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Photographic Observations of the Brightness of Neptune

Second paper:

Variability and Period of Rotation

By

E. Öpik and R. Livländer

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Abbreviation:

This series of publications is denoted for brevity's sake by the initial letters *T. P.*

K. Mattieseni trükk, Tartus.

Photographic Observations of the Brightness of Neptune.

Continued from *T.P.* 25_3 (1923).

1. Arrangement of Observations and Measures.

The method of observation and measurement was fully described in the preceding paper on the same subject[1]); so here shall be pointed out only those details in which the present investigation differs from the preceding one.

The diaphragm with the side-holes[2]) was placed immediately before the objective, at a distance of about 1 cm; the proportions of the diaphragm remained unchanged. The photographs were taken at an average distance = 2.9 mm extrafocally. The same rotating plate-holder was used as in the preceding year[3]); with the aid of this plate-holder two fields could be photographed on different places of the same plate, so that each plate might be made equivalent to two independent negatives. Within each field only two neighbouring photographs were obtained; such a small number was chosen with the purpose in view to reduce the danger of superposition of images of other stars on the image of Neptune. The guiding during the exposure was made always by pointing on Neptune, so that the image of the latter appeared in the centre of the field. The photographs were all obtained on Hauff Ultra-Rapide plates, Emulsion 10871.

The microphotometer readings and the measurement of the diameter (distance between the side-images) were made exactly in the same manner as described in the first paper[4]). As a

1) **T.P.** 25_3.
2) *Loc. cit.* p. 6, fig. 1.
3) *Loc. cit.* p. 7.
4) *Loc. cit.* pp. 12—16.

measure of the photographic intensity was taken the difference Δ between the microphotometer reading on the extrafocal stellar image and the mean reading on a number of points on the background of the free plate near the image.

All measures with the microphotometer and the general discussion of results were made by E. Ö. All measures of the diameter and the major part of the reductions were made by R. L., and a part of the computations — by Miss A. Piiri.

Table 1 gives the particulars of all photographs. Only clear, transparent and dark nights were chosen for observation. A number of exposures were, nevertheless, not measured, the reason for rejecting being chiefly haze or moonlight. As a rule,

Table 1.

Plate, Field and Exposure	Sid. Time of Middle	Duration	Observer	Remarks
				December 16, 1922.
	h m			
47 II 1	7 59.8	600s	Ö.	
2	8 16.9	„	„	$t^0 = -9^0.5$ C
47 I 1	8 35.1	„	„	
2	8 52.7	„	„	20^m after last exposure haze
				December 18, 1922.
52 II 1	6 48.6	600	Ö.	
2	7 02.1	„	„	
52 I 1	7 18.2	„	„	
2	7 31.8	„	„	
53 I 1	7 55.8	„	„	
2	8 11.0	602	„	
53 II 1	8 29.2	600	„	
2	8 45.6	„	„	$t^0 = -9^0.9$ C
54 II 1	9 12.4	„	„	
2	9 29.8	„	„	
54 I 1	9 47.9	„	„	
2	10 01.4	„	„	
55 I 1	10 58.2	„	„	
2	11 12.0	„	„	
55 II 1	11 25.7	„	„	
2	11 41.2	„ (?)	„	
				January 23, 1923.
57 I 1	8 20.9	600	Ö.	
2	8 35.3	„	„	$t^0 = -5^0.0$ C
57 II 1	8 51.8	„	„	Plates 57 and 58 were recorded in
2	9 07.0	„	„	the diary under the same number,
58 II 1	9 29.3	„	„	so the right order in which they were
2	9 42.8	„	„	taken is unknown. For this reason
58 I 1	9 59.6	„	„	both plates were not measured.
2	10 15.9	„	„	

Table 1. Continued.

