derived in the same manner as the Leiden epochs. The O—C's of the above elements derived from both branches are given in column 6. The older observations show systematically negative residuals.

Therefore another determination of the period has been made with the use of all epochs. The weights p_2 (column 4) for this new least squares solution were put inversely proportional to the square of the mean error of one epoch. The following values have been used for these mean errors:

Harvard plates	$\pm\ {}^{d}\cdot0600$
visual estimates by ZVEREV	$\pm\ \cdot0110$
Leiden observations, per unit of weight p_1	$\pm\ \cdot0144$

The resulting period is $4^{d}\cdot629619 \pm {}^{d}\cdot000007$ (m.e.). The new O—C's (column 7) are more satisfactory.

BURNHAM, while measuring the relative position of the components, once estimated the difference in brightness to be only ${}^{m}\cdot2$ (Table 1, line 6). The time of this observation is J.D. 2407456·71. For this time

TABLE 11.

Determination of the period.

observation	J.D.	p_1	p_2	epoch	O—C_1	O—C_2
	d				d	d
Miss HARWOOD, measurement, 1 plate	2415205·599	0	1	0	— ·0850	+ ·0160
,, ,, ,, ,,	5501·809	0	1	64	— ·1680	— ·0700
,, ,, ,, ,,	5774·848	0	1	123	— ·2740	— ·1780
,, ,, ,, ,,	5955·582	0	1	162	— ·0940	·0000
,, ,, ,, ,,	6390·638	0	1	256	— ·2190	— ·1280
,, ,, ,, ,,	6418·486	0	1	262	— ·1480	— ·0580
,, ,, ,, ,,	6603·702	0	1	302	— ·1160	— ·0260
ZVEREV, estimate, 1 plate	6969·44	0	1	381	— ·1150	— ·0280
Miss HARWOOD, measurement, 1 plate	7131·500	0	1	416	— ·0900	— ·0050
,, ,, ,, ,,	8867·661	0	1	791	— ·0230	+ ·0490
,, ,, ,, ,,	8955·495	0	1	810	— ·1510	— ·0800
,, ,, ,, ,,	9191·586	0	1	861	— ·1690	— ·1000
,, ,, ,, ,, (*H.C.* No. 194)	9890·777	0	1	1012	— ·0450	+ ·0190
HOFFMEISTER, 2 visual estimates in the minimum	2422881·486	0	1	1658	— ·0460	— ·0060
,, 4 ,, ,, ,, ,, ,,	2895·458	0	4	1661	+ ·0370	+ ·0770
BEYER, 2 ,, ,, ,, ,, ,,	5247·247	0	1	2169	— ·0020	+ ·0190
ZVEREV, 3 visual estimates on the ascending branch	7284·275	0	36	2609	+ ·0090	+ ·0150
,, 6 ,, ,, ,, ,, ,, ,,	7307·396	0	36	2614	— ·0180	— ·0120
KORDYLEWSKI, visual estimates (*S.A.C.* 1934)	7321·296	0	36	2617	— ·0060	— ·0010
ZVEREV, 2 visual estimates on the ascending branch	7335·197	0	36	2620	+ ·0060	+ ·0110
,, 7 ,, ,, ,, ,, ,, ,,	7534·261	0	36	2663	— ·0020	+ ·0010
,, 4 ,, ,, ,, ,, descending ,,	7543·530	0	36	2665	+ ·0080	+ ·0110
,, 8 ,, ,, ,, ,, ,, ,,	7557·409	0	36	2668	— ·0020	+ ·0010
,, 6 ,, ,, ,, ,, ascending ,,	7557·418	0	36	2668	+ ·0070	+ ·0100
PLAUT, observations on the ascending branch	7645·3748	42	730	2687	+ ·0017	+ ·0041
,, ,, ,, ,, descending ,,	7654·6307	48	831	2689	— ·0016	+ ·0008
,, ,, ,, ,, ,, ,,	7691·6670	38	663	2697	— ·0019	+ ·0001
,, ,, ,, ,, ascending ,,	7710·1918	42	730	2701	+ ·0045	+ ·0064
,, ,, ,, ,, ,, ,,	7881·4789	42	730	2738	— ·0029	— ·0024
,, ,, ,, ,, descending ,,	7904·6277	38	663	2743	— ·0020	— ·0017
,, ,, ,, ,, ascending ,,	7918·5176	38	663	2746	— ·0009	— ·0006
,, ,, ,, ,, descending ,,	7918·5197	46	800	2746	+ ·0012	+ ·0015
,, ,, ,, ,, ascending ,,	7932·4068	45	785	2749	— ·0004	— ·0003
,, ,, ,, ,, descending ,,	7955·5536	47	816	2754	— ·0016	— ·0016
,, ,, ,, ,, ascending ,,	7983·3329	44	764	2760	+ ·0002	·0000
,, ,, ,, ,, ,, ,,	8020·3700	42	730	2768	+ ·0007	+ ·0001
,, ,, ,, ,, ,, ,,	8057·4074	30	524	2776	+ ·0014	+ ·0006
,, ,, ,, ,, ,, ,,	8205·5510	45	785	2808	— ·0016	— ·0036
,, ,, ,, ,, ,, ,,	8219·4445	45	785	2811	+ ·0031	+ ·0010
,, ,, ,, ,, ,, ,,	8307·4054	45	785	2830	+ ·0019	— ·0009
,, ,, ,, ,, descending ,,	8404·6215	30	524	2851	— ·0032	— ·0068

O—C_1 = + $0^d·95$ and O—C_2 = + $1^d·09$. The observation thus occurs during maximum.

There remains a possibility of a small variation of the period. Therefore the definitive phases P_2 have been computed with the period derived from the Leiden observations only (the third of the solutions of p. 128), viz.

$$P_2 = {}^{d^{-1}}·21600217 \text{ (J.D. — 2420000)}.$$

Table 12 gives the means Δm_2 of about ten individual observations with the various quantities belonging to them. A dot after the Julian date indicates a new plate. The internal mean error of one exposure is given in units of $^m·001$.

Now with the new phases P_2 the phases of both minima have been computed by the method of *B.A.N.* Nos. 147 and 166:

$$P_2 \text{ (min I)} = {}^P·4171 \pm {}^P·0002 \text{ (m.e.)},$$
$$P_2 \text{ (min II)} = ·9099 \pm ·0026 \text{ (m.e.)}.$$

TABLE 12.

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2	J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	P			h			m		m		P			h			m		m
7530·5495	·6150	2·66	·92	14·2	17	7·6	—·877	41	—·822	7531·5593	·8332	1·86	1·12	14·5	19	8·6	—·858	43	—·821
·5631	·6180	2·48	·94	14·5	17	7·6	—·882	41	—·828	·5747	·8365	1·96	1·12	14·9	22	8·6	—·866	43	—·829
·5772	·6210	2·44	·90	14·8	16	7·6	—·874	41	—·818	·5918.	·8402	1·97	1·16	15·3	16	8·6	—·837	43	—·804
·5925.	·6243	2·23	·96	15·2	16	7·6	—·870	41	—·819	·6230	·8469	1·67	1·20	16·0	15	7·8	—·853	44	—·824
7531·5454	·8301	1·95	1·22	14·1	18	8·6	—·839	43	—·811	·6520.	·8532	1·58	1·16	16·7	16	7·8	—·875	44	—·841

TABLE 12 (*continued*).

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	P			h			m		m
7532·5780	·0532	1·82	1·17	15·0	17	9·5	−·899	40	−·865
·5933	·0565	1·85	1·16	15·4	17	9·5	−·886	40	−·851
·6480.	·0683	1·92	1·18	16·7	17	9·4	−·910	40	−·876
7548·3481	·4596	3·03	1·16	10·5	10	13·3	−·726	43	−·697
·3636.	·4629	3·13	1·18	10·9	10	13·3	−·785	43	−·756
·3901	·4686	2·56	1·24	11·5	12	12·3	−·864	50	−·837
·4040.	·4716	2·82	1·22	11·9	12	12·1	−·824	50	−·797
·4363.	·4786	2·81	1·28	12·6	14	12·7	−·854	56	−·831
7564·3918	·9250	2·58	1·21	12·6	25	12·6	−·746	43	−·721
·4100	·9290	2·61	1·20	13·1	26	12·6	−·764	43	−·737
·4258.	·9324	2·54	1·18	13·4	25	12·5	−·785	43	−·756
7567·5283.	·6025	3·04	1·26	16·1	21	11·7	−·869	38	−·843
·5484.	·6069	2·04	1·18	16·6	30	11·7	−·894	38	−·861
7568·4058.	·7921	2·39	1·08	13·2	28	10·7	−·835	48	−·796
·4390	·7992	2·12	1·07	14·0	29	12·1	−·841	54	−·801
·4543.	·8026	2·17	1·00	14·4	27	12·3	−·872	54	−·825
7569·4037	·0076	2·89	1·28	13·2	24	15·4	−·844	40	−·821
·4159.	·0103	3·02	1·27	13·5	24	15·4	−·821	40	−·798
7575·4149	·3061	2·87	1·26	13·9	12	15·0	−·882	39	−·856
·4303	·3094	2·80	1·28	14·3	14	15·0	−·879	39	−·855
·4592.	·3156	2·49	1·18	15·0	18	14·7	−·910	39	−·877
7586·4816.	·6965	2·15	1·08	16·2	22	14·1	−·901	35	−·859
·5066.	·7019	2·20	·96	16·8	35	13·9	−·885	43	−·834
7587·4297.	·9013	2·34	1·08	15·1	13	14·0	−·762	26	−·726
·4671.	·9094	2·18	1·06	16·0	13	14·9	−·739	27	−·703
·5031.	·9171	2·29	1·10	16·8	20	15·5	−·758	25	−·724
·5294.	·9228	2·18	·96	17·5	24	14·0	−·767	27	−·722
7588·4207	·1153	1·93	·96	14·9	36	13·2	−·894	50	−·841
·4450.	·1206	2·05	·91	15·5	36	13·2	−·939	50	−·879
7604·4625.	·5804	2·27	1·10	17·0	30	12·6	−·889	60	−·849
7605·4355.	·7906	2·39	1·14	16·4	12	13·4	−·815	41	−·781
7620·4560	·0350	1·81	1·28	17·9	9	12·4	−·852	30	−·829
·4713.	·0383	1·95	1·30	18·2	9	12·8	−·839	30	−·818
·4958.	·0436	2·15	1·21	18·8	23	6·6	−·829	71:	−·801
7624·4209.	·8915	1·48	1·18	17·3	10	6·3	−·773	22	−·745
7625·5470.	·1347	1·68	1·12	20·4	31	10·4	−·903	35	−·864
7626·4250	·3243	1·62	1·12	17·5	18	9·7	−·909	34	−·870
·4403.	·3277	1·66	1·08	17·9	22	9·8	−·912	34	−·869
·4680	·3336	1·58	1·31	18·6	20	11·0	−·879	36	−·858
·4832	·3369	1·64	1·28	18·9	22	11·0	−·901	36	−·877
·4984.	·3402	1·68	1·22	19·3	23	11·0	−·906	36	−·876
·5227	·3455	1·60	1·16	19·9	26	11·4	−·892	44	−·858
·5379	·3487	1·63	1·16	20·2	27	11·6	−·873	44	−·839
·5531.	·3520	1·75	1·19	20·6	23	11·5	−·878	44	−·847
7627·4867	·5537	2·26	1·37	19·1	17	12·1	−·848	30	−·833
·5020.	·5570	2·15	1·30	19·4	21	12·4	−·858	30	−·837
7636·5098.	·5027	2·45	1·22	20·2	13	8·8	−·819	45	−·792
7640·4160	·3464	2·26	1·16	18·4	6	11·7	−·830	26	−·797
·4321.	·3499	2·49	1·06	18·6	7	11·7	−·854	26	−·813
·4989	·3643	3·20	1·17	20·2	10	13·0	−·867	73	−·834
·5322.	·3715	2·70	1·28	21·0	11	13·0	−·707	73	−·688
·5592	·3774	2·70	1·10	21·7	10	11·1	−·680	52	−·650
·5744.	·3807	2·57	1·07	22·0	10	11·0	−·603	52	−·574
7645·4131.	·4258	2·00	1·07	18·5	15	11·5	+·258	59	+·246
·4463.	·4330	2·00	1·00	19·3	18	9·7	+·055	34	+·052
·4782.	·4399	2·00	1·02	20·1	18	11·8	−·168	37	−·159
·5047.	·4456	2·01	1·07	20·7	16	10·2	−·357	33	−·340
5524.	·4559	2·10	1·07	21·8	16	9·8	−·623	35	−·593
·5772.	·4613	2·17	1·08	22·4	17	12·0	−·728	26	−·694
7654·3939	·3657	1·59	1·28	18·6	12	10·1	−·832	33	−·810

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	P			h			m		m
7654·4061	·3683	1·79	1·26	18·9	12	10·2	−·808	33	−·785
·4165.	·3706	1·83	1·20	19·2	15	10·3	−·787	33	−·760
·4325	·3740	1·78	1·20	19·6	19	10·0	−·723	29	−·697
·4429	·3763	1·77	1·18	19·8	19	10·0	−·668	29	−·644
·4532.	·3785	1·79	1·15	20·1	19	10·0	−·630	29	−·605
·4674	·3816	1·78	1·19	20·4	16	10·4	−·546	31	−·526
·4778	·3838	1·88	1·22	20·6	15	10·4	−·478	31	−·463
·4883.	·3861	2·04	1·22	20·9	15	10·4	−·435	31	−·421
·5028	·3892	2·38	1·20	21·2	14	11·8	−·340	33	−·328
·5132	·3915	2·51	1·16	21·5	14	11·8	−·311	33	−·299
·5235.	·3937	2·62	1·16	21·7	13	11·7	−·206	33	−·198
·5391	·3971	2·84	1·02	22·1	14	11·6	−·105	78	−·099
·5496	·3993	2·89	1·04	22·4	14	11·6	+·018	78	+·017
·5601.	·4016	3·02	1·04	22·6	13	11·6	+·099	78	+·094
·5838.	·4067	2·77	·98	23·2	13	11·4	+·222	52	+·209
7667·5112	·1991	3·12	1·14	22·3	14	11·5	−·867	53	−·832
·5293	·2030	3·21	1·17	22·7	13	11·8	−·856	53	−·824
·5501.	·2075	3·20	1·10	23·2	14	12·3	−·858	53	−·819
7670·5033.	·8454	2·89	1·21	22·3	14	13·8	−·840	42	−·812
7677·3502	·3243	2·13	1·12	19·1	13	10·2	−·857	45	−·820
·3659.	·3277	2·21	1·11	19·5	13	10·2	−·862	45	−·824
7682·3492	·4041	2·34	1·12	19·4	16	10·4	+·153	51	+·146
·3734.	·4093	2·46	1·12	20·0	18	10·4	+·263	51	+·252
·4653.	·4292	2·49	1·33	22·2	16	13·1	+·174	61:	+·170
7686·3429	·2667	1·99	1·43	19·5	13	14·0	−·855	36	−·845
·3543	·2692	1·97	1·41	19·8	17	14·1	−·871	36	−·859
·3658.	·2717	1·92	1·36	20·1	18	14·1	−·877	36	−·860
7691·3568	·3498	2·33	1·34	20·2	16	9·8	−·838	39	−·821
·3721	·3531	2·20	1·33	20·5	16	9·8	−·858	39	−·839
·3873.	·3563	2·09	1·30	20·9	16	9·8	−·852	39	−·831
·4122	·3617	1·76	1·29	21·5	20	12·4	−·854	40	−·832
·4313	·3659	1·73	1·36	22·0	21	12·3	−·813	40	−·798
·4470.	·3692	1·85	1·40	22·3	21	12·4	−·756	40	−·744
·4683	·3738	1·98	1·28	22·8	21	11·1	−·715	35	−·696
·4836	·3771	2·05	1·30	23·2	20	11·2	−·650	35	−·634
·4988.	·3804	2·13	1·33	23·6	18	11·1	−·577	35	−·564
·5210	·3852	1·95	1·42	0·1	16	12·7	−·445	36	−·439
·5362.	·3885	2·02	1·44	0·4	16	12·7	−·343	36	−·339
7693·3308.	·7761	1·76	1·40	19·7	12	13·2	−·821	30	−·808
7694·3226	·9904	2·47	1·30	19·5	10	12·9	−·800	36	−·780
·3330	·9926	2·46	1·24	19·8	12	12·9	−·826	36	−·800
·3434.	·9949	2·32	1·30	20·0	12	12·9	−·809	36	−·789
7695·4694	·2381	2·48	1·27	23·1	6	8·8	−·825	58	−·802
·4852.	·2415	2·43	1·26	23·5	6	8·8	−·857	58	−·832
7696·3048	·4185	1·95	1·04	19·2	9	8·1	+·368	45	+·349
·3221.	·4223	1·93	1·10	19·7	9	8·0	+·325	45	+·310
·3456.	·4274	2·30	1·17	20·2	18	11·0	+·216	59	+·208
7709·2911	·2236	2·70	1·24	19·8	9	14·4	−·855	32	−·828
·3036	·2263	2·80	1·23	20·1	9	14·3	−·852	32	−·825
·3175.	·2293	2·97	1·20	20·4	9	14·3	−·854	32	−·824
7710·2864	·4386	2·66	1·20	19·7	11	13·8	−·101	31	−·097
·3017	·4419	2·68	1·18	20·1	13	13·9	−·230	31	−·222
·3264.	·4472	2·76	1·15	20·7	14	13·9	−·383	31	−·368
7772·2148	·8153	2·74	1·06	22·0	32	10·0	−·836	50	−·795
·2279	·8181	3·00	·98	22·4	33	9·8	−·852	50	−·804
·2405.	·8208	3·15	·98	22·7	33	9·8	−·844	50	−·797
7830·5883.	·4241	1·74	1·14	10·8	14	10·5	+·247	59	+·237
7840·6278	·5926	2·02	1·00	12·4	26	10·7	−·888	33	−·839
·6417	·5956	1·90	1·06	12·8	26	10·7	−·878	33	−·835
·6555	·5986	1·90	1·08	13·1	27	10·7	−·871	33	−·831

TABLE 12 (*continued*).

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2	J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	P			h			m		m		P			h			m		m
7840·6708.	·6019	1·94	1·06	13·5	27	10·7	−·879	33	−·837	7881·5525.	·4324	1·95	1·10	13·3	12	11·7	+·022	44	+·021
7841·5362	·7888	2·57	1·16	10·3	34	14·2	−·842	40	−·809	·5931.	·4412	2·08	1·13	14·3	12	12·5	−·242	32	−·232
·5466	·7911	2·70	1·12	10·5	34	14·3	−·823	40	−·787	·6253	·4482	2·08	1·18	15·1	12	13·2	−·443	46	−·426
·5570.	·7933	2·71	1·09	10·8	34	14·2	−·825	40	−·787	·6391.	·4511	2·33	1·15	15·4	13	13·2	−·516	46	−·495
·6262	·8083	2·70	1·06	12·5	34	14·0	−·846	43	−·804	·6644	·4566	2·07	1·22	16·0	10	16·1	−·625	40	−·605
·6366	·8105	2·76	1·06	12·7	34	14·0	−·854	43	−·813	·6779.	·4595	2·12	1·20	16·3	10	16·1	−·726	40	−·701
·6470.	·8128	2·86	1·05	13·0	32	14·1	−·858	43	−·815	7882·5406	·6459	2·50	1·16	13·1	12	12·8	−·859	55	−·826
7860·4497	·8742	1·99	1·28	9·5	18	13·2	−·805	35	−·783	·5527.	·6485	2·56	1·12	13·4	13	12·8	−·868	55	−·831
·4652	·8775	1·97	1·16	9·7	20	13·2	−·807	35	−·775	7883·5697	·8682	1·70	1·28	13·9	16	15·4	−·831	32	−·809
·5030.	·8857	2·16	1·15	10·6	22	13·2	−·791	35	−·759	·5819.	·8708	1·78	1·28	14·2	16	15·5	−·808	32	−·786
·5309	·8917	1·88	1·16	11·4	23	12·0	−·784	32	−·753	·5975	·8742	1·94	1·30	14·5	13	16·5	−·802	27	−·782
·5691	·9000	1·85	1·12	12·3	23	12·0	−·769	32	−·736	·6096.	·8768	1·93	1·24	14·8	15	16·5	−·784	27	−·760
·6009.	·9069	1·90	1·13	13·1	24	11·8	−·782	32	−·749	7888·6581	·9673	2·03	1·30	16·3	27	16·2	−·854	37	−·833
·6327.	·9137	1·95	1·19	13·9	19	11·4	−·752	29	−·725	·6696.	·9698	2·00	1·24	16·6	30	16·1	−·833	37	−·807
7864·5293.	·7554	2·14	1·10	11·6	32	10·4	−·864	49	−·825	7889·5714	·1645	2·79	1·31	14·3	25	17·7	−·862	38	−·841
7869·5000	·8291	1·91	1·09	11·3	22	8·8	−·844	40	−·805	·5847.	·1675	2·84	1·38	14·6	25	17·7	−·853	38	−·838
·5139	·8321	1·81	1·05	11·6	24	8·8	−·841	40	−·799	7895·3702.	·4171	1·62	1·48	9·8	25	16·5	+·316	—	+·314
·5277.	·8351	1·90	1·10	11·9	23	8·8	−·842	40	−·805	7899·5174	·3129	2·03	1·40	13·7	26	18·1	−·857	38	−·845
·6095	·8527	1·86	1·06	13·9	23	7·7	−·850	35	−·809	·5298	·3156	1·97	1·24	14·0	28	18·0	−·893	38	−·865
·6233	·8557	1·80	1·09	14·2	23	7·7	−·836	35	−·798	·5402.	·3178	1·98	1·38	14·2	26	18·0	−·860	38	−·846
·6372.	·8587	1·87	1·08	14·6	23	7·7	−·851	35	−·812	·5662	·3234	2·14	1·45	14·8	23	17·6	−·841	55	−·833
7870·4793	·0406	1·81	1·02	10·8	21	4·4	−·872	48	−·826	·5788.	·3262	2·52	1·40	15·1	25	17·6	−·850	55	−·837
·4932	·0436	1·61	1·14	11·2	18	4·4	−·855	48	−·820	7904·4104	·3698	2·82	1·26	11·4	6	17·8	−·729	39	−·708
·5070.	·0466	1·51	1·11	11·5	18	4·3	−·868	48	−·830	·4267.	·3733	2·62	1·24	11·8	6	17·7	−·692	39	−·670
·5340	·0524	2·56	1·20	12·2	22	9·2	−·880	56	−·849	·4662	·3819	2·55	1·32	12·7	7	17·4	−·535	53	−·523
·5479	·0554	2·55	1·18	12·5	19	9·2	−·860	56	−·828	·5110.	·3915	2·28	1·32	13·7	10	17·4	−·262	53	−·256
·5617.	·0584	2·68	1·24	12·8	19	9·2	−·841	56	−·815	·5314.	·3959	2·23	1·50	14·3	13	11·8	−·115	—	−·114
7871·4747	·2556	1·88	1·30	10·8	25	13·8	−·838	34	−·817	7905·5006.	·6053	2·06	1·49	13·6	9	16·0	−·853	36	−·848
·5036	·2619	1·90	1·30	11·5	25	13·8	−·871	34	−·849	·5696.	·6202	1·85	1·51	15·3	15	15·9	−·858	24	−·854
·5175.	·2649	1·88	1·36	11·8	25	13·8	−·846	34	−·829	7916·4163	·9631	2·40	1·52	12·3	19	16·3	−·800	38	−·798
·5471	·2713	1·88	1·34	12·5	19	14·7	−·859	34	−·841	·4287	·9658	2·44	1·52	12·6	18	16·5	−·811	38	−·808
·5599	·2740	2·09	1·37	12·8	18	14·7	−·882	34	−·866	·4405.	·9683	2·22	1·48	13·0	16	16·4	−·804	38	−·798
·5742.	·2771	2·04	1·36	13·2	18	14·7	−·875	34	−·858	·4696	·9746	2·27	1·50	13·6	18	17·0	−·808	37	−·804
·6075	·2843	2·04	1·38	14·0	23	14·3	−·857	41	−·842	·4817	·9772	2·29	1·48	13·9	20	17·0	−·796	37	−·791
·6214.	·2873	2·04	1·38	14·3	23	14·4	−·854	41	−·839	·4938.	·9798	2·19	1·50	14·2	20	17·0	−·808	37	−·804
7872·5479	·4874	1·87	1·40	12·6	21	14·4	−·849	37	−·837	·5166	·9848	2·30	1·50	14·8	14	16·7	−·816	33	−·812
·5632	·4907	1·93	1·41	13·0	18	14·4	−·867	37	−·855	·5299	·9876	2·36	1·46	15·1	15	16·8	−·816	33	−·809
·5777.	·4939	1·87	1·44	13·3	20	14·4	−·841	37	−·832	·5450	·9909	2·36	1·50	15·4	12	16·8	−·813	33	−·808
·6220	·5034	1·83	1·43	14·4	16	14·4	−·854	22	−·844	·5624.	·9947	2·41	1·52	15·8	12	16·7	−·820	33	−·817
·6373.	·5067	1·83	1·44	14·9	19	14·4	−·851	22	−·841	7918·3555	·3820	2·36	1·36	11·0	17	16·1	−·567	38	−·556
7874·4806	·9049	2·49	1·20	11·1	25	13·8	−·778	39	−·751	·3678	·3846	2·38	1·37	11·3	18	16·2	−·491	38	−·482
·4910	·9071	2·51	1·14	11·4	28	13·8	−·791	39	−·758	·3805.	·3874	2·40	1·36	11·6	18	16·1	−·417	38	−·409
·5014.	·9094	2·60	1·24	11·6	25	13·8	−·742	39	−·719	·3978	·3911	2·43	1·42	12·0	26	17·1	−·302	42	−·298
·5263	·9148	2·60	1·19	12·2	21	15·2	−·779	46	−·751	·4099	·3937	2·44	1·46	12·3	24	17·1	−·218	42	−·216
·5567	·9170	2·64	1·18	12·5	21	15·1	−·761	46	−·733	·4229.	·3965	2·46	1·42	12·6	25	17·0	−·112	42	−·110
·5471.	·9193	2·68	1·21	12·7	19	15·2	−·782	46	−·755	·4428	·4008	2·50	1·45	13·1	22	16·8	+·055	61	+·054
·5713	·9245	2·57	1·24	13·3	22	14·3	−·776	36	−·752	·4882	·4106	2·11	1·43	14·2	20	16·8	+·238	61	+·235
·5817	·9267	2·59	1·28	13·6	20	14·4	−·779	36	−·758	·5029.	·4138	2·04	1·48	14·6	20	16·8	+·350	61	+·348
·5949.	·9296	2·60	1·26	13·9	18	14·3	−·758	36	−·736	·5226	·4181	2·15	1·44	15·0	18	17·1	+·334	43	+·330
·6163	·9342	2·54	1·36	14·4	21	15·6	−·766	41	−·751	·5493.	·4238	1·88	1·52	15·7	16	17·1	+·281	43	+·280
·6267	·9365	2·50	1·38	14·6	19	15·6	−·770	41	−·757	·5725	·4288	1·72	1·40	16·2	14	17·2	+·184	38	+·181
·6371.	·9387	2·58	1·44	14·9	20	15·6	−·778	41	−·769	·5915	·4329	2·06	1·32	16·7	14	17·2	+·041	38	+·040
·6681	·9454	2·45	1·36	15·6	20	14·6	−·776	51	−·761	·6177.	·4386	2·02	1·28	17·3	13	17·2	−·147	38	−·143
·6795	·9479	2·59	1·35	15·9	17	14·6	−·801	51	−·785	7919·3688	·6008	2·82	1·46	11·4	15	18·5	−·854	42	−·847
·6925.	·9507	2·58	1·31	16·2	16	14·6	−·806	51	−·787	·3809	·6035	2·52	1·48	11·7	15	18·5	−·847	42	−·841
7875·5944	·1455	2·78	1·32	13·9	22	12·6	−·847	45	−·827	·3930.	·6061	2·61	1·46	12·0	15	18·5	−·865	42	−·857
·6208.	·1512	2·77	1·28	14·6	20	12·6	−·891	45	−·867	7925·3859	·9006	1·97	1·42	12·2	17	16·2	−·758	37	−·748
7881·4563.	·4117	1·66	1·08	11·0	24	9·6	+·239	32	+·228	·4015	·9039	2·18	1·38	12·6	21	16·2	−·746	37	−·734
·4888.	·4187	1·79	1·07	11·8	20	10·4	+·292	48	+·278	·4171.	·9073	2·06	1·33	13·0	22	16·2	−·752	37	−·735
·5207.	·4256	1·94	1·06	12·5	15	11·6	+·207	54	+·197	7926·4548	·1314	2·42	1·44	13·9	16	16·4	−·837	31	−·826

TABLE 12 (*continued*).

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	P			h			m		m
7926·4670	·1341	2·39	1·44	14·2	16	16·4	−·846	31	−·835
·4791.	·1367	2·41	1·46	14·5	16	16·5	−·845	31	−·837
7932·3589.	·4067	1·52	1·20	12·0	13	14·0	+·204	—	+·197
·3853.	·4124	1·50	1·40	12·7	18	15·4	+·288	—	+·284
·4035.	·4164	1·51	1·34	13·1	21	15·1	+·326	27	+·319
·4284	·4217	1·48	1·32	13·7	24	14·9	+·282	35	+·275
·4457.	·4255	1·56	1·36	14·1	23	14·9	+·227	35	+·223
·4679	·4303	1·68	1·40	14·6	16	15·6	+·122	33	+·120
·4852.	·4340	1·68	1·46	15·1	15	15·5	+·007	33	+·007
·5091	·4392	2·14	1·41	15·6	16	15·1	−·175	35	−·173
·5229	·4422	2·12	1·42	16·0	15	15·1	−·255	35	−·252
·5368.	·4452	2·17	1·42	16·3	15	15·0	−·335	35	−·331
·5608	·4503	1·95	1·52	16·9	14	14·7	−·477	39	−·476
·5730	·4530	1·98	1·51	17·2	13	14·7	−·535	39	−·533
·5851.	·4556	2·03	1·49	17·5	12	14·7	−·594	39	−·590
·6010.	·4590	1·84	1·34	17·8	12	14·3	−·676	22	−·661
7944·4045	·0086	2·11	1·44	13·9	17	14·6	−·800	37	−·790
·4149	·0109	2·04	1·43	14·2	17	14·6	−·826	37	−·816
·4255.	·0131	2·09	1·44	14·4	19	14·6	−·829	37	−·820
7951·4122	·5223	2·76	1·36	14·6	12	15·5	−·838	35	−·822
·4226.	·5245	2·76	1·37	14·8	13	15·1	−·836	35	−·821
7955·4068	·3851	2·23	1·16	14·7	20	13·1	−·463	66	−·445
·4172	·3874	2·29	1·18	14·9	20	13·0	−·377	66	−·363
·4276.	·3896	2·40	1·16	15·2	23	13·0	−·339	66	−·326
·4438	·3931	2·42	1·35	15·6	25	15·6	−·203	42	−·199
·4557	·3957	2·44	1·31	15·9	25	15·6	−·140	42	−·137
·4678.	·3983	2·59	1·29	16·2	25	15·6	−·075	42	−·073
·4896	·4030	2·62	1·24	16·7	22	15·5	+·141	67	+·137
·5043	·4062	2·51	1·30	17·0	21	15·4	+·198	67	+·193
·5208.	·4098	2·35	1·36	17·4	21	15·5	+·295	67	+·289
7961·4652	·6938	1·94	1·68	16·5	12	14·8	−·804	52	−·815
·4783.	·6966	1·93	1·66	16·8	12	14·8	−·794	52	−·803
7983·4353	·4393	1·79	1·43	17·2	12	14·1	−·134	38	−·132
·4492	·4424	1·79	1·44	17·6	14	14·0	−·246	38	−·243
·4630.	·4453	1·68	1·46	17·9	15	14·0	−·346	38	−·343
·4830	·4497	1·94	1·46	18·4	17	14·5	−·475	51	−·471
·4944	·4521	1·88	1·50	18·7	16	14·4	−·530	51	−·527
·5072.	·4549	1·89	1·50	19·0	16	14·4	−·586	51	−·583
·5245	·4586	1·58	1·50	19·4	13	13·8	−·674	31	−·670
·5366	·4612	1·66	1·44	19·7	15	13·8	−·753	31	−·745
·5487.	·4638	1·64	1·40	20·0	14	14·0	−·787	31	−·776
7990·4693	·9587	1·92	1·62	18·5	13	14·8	−·760	28	−·765
·5019	·9657	1·81	1·61	19·3	14	14·7	−·777	28	−·782
·5164.	·9689	1·85	1·61	19·6	15	14·7	−·782	28	−·787
·5369.	·9733	2·35	1·52	20·1	14	15·0	−·792	26	−·790
8017·3930	·7743	2·45	1·44	18·5	14	14·8	−·802	56	−·793
·4052	·7769	2·47	1·38	18·8	15	14·8	−·835	56	−·821
·4179.	·7797	2·50	1·44	19·1	14	14·8	−·801	56	−·792
8020·3855.	·4207	1·06	1·56	18·5	15	12·7	+·338	—	+·338
·4082	·4256	1·05	1·52	19·0	22	12·4	+·243	24	+·242
·4325.	·4308	·90	1·48	19·6	22	12·4	+·116	24	+·115
·4612	·4370	1·11	1·52	20·3	22	12·2	−·090	38	−·090
·4820.	·4415	1·30	1·54	20·8	21	12·2	−·209	38	−·209
·5097.	·4475	1·79	1·56	21·5	18	12·7	−·398	33	−·398
8048·3382	·4585	2·71	1·47	19·2	16	16·4	−·682	33	−·676
·3504	·4612	2·64	1·52	19·5	17	16·5	−·735	33	−·733
·3619.	·4636	2·55	1·59	19·7	17	16·5	−·757	33	−·760
·3923	·4702	2·70	1·49	20·5	20	17·0	−·830	39	−·825
·4139.	·4749	2·77	1·54	21·0	20	17·1	−·870	39	−·869
8049·3760.	·6827	2·71	1·51	20·2	14	17·6	−·826	59	−·823
8057·4007.	·4160	1·89	1·15	21·3	9	14·4	+·330	45	+·317
·4298.	·4223	1·96	1·14	22·0	9	14·0	+·309	36	+·296
·4608.	·4290	2·09	1·11	22·7	12	13·5	+·161	60	+·154
·4885.	·4350	2·23	1·08	23·4	10	15·0	−·012	37	−·011
8098·2676	·2434	2·57	1·40	20·8	16	17·5	−·897	35	−·884
·2889.	·2480	2·56	1·36	21·3	20	17·5	−·871	35	−·854
8119·2528	·7762	1·52	1·20	21·8	23	16·7	−·798	37	−·770
·2716.	·7803	1·82	1·24	22·2	23	16·6	−·788	37	−·763
8205·6044	·4284	1·42	1·17	11·9	15	8·2	+·172	33	+·165
·6200.	·4317	1·73	1·10	12·2	15	8·2	+·079	33	+·075
·6413	·4363	1·27	1·21	12·7	13	8·1	−·070	38	−·068
·6586.	·4401	1·67	1·16	13·2	12	8·2	−·186	38	−·179
·6870	·4462	1·19	1·27	13·8	13	9·6	−·392	39	−·381
·7043.	·4499	1·60	1·27	14·3	12	9·6	−·511	39	−·497
·7254	·4545	1·42	1·24	14·8	11	12·8	−·624	30	−·605
·7393.	·4575	1·41	1·30	15·1	11	12·9	−·694	30	−·676
8206·6185	·6474	1·91	1·12	12·3	13	14·1	−·900	45	−·861
·6302.	·6499	2·08	1·16	12·5	14	14·1	−·849	45	−·816
·6545	·6552	1·77	1·18	13·1	12	14·7	−·852	35	−·820
·6670.	·6579	2·06	1·20	13·4	16	14·8	−·842	35	−·813.
·7030	·6657	1·40	1·20	14·3	14	13·5	−·871	36	−·841
·7174.	·6688	1·52	1·22	14·7	15	13·7	−·859	36	−·831
·7362.	·6728	1·31	1·30	15·6	16	16·1	−·856	26	−·834
8209·6068	·2929	1·32	1·28	12·2	13	13·6	−·847	35	−·824
·6172	·2951	1·38	1·26	12·4	13	13·5	−·863	35	−·838
·6276.	·2974	1·49	1·28	12·7	13	13·5	−·865	35	−·842
·6525	·3028	1·21	1·28	13·3	12	14·3	−·859	34	−·836
·6629	·3050	1·31	1·28	13·5	12	14·3	−·875	34	−·851
·6733.	·3072	1·42	1·34	13·8	12	14·3	−·852	34	−·834
·6913	·3111	1·29	1·29	14·2	11	14·2	−·867	31	−·844
·7017	·3134	1·31	1·29	14·5	13	14·2	−·856	31	−·834
·7121.	·3156	1·35	1·32	14·7	12	14·1	−·860	31	−·840
·7320	·3199	1·33	1·34	15·2	11	14·6	−·844	25	−·826
·7425.	·3222	1·38	1·26	15·4	10	14·7	−·873	25	−·848
8210·5529	·4973	1·62	1·17	10·9	17	15·3	−·882	37	−·849
·5633	·4995	1·64	1·20	11·2	17	15·3	−·860	37	−·830
·5737.	·5017	1·73	1·24	11·4	16	15·4	−·864	37	−·837
·5910	·5055	1·48	1·22	11·9	17	15·5	−·878	30	−·849
·6014	·5077	1·46	1·22	12·1	17	15·3	−·877	30	−·848
·6118.	·5100	1·65	1·31	12·4	16	15·4	−·853	30	−·833
·6304	·5140	1·53	1·28	12·8	13	16·2	−·860	34	−·837
·6408	·5162	1·53	1·28	13·1	14	16·3	−·870	34	−·846
·6512.	·5185	1·63	1·30	13·3	14	16·3	−·863	34	−·841
·6762	·5239	1·52	1·27	13·9	12	16·1	−·880	32	−·855
·6866	·5261	1·56	1·30	14·2	12	16·1	−·848	32	−·826
·6969.	·5283	1·54	1·30	14·4	12	16·1	−·868	32	−·847
·7136	·5320	1·55	1·29	14·8	13	16·6	−·870	32	−·847
·7244	·5343	1·71	1·29	15·1	12	16·3	−·867	32	−·844
·7343.	·5364	1·98	1·30	15·3	12	16·2	−·835	32	−·814
8219·5359	·4376	1·82	1·60	11·1	16	16·9	−·090	27	−·090
·5494	·4405	1·98	1·60	11·5	16	17·0	−·190	27	−·191
·5632.	·4435	1·72	1·64	11·8	13	17·0	−·266	27	−·268
·5851	·4482	2·65	1·51	12·3	13	17·7	−·421	42	−·419
·5951	·4504	2·78	1·50	12·5	11	17·7	−·489	42	−·486
·6058.	·4527	2·79	1·53	12·8	10	17·7	−·540	42	−·539
·6252	·4569	2·69	1·53	13·3	12	18·0	−·652	34	−·651
·6356	·4591	2·53	1·52	13·5	12	18·0	−·708	34	−·705
·6460.	·4614	2·52	1·52	13·8	11	18·0	−·754	34	−·752
·6619	·4648	2·64	1·50	14·2	12	18·2	−·784	33	−·780
·6723	·4671	2·62	1·51	14·4	12	18·2	−·784	33	−·780

TABLE 12 (*continued*).

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2	J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	P			h			m		m		P			h			m		m
8219·6827	·4693	2·68	1·52	14·7	12	18·2	—·834	33	—·831	8249·4838	·9064	1·97	1·64	11·8	16	14·7	—·708	35	—·714
·6931.	·4717	2·75	1·51	14·9	12	18·2	—·848	33	—·844	·4942	·9086	2·04	1·59	12·1	15	14·7	—·720	35	—·723
·7125	·4757	2·11	1·32	15·4	10	15·8	—·826	19	—·807	·5046.	·9109	2·02	1·58	12·3	17	14·5	—·727	35	—·729
·7229	·4780	2·04	1·28	15·6	9	15·8	—·824	19	—·802	·5264.	·9156	2·12	1·66	12·9	15	14·4	—·709	27	—·717
·7333.	·4802	2·10	1·22	15·9	9	15·8	—·839	19	—·812	8251·5324	·3489	2·27	1·65	13·1	11	15·0	—·822	37	—·830
8221·5748	·8780	2·31	1·41	12·2	20	17·4	—·775	36	—·764	·5428	·3512	2·23	1·64	13·4	9	15·0	—·820	37	—·827
·5850	·8802	2·39	1·46	12·4	20	17·4	—·749	36	—·743	·5532.	·3534	2·07	1·64	13·6	11	15·0	—·834	37	—·842
·5946.	·8823	2·46	1·45	12·7	20	17·4	—·754	36	—·746	·5712	·3573	2·25	1·60	14·1	11	15·1	—·838	35	—·842
·6330	·8906	2·31	1·28	13·6	25	17·1	—·757	42	—·737	·5816	·3595	2·25	1·62	14·3	10	15·1	—·828	35	—·834
·6433	·8928	2·33	1·32	13·8	27	17·1	—·749	42	—·731	·5919.	·3618	2·32	1·63	14·6	11	15·1	—·831	35	—·837
·6537.	·8950	2·42	1·30	14·1	26	17·1	—·745	42	—·726	·6072	·3651	2·16	1·66	14·9	9	15·9	—·811	37	—·819
·6814	·9010	2·18	1·28	14·8	28	17·4	—·742	35	—·722	·6176	·3673	2·24	1·65	15·2	10	15·9	—·786	37	—·794
·6967	·9043	2·07	1·30	15·1	25	17·3	—·734	35	—·716	·6280	·3696	2·34	1·60	15·4	12	15·8	—·776	37	—·779
·7141.	·9081	2·05	1·32	15·5	24	17·3	—·761	35	—·743	·6384.	·3718	2·41	1·61	15·7	10	15·9	—·732	37	—·736
8233·5919	·4737	1·94	1·32	13·4	9	12·8	—·807	31	—·789	·6548.	·3753	2·59	1·64	16·1	11	14·4	—·677	58	—·683
·6023.	·4760	2·01	1·33	13·6	9	12·8	—·813	31	—·795	8263·4060	·9136	2·02	1·24	10·9	11	13·3	—·735	36	—·713
·6204	·4799	1·95	1·34	14·1	11	13·5	—·805	38	—·789	·4174.	·9159	2·08	1·23	11·1	11	13·3	—·708	36	—·685
·6298.	·4819	2·40	1·24	14·3	10	13·5	—·838	38	—·813	·4316	·9192	1·76	1·22	11·5	14	13·4	—·730	43	—·706
8235·4971	·8852	2·15	1·18	11·2	14	8·2	—·733	53	—·706	·4420.	·9214	1·88	1·25	11·8	15	13·5	—·726	43	—·704
·5075	·8875	2·32	1·11	11·5	14	8·2	—·752	53	—·719	8266·4392	·5688	1·85	1·20	11·9	16	14·0	—·853	35	—·824
·5179.	·8897	2·64	1·06	11·7	15	8·1	—·759	53	—·722	·4496.	·5711	1·89	1·22	12·1	16	13·9	—·830	35	—·803
·6231	·9125	2·04	1·20	14·3	12	12·1	—·692	41	—·668	·4657.	·5745	1·90	1·28	12·5	20	15·5	—·840	34	—·817
·6335.	·9147	2·38	1·16	14·5	10	12·1	—·739	41	—·710	·4890	·5796	1·88	1·18	13·1	13	14·3	—·856	41	—·825
·6488	·9180	2·10	1·18	14·9	11	13·6	—·719	40	—·692	·4994.	·5818	1·97	1·20	13·3	13	14·2	—·854	41	—·824
·6591.	·9202	2·35	1·16	15·1	10	13·6	—·709	40	—·681	·5161	·5854	1·84	1·20	13·7	13	14·3	—·837	34	—·808
·6763	·9240	2·32	1·20	15·6	6	14·3	—·710	44	—·686	·5264.	·5876	2·06	1·19	14·0	13	14·3	—·859	34	—·828
·6862.	·9261	2·53	1·20	15·8	8	14·3	—·703	44	—·678	·5438	·5914	1·93	1·20	14·4	14	14·8	—·826	37	—·797
·7014.	·9294	2·51	1·28	16·2	6	16·2	—·699	28	—·680	·5542.	·5936	2·06	1·23	14·7	14	14·8	—·843	37	—·816
8239·4813	·7458	1·98	1·32	11·1	20	16·2	—·801	29	—·783	·6068	·6050	2·13	1·22	15·9	9	15·9	—·832	34	—·805
·4917.	·7481	2·06	1·32	11·4	21	16·3	—·795	29	—·777	·6172.	·6073	2·27	1·20	16·2	10	15·9	—·852	34	—·823
·5090.	·7518	2·05	1·36	11·8	19	16·5	—·829	36	—·813	·6331	·6107	2·11	1·23	16·6	12	15·5	—·835	40	—·808
8246·4435	·2497	3·20	1·52	10·7	10	17·3	—·854	46	—·850	·6435.	·6129	2·28	1·24	16·8	12	15·5	—·831	40	—·805
·4538	·2519	3·08	1·54	10·9	10	17·4	—·830	46	—·829	8271·4369	·6483	2·37	1·68	12·2	14	15·0	—·798	36	—·808
·4643.	·2542	3·07	1·54	11·2	11	17·5	—·824	46	—·823	·4462.	·6503	2·58	1·67	12·4	14	15·0	—·811	36	—·821
·4795	·2575	2·67	1·60	11·5	12	16·6	—·834	36	—·838	8286·3602	·8718	2·05	1·37	11·3	20	14·5	—·753	51	—·739
·4899	·2597	2·63	1·60	11·8	11	16·4	—·839	36	—·843	·3706.	·8740	2·13	1·34	11·6	21	14·3	—·782	51	—·766
·5003.	·2620	2·79	1·59	12·0	9	16·5	—·807	36	—·810	8290·4544.	·7561	2·14	1·34	13·8	24	14·7	—·790	24	—·773
·5155	·2652	2·57	1·63	12·4	11	15·7	—·835	41	—·841	8292·5113	·2004	2·03	1·28	15·3	19	14·6	—·863	49	—·839
·5259	·2675	2·48	1·62	12·7	12	15·8	—·812	41	—·817	·5217.	·2027	2·11	1·26	15·6	19	14·6	—·852	49	—·828
·5363.	·2697	2·43	1·64	12·9	10	15·8	—·808	41	—·815	·5431	·2073	1·98	1·30	16·1	22	14·7	—·856	41	—·835
·6417	·2925	1·95	1·64	15·4	9	15·7	—·806	26	—·813	·5535.	·2096	2·06	1·28	16·4	24	14·7	—·869	41	—·846
·6524	·2948	2·03	1·62	15·7	9	15·6	—·804	26	—·809	·5715	·2134	2·16	1·33	16·8	21	14·9	—·858	43	—·839
·6630.	·2971	2·04	1·64	15·9	8	15·8	—·808	26	—·815	·5819.	·2157	2·18	1·38	17·0	20	15·0	—·859	43	—·844
·6776	·3003	1·97	1·54	16·3	7	15·5	—·825	41	—·824	·5958	·2187	1·58	1·44	17·4	17	12·0	—·860	38	—·850
·6880.	·3025	1·96	1·52	16·6	7	15·5	—·852	41	—·850	·6062.	·2209	1·66	1·41	17·6	16	12·0	—·871	38	—·859
8247·5461	·4879	2·65	1·52	13·2	12	16·3	—·843	42	—·840	8301·5073	·1436	1·98	1·64	15·8	17	13·1	—·847	41	—·854
·5565	·4901	2·64	1·53	13·5	11	16·3	—·852	42	—·850	·5171	·1457	2·10	1·58	16·1	17	13·1	—·853	41	—·855
·5669.	·4923	2·68	1·54	13·7	10	16·3	—·823	42	—·822	·5281.	·1481	1·88	1·62	16·3	18	13·1	—·853	41	—·859
·5842	·4961	2·61	1·54	14·1	11	16·2	—·814	39	—·813	8304·5447	·7997	2·68	1·46	16·9	14	12·5	—·789	50	—·781
·5946	·4983	2·62	1·57	14·4	11	16·2	—·829	39	—·831	·5551	·8019	2·53	1·52	17·2	14	12·5	—·765	50	—·762
·6050.	·5006	2·59	1·59	14·6	11	16·0	—·830	39	—·833	·5655.	·8042	2·46	1·46	17·4	14	12·5	—·743	50	—·737
·6204	·5039	2·52	1·57	15·0	12	15·3	—·827	33	—·829	8305·3869	·9816	2·47	1·39	13·2	10	12·9	—·801	66	—·788
·6314	·5063	2·42	1·55	15·3	11	15·3	—·852	33	—·852	·3973.	·9838	2·45	1·41	13·5	11	12·9	—·784	66	—·773
·6417.	·5085	2·57	1·58	15·5	9	15·3	—·811	33	—·814	8306·3925	·1988	2·23	1·52	13·4	14	12·5	—·855	42	—·852
·6617	·5128	2·31	1·54	16·0	11	15·0	—·818	40	—·817	·4029	·2011	2·12	1·51	13·7	16	12·5	—·839	42	—·836
·6721	·5151	2·40	1·51	16·2	9	15·0	—·820	40	—·817	·4138.	·2034	1·82	1·50	13·9	16	12·6	—·852	42	—·848
·6825.	·5173	2·39	1·48	16·5	7	14·8	—·844	40	—·838	·4313	·2072	2·10	1·56	14·3	18	13·9	—·876	41	—·877
8249·4471	·8985	2·33	1·63	11·0	16	15·2	—·723	34	—·729	·4416	·2094	2·10	1·58	14·6	18	13·9	—·852	41	—·856
·4575	·9007	2·26	1·61	11·2	15	15·2	—·715	34	—·719	·4552.	·2123	2·15	1·60	14·9	17	13·9	—·866	41	—·870
·4679.	·9030	2·18	1·68	11·5	15	15·1	—·719	34	—·728	·4799	·2177	1·86	1·59	15·5	13	13·3	—·844	34	—·847

TABLE 12 (*continued*).

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	p			h			m		m
8306·4920.	·2203	2·08	1·60	15·8	13	13·3	—·860	34	—·864
8307·3921	·4147	1·98	1·32	13·5	10	14·0	+·353	51	+·345
·4060.	·4177	1·82	1·33	13·8	12	14·0	+·351	51	+·343
·4257	·4220	1·31	1·54	14·3	18	14·7	+·321	35	+·321
·4448.	·4261	1·04	1·54	14·7	19	14·7	+·239	35	+·239
·4680	·4311	1·35	1·59	15·3	16	14·7	+·110	28	+·110
·4861.	·4350	1·54	1·62	15·7	15	14·7	—·020	28	—·020
·5067	·4395	1·64	1·62	16·2	11	14·6	—·155	41	—·156
·5223.	·4428	2·02	1·60	16·6	11	14·6	—·233	41	—·234
·5440	·4477	2·18	1·52	17·1	10	14·5	—·406	41	—·405
·5571	·4504	2·09	1·48	17·4	10	14·5	—·469	41	—·466
·5704.	·4532	2·04	1·47	17·8	10	14·6	—·556	41	—·551
8308·3960	·6316	2·22	1·40	13·6	11	14·5	—·814	40	—·802
·4064	·6338	2·19	1·44	13·9	12	14·5	—·798	40	—·790
·4168.	·6361	2·17	1·46	14·1	12	14·5	—·802	40	—·795
·4320	·6393	2·19	1·58	14·5	14	14·9	—·794	41	—·796
·4424	·6416	2·27	1·56	14·7	14	14·9	—·797	41	—·798
·4528.	·6438	2·30	1·54	15·0	15	14·7	—·823	41	—·822
·5691	·6690	2·36	1·37	17·8	6	13·6	—·772	45	—·758
·5795.	·6712	2·41	1·30	18·0	6	13·6	—·769	45	—·750
8313·5044	·7350	2·09	1·50	16·6	13	14·8	—·786	42	—·782
·5165	·7376	2·25	1·45	16·9	11	14·8	—·811	42	—·803
·5286.	·7402	2·28	1·44	17·2	12	14·8	—·814	42	—·805
·5514	·7451	2·21	1·38	17·7	12	14·9	—·800	28	—·786
·5636.	·7478	2·28	1·36	18·0	12	14·9	—·802	28	—·787
8320·4185	·2285	1·94	1·34	15·0	9	12·9	—·843	45	—·825
·4361.	·2323	2·03	1·40	15·4	8	12·7	—·828	45	—·815
8336·4396	·6890	2·49	1·43	16·5	12	14·7	—·827	56	—·817
·4502	·6913	2·48	1·47	16·7	11	14·8	—·780	56	—·774
·4604.	·6935	2·47	1·46	17·0	12	14·8	—·805	56	—·798
·4756	·6968	2·40	1·54	17·4	13	15·0	—·807	43	—·806
·4859	·6990	2·33	1·54	17·6	14	15·0	—·795	43	—·794
·4959.	·7012	2·42	1·46	17·9	15	14·9	—·808	43	—·801
·5123	·7047	2·30	1·46	18·3	14	14·5	—·793	53	—·786
·5227.	·7070	2·38	1·46	18·5	15	14·5	—·801	53	—·794
·5372	·7101	2·16	1·37	18·9	12	13·6	—·781	48	—·767
·5476.	·7124	2·14	1·30	19·1	14	13·6	—·832	48	—·811
8337·4286	·9027	2·03	1·41	16·3	16	10·4	—·720	41	—·710
·4398	·9051	1·93	1·49	16·6	14	10·4	—·722	41	—·718
·4520.	·9077	2·08	1·44	16·9	14	10·4	—·718	41	—·710
8339·4833	·3465	2·27	1·53	17·8	13	12·0	—·837	54	—·835
·4937	·3487	2·23	1·54	18·0	14	12·0	—·827	54	—·826
·5041.	·3510	2·32	1·58	18·3	14	12·0	—·825	54	—·827
8342·4296	·9829	1·70	1·52	16·7	7	9·5	—·777	55	—·775
·4449.	·9862	1·69	1·50	17·0	9	9·4	—·784	55	—·780

J.D. 242....	P_2	D	G	St	S	F	Δm_1	m.e.	Δm_2
	p			h			m		m
8342·4647	·9905	1·72	1·79	17·5	14	10·3	—·760	36	—·778
·4751.	·9927	1·81	1·67	17·8	12	10·3	—·805	36	—·814
·4896	·9959	1·76	1·72	18·1	12	10·2	—·760	44	—·773
·5000.	·9981	1·95	1·65	18·4	10	10·1	—·794	44	—·802
8344·4513	·4196	1·74	1·49	17·3	10	12·0	+·338	73	+·336
·4720.	·4241	1·59	1·53	17·8	11	12·0	+·266	73	+·265
8347·4395	·0650	1·98	1·49	17·2	17	12·4	—·817	52	—·812
·4633.	·0702	1·81	1·51	17·9	18	12·4	—·822	52	—·819
·4822	·0743	1·80	1·60	18·3	14	12·0	—·826	38	—·830
·4926	·0765	1·83	1·59	18·5	15	12·0	—·830	33	—·833
·5030.	·0788	1·82	1·55	18·9	16	12·0	—·829	38	—·829
·5224	·0830	1·56	1·62	19·2	14	10·3	—·829	37	—·835
·5327	·0852	1·66	1·57	19·5	11	10·3	—·832	37	—·834
·5431.	·0874	1·67	1·57	19·7	12	10·3	—·832	37	—·834
8351·4268	·9263	1·60	1·36	17·2	17	12·8	—·744	39	—·729
·4372.	·9286	1·66	1·36	17·5	18	12·7	—·730	39	—·716
·4517.	·9317	1·71	1·53	17·8	16	14·2	—·736	31	—·734
8389·4048	·1296	2·29	1·59	19·2	10	11·1	—·848	38	—·851
·4153	·1319	2·23	1·60	19·4	13	11·1	—·819	38	—·823
·4257.	·1342	2·04	1·59	19·7	15	11·1	—·829	38	—·832
8390·5030	·3669	2·49	1·39	21·5	21	12·2	—·816	40	—·803
·5184.	·3702	2·53	1·44	21·9	19	12·2	—·744	40	—·736
·5391	·3747	2·59	1·35	22·4	18	9·8	—·660	61	—·647
·5582.	·3788	2·67	1·30	22·7	15	9·8	—·635	61	—·619
8396·3795	·6362	2·35	1·46	18·9	30	12·1	—·844	46	—·836
·3917	·6388	2·36	1·44	19·2	30	12·1	—·827	46	—·818
·4038.	·6414	2·52	1·46	19·5	29	12·1	—·856	46	—·849
·4294	·6470	2·51	1·48	20·1	28	11·9	—·852	66	—·846
·4415	·6496	2·60	1·46	20·4	28	11·9	—·860	66	—·853
·4537.	·6522	2·62	1·50	20·7	22	12·0	—·856	66	—·852
·4753.	·6569	2·83	1·50	21·2	18	12·6	—·842	56	—·837
8403·4272	·1585	2·28	1·57	21·7	18	10·1	—·852	43	—·854
·4378	·1608	2·24	1·58	21·9	19	10·4	—·832	43	—·834
·4567.	·1649	2·41	1·64	22·4	18	10·3	—·837	43	—·845
·4748	·1688	2·47	1·53	22·8	17	10·1	—·865	45	—·863
·4918.	·1725	2·58	1·60	23·2	17	10·1	—·847	45	—·851
8404·4062	·3700	2·45	1·54	20·2	14	12·0	—·772	56	—·771
·4190	·3727	2·49	1·56	20·5	12	11·8	—·728	56	—·728
·4335.	·3759	2·54	1·61	20·9	10	11·9	—·649	56	—·653
·5499.	·4010	2·56	1·57	23·7	11	12·2	+·052	58	+·052
8410·3422.	·6522	2·65	1·46	19·1	12	12·6	—·820	52	—·812
·3546.	·6548	2·56	1·48	19·4	18	13·2	—·851	—	—·845
8421·3544	·0308	2·66	1·66	20·1	13	11·8	—·800	56	—·809
·3665.	·0334	2·54	1·62	20·4	14	11·8	—·786	56	—·791
8426·3976	·1202	2·78	1·48	21·4	13	10·8	—·836	50	—·830
·4113	·1231	2·89	1·42	21·8	14	10·6	—·843	50	—·832

The light curve is shown in Figure 2. Each dot represents a normal point of 10 means Δm_2. The maximum brightness is greater near the primary minimum than near the secondary. From least squares solutions the inclination of the light curve is found to be:

m/p		m/p	
·0104	±	·0023	(m.e.) between the primary and the secondary minimum,
·0088	±	·0027	(m.e.) between the secondary and the primary minimum,
·0098	±	·0020	(m.e.) for both parts.

The fluctuations, though the value of the inclination is five times the mean error, are probably not real variations of the brightness of the variable, but are caused by systematic errors. Also from the phases of both minima it can not be concluded that the orbit is somewhat eccentric.

FIGURE 2.

Normal points of 10 means Δm_2.

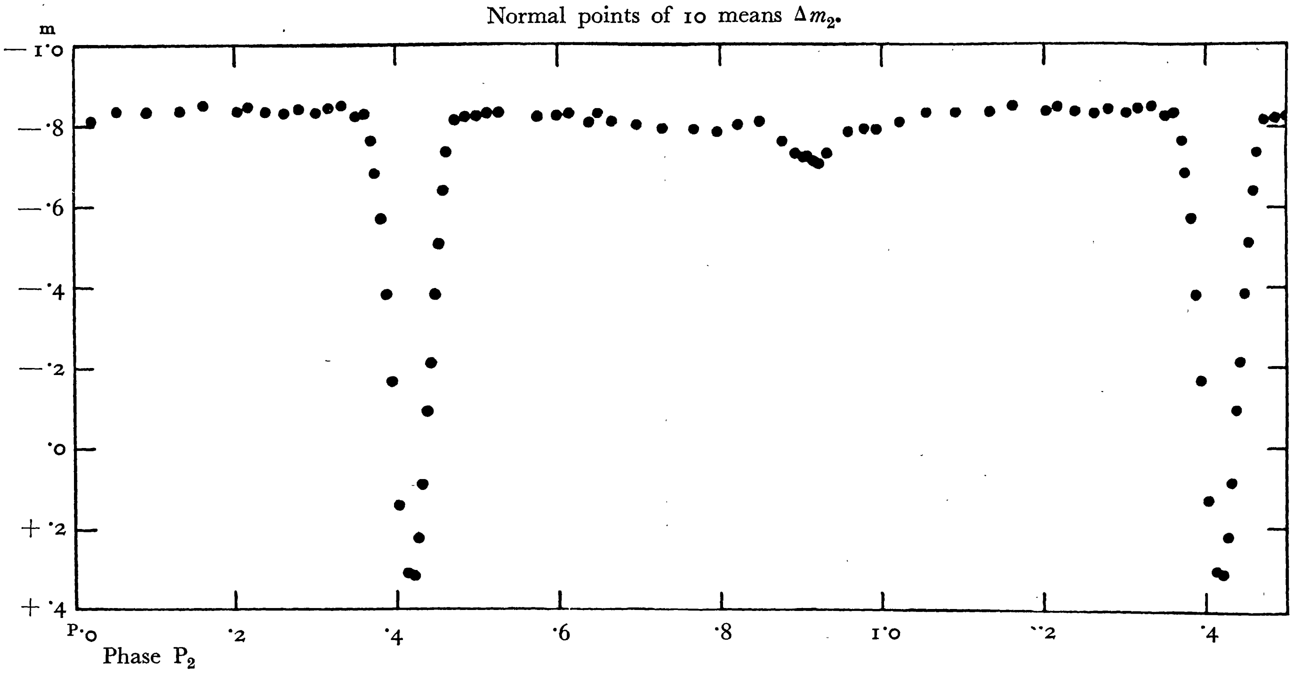
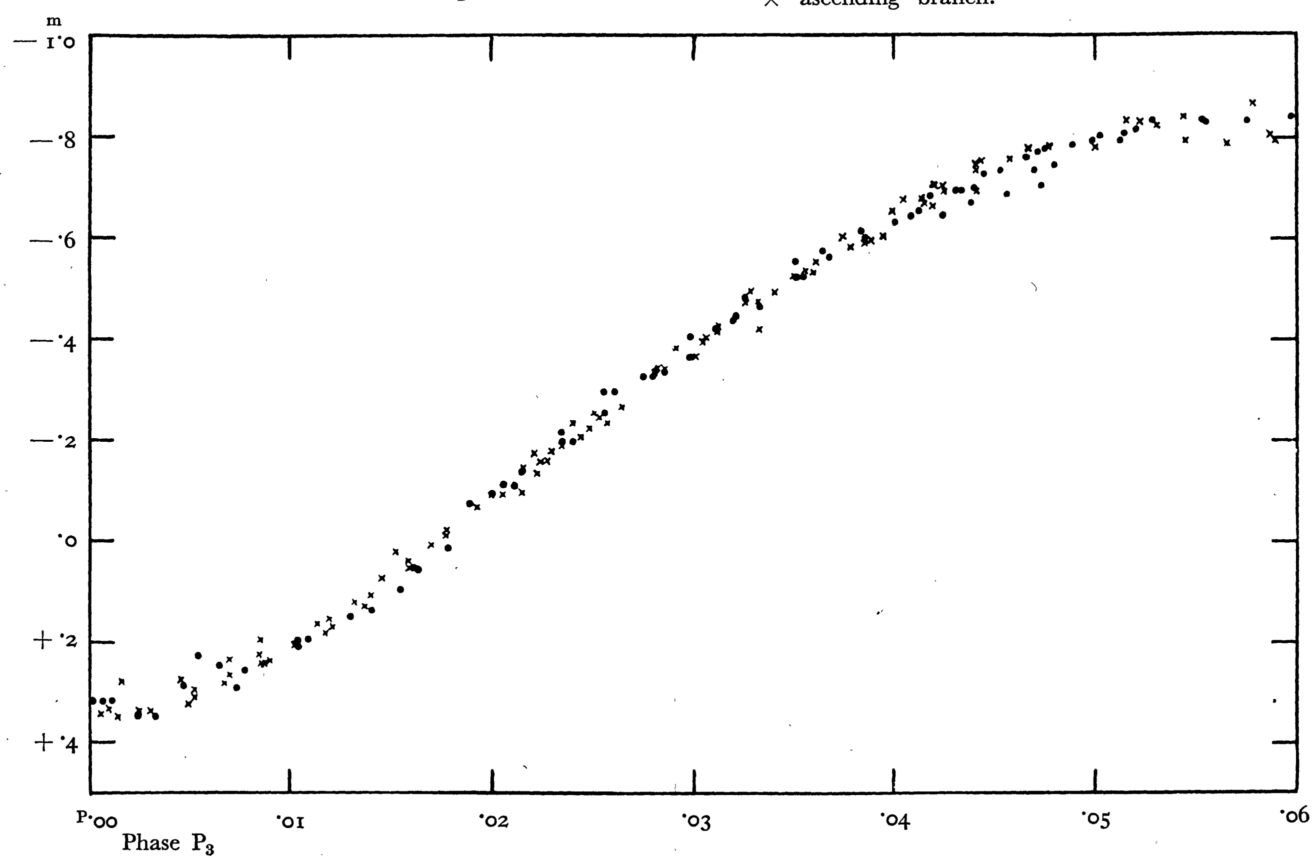


FIGURE 3.

Means Δm_2 of about 10 observations, ● descending branch, × ascending branch.



New phases $P_3 = |P_2 - {}^{P}{\cdot}4171|$ or reflected with respect to the primary minimum, have been computed. The observations on both branches of the primary minimum are given in Figure 3. Normal points representing 10 Δm_2's which follow each other in phase P_3 have been derived (Table 13, last line mean of 11).

The asymmetry of the maximum and the secondary minimum is also shown by a comparison of the external mean errors of one Δm_2, derived when they are arranged respectively according to the phases P_2 (see p. 128) or P_3. For this latter case the square of the mean external error is:

for the maximum	$^{m^2}{\cdot}000485 = (\pm\ ^{m}{\cdot}022)^2$	from 329	differences,
for the primary minimum	$\cdot000499 = (\pm\ \cdot022)^2$	„ 169	„
for the secondary minimum	$\cdot000495 = (\pm\ \cdot022)^2$	„ 82	„

The maximum magnitude of the combined light of both stars has been determined by BERGSTRAND (*Medd. Upsala* No. 57, 1933) to be $8^m{\cdot}41 \pm {}^m{\cdot}04$ (m.e.). Then the maximum brightness of WW Draconis is $8^m{\cdot}82 \pm {}^m{\cdot}04$ (m.e.).

TABLE 13.
Normal points.

P_3	Δm_2	P_3	Δm_2	P_3	Δm_2	P_3	Δm_2
P	m	P	m	P	m	P	m
·0015	+·328	·0483	—·768	·1859	—·832	·3907	—·796
·0054	+·280	·0528	—·823	·1934	—·835	·4095	—·808
·0086	+·237	·0588	—·823	·2030	—·842	·4219	—·804
·0122	+·155	·0650	—·823	·2126	—·832	·4307	—·793
·0158	+·055	·0706	—·837	·2210	—·824	·4411	—·804
·0197	—·081	·0799	—·842	·2320	—·833	·4529	—·790
·0226	—·164	·0880	—·838	·2451	—·830	·4628	—·759
·0251	—·244	·0939	—·834	·2601	—·836	·4738	—·745
·0284	—·343	·1010	—·845	·2763	—·819	·4833	—·738
·0313	—·427	·1086	—·841	·2844	—·825	·4873	—·723
·0341	—·495	·1181	—·832	·3029	—·814	·4905	—·730
·0371	—·576	·1362	—·841	·3325	—·810	·4938	—·712
·0403	—·645	·1515	—·829	·3504	—·813	·4983	—·716
·0427	—·689	·1622	—·832	·3653	—·821		
·0453	—·740	·1741	—·830	·3774	—·803		

The mean result of the 18 photovisual exposures is given in the first line of Table 14. All these exposures have been taken during the maximum. They have been reduced in the same way as the photographic exposures with the exception that no correction for systematic errors has been applied. Prof. HERTZSPRUNG has been so kind to place at my disposal three photovisual plates of WW Draconis, which had been taken by him with the 36-inch refractor of the Lick Observatory. These plates, however, show a very irregular plate fog. The two plates L 40 and L 41 have been taken without a grating and were therefore reduced by the aid of a mean gradation derived from measurements of a series of similar plates by Mr. KOOREMAN. The mean internal error of one photovisual exposure is $\pm\ ^m{\cdot}07$. The results of the Lick plates are also given in Table 14. The last column gives a comparison with the photographic light curve. For the middle of the primary minimum $\Delta m_{pg} - \Delta m_{pv} = +\ ^m{\cdot}500$ may be derived herefrom. The different amplitudes are:

TABLE 14.
Photovisual exposures.

Plate	*n*	J.D. – 2420000	Δm_{pv}	P_3	$\Delta m_{pg} - \Delta m_{pv}$
			m		m
Leiden	18	—	—1·079	maximum	} +·254
L 17	7	8752·6806	—1·080	·1809	}
L 40	18	8765·6703	— ·391	·0133	+·519
L 40	18	·6767	— ·350	·0119	+·509
L 40	18	·6901	— ·286	·0090	+·498
L 40	17	·7034	— ·144	·0061	+·514
L 41	18	·7635	— ·201	·0068	+·465
L 41	17	·7703	— ·208	·0083	+·446

photographic amplitude of the primary minimum	$1^m{\cdot}153 \pm\ ^m{\cdot}006$ (m.e.),
photographic amplitude of the secondary minimum	$0\ {\cdot}111 \pm\ \cdot003$ (m.e.),
photovisual amplitude of the primary minimum	$0\ {\cdot}907 \pm\ \cdot021$ (m.e.).

Dr. A. H. JOY has been so kind to place at my disposal the preliminary results derived from about twenty spectrograms taken at the Mt. Wilson Observatory.

Dr. JOY writes:

	Amplitude in radial velocity	Mass	Spectrum
"Primary component of WW Draconis	95 km/sec	3·4 ⊙	gG5
secondary component of WW Draconis	135 „	2·4 ⊙	gG8

The spectrum of the secondary is very much weaker than that of the primary, and it has been possible to measure only a few lines, but the velocity curve for the primary is well defined and I think fairly accurate. There seems to be no indication of eccentricity in the orbit. The spectral type of the secondary is determined from plates taken at primary minimum on the assumption that the eclipse is total or nearly so."

Determination of orbital elements.

The same method as used in the case of CV Carinae (*B.A.N.* No. 323, 1939; compare also VAN GENT, *B.A.N.* No. 215, 1931) has been followed. The real variation of the intensity during the maximum could not be determined on account of systematical errors as mentioned above. Therefore the reflection effect has been neglected and also the components have been assumed to be spherical, though it may be possible to make some theoretical assumptions. As found by Dr. JOY the orbit is circular. The two extreme assumptions about limb darkening, the *U* and *D* hypotheses, have been made.

U hypothesis.

From the amplitudes of both minima, $1-l$ (min I) $= {\cdot}6542$ and $1-l$ (min II) $= {\cdot}0972$, the ratio of the surface brightnesses $J_1 : J_2 = 6{\cdot}73 = -2^m{\cdot}07$ is derived. The smaller component is the brighter one.

Suppose:

L_1, L_2 = the intensities of both components,
k = the ratio of the radii, $k \leq 1$,
r_1, r_2 = the radii in units of the radius of the orbit,
δ = the projected distance of the centres of both stars in the same unit,
α_1, α_2 = the loss of light in units of the intensity of the eclipsed component,
θ = the orbital longitude counted from mid-eclipse,
i = the inclination of the orbit.

For different values of k the intensities L_1 and L_2 are given in Table 15 as derived from

$$L_2 = \frac{1}{6{\cdot}73\,k^2 + 1}, \quad L_1 + L_2 = 1.$$

TABLE 15.

Results of the different theoretical light curves.

	k	L_1	L_2	Δm	m.e. of a single normal point	r_2	m.e.	i	m.e.
				m	m			°	°
U	·53	·6540	·3460	·691	± ·0088	·2284	± ·0014	83·6	± ·1
	·58	·6936	·3064	·887	·0091	·2271	9	83·3	·1
	·63	·7276	·2724	1·067	·0143	·2227	14	83·4	·1
	·68	·7568	·2432	1·233	·0191	·2178	19	83·6	·2
	·73	·7820	·2180	1·387	·0231	·2128	22	83·9	·2
D	·50	·6560	·3440	·701	·0259	·2394	36	82·1	·2
	·60	·7157	·2843	1·002	·0075	·2350	8	82·0	·1
	·70	·7732	·2268	1·332	·0087	·2259	9	82·4	·1

In the fourth column the difference in magnitude between both components is given. Then α for mid-eclipse is known for each k. The eclipse of the smaller, brighter component is total for $k = {\cdot}5302$. A smaller value of k is not possible without varying the ratio of the surface brightnesses.

Following RUSSELL (*Ap. J.* 35, 315, 1912):

$$\left(\frac{\delta}{r_2}\right)^2 = \frac{1}{r_2{}^2} - \frac{1}{r_2{}^2}\cos^2\theta\,\sin^2 i.$$

The quantities α and θ are known for each normal point, $\frac{\delta}{r_2}$ has been tabulated by HETZER (*Beitrag zu*

TABLE 16.

O—C for different theoretical light curves.

Phase	$m-m_{max}$	*U* hypothesis					*D* hypothesis		
		$k =$ ·53	·58	·63	·68	·73	·50	·60	·70
P	m	m	m	m	m	m	m	m	m
·0483	·057	+ ·009	− ·003	− ·010	− ·016	− ·021	+ ·026	+ ·005	− ·007
·0453	·085	− 5	− 18	− 24	− 29	− 34	+ 17	− 6	− 18
·0427	·136	+ 3	− 9	− 15	− 20	− 23	+ 27	+ 3	− 7
·0403	·180	+ 2	− 10	− 15	− 18	− 21	+ 24	+ 3	− 6
·0371	·249	+ 2	− 7	− 10	− 12	− 14	+ 18	+ 3	− 3
·0341	·330	+ 10	+ 4	+ 3	+ 2	+ 2	+ 18	+ 10	+ 8
·0313	·398	+ 4	+ 2	+ 2	+ 3	+ 4	+ 2	+ 2	+ 4
·0284	·482	+ 4	+ 6	+ 9	+ 11	+ 13	− 8	0	+ 6
·0251	·581	+ 1	+ 8	+ 13	+ 17	+ 21	− 22	− 3	+ 7
·0226	·661	− 2	+ 10	+ 16	+ 22	+ 26	− 30	− 5	+ 7
·0197	·744	− 15	0	+ 7	+ 13	+ 18	− 46	− 18	− 4
·0158	·880	− 6	+ 12	+ 19	+ 25	+ 29	− 31	− 2	+ 9
·0122	·980	− 10	+ 6	+ 11	+ 14	+ 17	− 20	0	+ 5
·0086	1·062	− 10	− 3	− 3	− 4	− 5	− 2	+ 2	− 3
·0054	1·105	− 10	− 14	− 20	− 26	− 31	+ 9	− 2	− 15
·0015	1·153	+ 16	− 2	− 14	− 23	− 31	+ 38	+ 15	− 4

H. N. RUSSELL's *Methode* . . ., Diss., Leipzig 1931) for the case of the U hypothesis as a function of k and α.

Suppose:

$$u = \left(\frac{\delta}{r_2}\right)^2 ; t = -\cos^2\theta ; A = \frac{1}{r_2^{\,2}} ; B = \frac{1}{r_2^{\,2}} \sin^2 i.$$

Then for a fixed value of k each normal point gives an equation of condition of the usual form $u = A + Bt$ for the determination of r_2 and i.

The normal points used for such least squares solutions are given in Table 16. The weights for u, which are not all the same, have been determined empirically by computing u also for $m - m_{max} + {}^{m}{\cdot}005$. They are taken proportional to $(\Delta u)^{-2}$. Table 16 and Figure 4 give the O—C's for the various solutions. The resulting values of r_2, i and the mean error of a single normal point, as derived from the O—C's, are given in Table 15, while this mean error is plotted against k in Figure 5 (the right one of the dotted lines gives k for total eclipse).

FIGURE 4.

O—C's of the normal points.

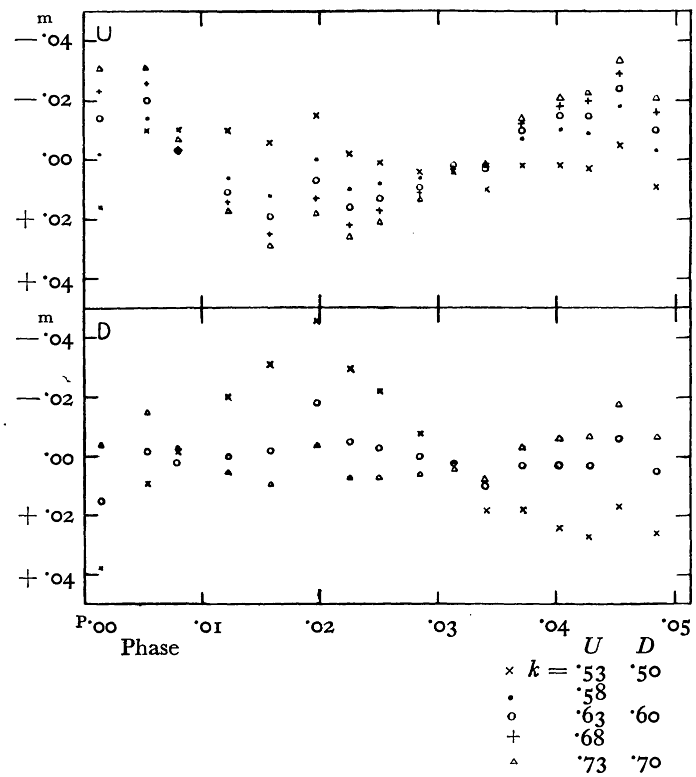
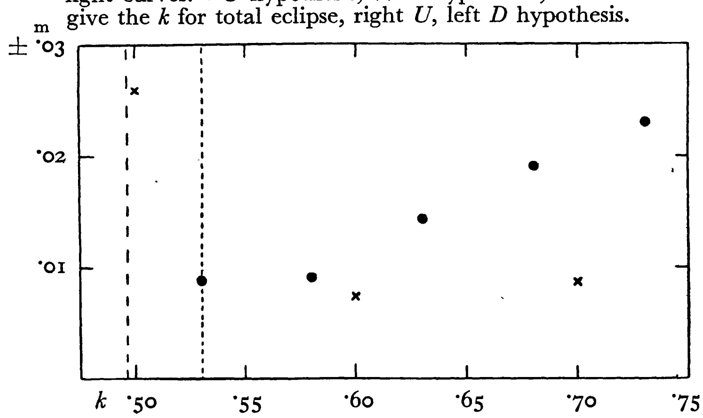


FIGURE 5.

Mean error of a single normal point for different theoretical light curves. • U hypothesis, × D hypothesis, the dotted lines give the k for total eclipse, right U, left D hypothesis.



The agreement between the observed and the theoretical light curves is best for $k = {\cdot}55$. The resulting elements are given in Table 17. The mean errors have been determined by the method of PANNEKOEK and Miss VAN DIEN (*B.A.N.* No. 297, 1937). Here it should be mentioned that the whole derivation of the elements k, r_2 and i is based on the ratio of surface brightnesses, for which quantity a fixed value has been adopted as derived from the depths of both minima. Thus the normal point near the middle of the primary minimum has received a too large weight. The disadvantage of this fact can be avoided if both minima are observed with the same accuracy during the whole partial phases. In this case the ratio of the surface brightnesses can be determined by the aid of the whole light variation during the minima, as has been done by WESSELINK (l.c.).

TABLE 17.

Definitive results.

	U hypothesis	(m.e.)	D hypothesis	(m.e.)
k	·55	± ·03	·64	± ·03
r_2	·228	± ·003	·231	± ·004
i	83°·5	± °·2	82°·2	± °·2
J_1:J_2	6·73	± ·15	6·99	± ·16
Δm	m·79	± m·11	1m·14	± m·11
D	P·1094	± P·0024	P·1162	± P·0024

D hypothesis.

For the middle of both eclipses:

$$\alpha_2 = \frac{\alpha_1\,[1 - \mathrm{l\,(min\,II)}]}{\alpha_1 - [1 - \mathrm{l\,(min\,I)}]} = \frac{{\cdot}0972\,\alpha_1}{\alpha_1 - {\cdot}6542}.$$

Further, for both eclipses:

$\left(\frac{\delta}{r_2}\right)_1 = f_1\,(k, \alpha_1)$ resp. $\left(\frac{\delta}{r_2}\right)_2 = f_2\,(k, \alpha_2)$, while for corresponding phases at both eclipses $f_1\,(k, \alpha_1) = f_2\,(k, \alpha_2)$. Here the indices of α, $\left(\frac{\delta}{r_2}\right)$ and f refer to the eclipses of the component 1 resp. 2. The function f_1 has been tabulated by ZESSEWITSCH (*Poulkovo Circ.*

No. 24, 41, 1938), the function f_2 by RUSSELL and SHAPLEY (*Ap. J.* **36**, 39, 1912, Table I_y).

Thus, for a fixed value of k there are two relations which connect α_1 and α_2 for the middle of the eclipses and these quantities can be determined. Table 15 gives the values of L_1, L_2 and Δm as derived from α_1 and α_2. The eclipse is total for k = ·4953 (the left one of the dotted lines in Figure 5). The elements k, r_2 and i have been determined in the same way as in the case of the U hypothesis and the results and the O—C's are given in the corresponding tables and figures. The difference in magnitude between the components, $\Delta m = 1^m{\cdot}14 \pm {}^m{\cdot}11$, can scarcely be brought into agreement with the fact that the spectral lines of the fainter component have been measured on some of the Mt. Wilson spectrograms. The remark made above at the end of the computations for the U hypothesis holds also here.

No conclusion about the limb darkening can be made.

TABLE 18.

Absolute dimensions.

K_2		masses M_1	masses M_2	radius of the orbit a	r_1		r_2	
units: km/sec		☉	☉	10^6km	10^6km	$r_☉$	10^6km	$r_☉$
U	120	2·72	2·16	13·8	1·73	2·49	3·14	4·52
	135	3·51	2·47	14·7	1·84	2·65	3·35	4·82
	150	4·42	2·80	15·7	1·97	2·83	3·58	5·15
D	120	2·73	2·18	13·7	2·02	2·91	3·16	4·55
	135	3·53	2·48	14·8	2·19	3·15	3·42	4·92
	150	4·46	2·82	15·8	2·34	3·37	3·65	5·25

Absolute magnitudes.

K_2		photographic 1	photographic 2	bolometric 1	bolometric 2	bolometric according to EDDINGTON, *I.C.S.* 1	bolometric according to EDDINGTON, *I.C.S.* 2	parallax	distance
km/sec		m	m	m	m	m	m	″	
U	120	+ 4·94	+ 5·73	+ 3·74	+ 3·86	+ 1·03	+ 1·95	·0138	72 ps
	135	+ 4·80	+ 5·59	+ 3·60	+ 3·72	+ 0·25	+ 1·50	·0129	78
	150	+ 4·66	+ 5·45	+ 3·46	+ 3·58	— 0·40	+ 1·09	·0121	83
D	120	+ 4·60	+ 5·74	+ 3·40	+ 3·87	+ 1·02	+ 1·92	·0126	79
	135	+ 4·43	+ 5·57	+ 3·23	+ 3·70	+ 0·23	+ 1·48	·0114	88
	150	+ 4·28	+ 5·42	+ 3·08	+ 3·55	— 0·43	+ 1·07	·0106	94

Absolute dimensions.

The absolute dimensions can be derived from the combination of the spectroscopic and photometric observations in the usual manner. The amplitude K_2 of the radial velocity of the fainter component is not accurately known. Therefore the computations have been made for the values K_2 = 120, 135 and 150 km/sec. The results are given in Table 18. The absolute bolometric magnitudes are very sensitive to small changes in K_1 and K_2 when the mass-luminosity relation is used. Therefore the discrepancy between these absolute magnitudes and those derived from the combination of the photometric and spectroscopic observations is probably not real.

With the assumption of a distance of 80 parsecs the projected distance between WW Draconis and component B of Σ 2092 is $1{\cdot}0 \cdot 10^{11}$ km. This value multiplied with 1·13 yields the probable value of the semi-major axis of the orbit (HERTZSPRUNG, *B.A.N.* No. 25, 1922). With the assumption of 9 ☉ as the sum of the masses of the three stars the period of Σ 2092 is of the order of 7000 years.