Plate, Field and Exposure	Sid. Time of Middle	Duration	Observer	Remarks
				February 12, 1923.
	h m			
64 I 1	6 13.6	611s	L.	
2	6 32.8	600	Ö.	
64 II 1	6 48.7	800	„	
2	7 03.1	600	„	
65 II 1	7 26.5	„	„	
2	7 38.8	„	„	
65 I 1	7 53.8	„	„	
2	8 08.3	„	„	$t^0 = -12^0.4$ C
66 I 1	8 49.8	600 ±	L.	
2	9 12.8	607	„	
67 I 1	11 34.8	605(?)	Ö.	
2	11 47.6	600 ±	„	
67 II 1	12 02.6	752 ±	„	
2	12 15.8	600	„	
68 II 1	12 31.2	„	„	
2	12 48.8	„	„	
68 I 1	13 04.3	„	„	
				February 13, 1923.
70 I 1	6 34.5	600	Ö.	
2	6 47.9	„	„	
70 II 1	7 03.3	„	„	
2	7 15.5	„	„	
71 II 1	7 39.6	606	„	
2	7 55.7	725	„	
71 I 1	8 11.5	600	„	
2	8 24.0	„	„	
72 I 1	9 18.0	„	L.	$t^0 = -14^0.5$ C
2	9 38.0	613	„	
73 II 1	11 28.2	600	Ö.	
2	11 40.3	„	„	
73 I 1	11 54.2	„	„	
2	12 06.0	„	„	
74 I 1	12 28.0	„	„	
2	12 42.0	„	„	
74 II 1	12 55.5	„	„	
2	13 08.0	„	„	
				February 22, 1923.
75 I 1	11 13.3	600	Ö.	
2	11 26.5	„	„	* $t^0 = -16^0.2$ C
75 II 1	11 40.1	„	„	On the exposures marked with *
2	11 53.5	„	„	* falls evidently a superposed image
76 II 1	12 09.0	„	„	* of a 12—13 magn. star.
2	12 21.2	„	„	
76 I 1	12 36.0	„	„	
2	12 49.8	750	„	*
				March 5, 1923.
77 I 1	7 26.6	600	Ö.	
2	7 37.7	750	„	$t^0 = -6^0.5$ C

Table 1. Continued.

Plate, Field and Exposure	Sid. Time of Middle	Duration	Observer	Remarks
	h m			March 5, 1923. Continued.
77 II 1	7 53.5	600s	Ö.	
2	8 07.1	„	„	
78 II 1	8 28.3	604	„	Brightening background } these two exposures not measured.
2	8 41.5	602	„	Moon above horizon }
				March 6, 1923.
80 I 1	6 57.5	602	Ö.	$t^0 = -12^0.0$ C } not measured
2	7 10.4	600	„	
80 II 1	7 27.0	755	„	
2	7 40.8	600	„	Haze rapidly forming }
				March 12, 1923.
81 I 1	8 03.1	600	Ö.	
2	8 17.0	„	„	
81 II 1	8 32.2	„	„	
2	8 47.2	„	„	$t^0 = -6^0.5$ C
82 II 1	9 07.3	601	„	
2	9 20.7	762	„	
82 I 1	9 37.5	600	„	
2	9 51.0	„	„	
83 I 1	11 46.0	„	„	
2	11 58.3	„	„	
83 II 1	12 13.8	„	„	During last exposure haze ; not measured.
				March 13, 1923.
84 I 1	8 13.7	600(?)	Ö.	
2	8 26.7	600±	„	
84 II 1	8 43.4	600	„	
2	8 56.9	600(?)	„	$t^0 = -2^0.3$ C
85 II 1	9 21.7	600	„	
2	9 35.0	„	„	
85 I 1	9 50.2	606	„	
2	10 08.3	600	„	
86 I 1	10 29.8	„	„	
2	10 45.8	600±	„	
86 II 1	10 59.9	600	„	
2	11 12.4	„	„	
				March 15, 1923.
87 I 1	7 33.7	600	Ö.	
2	7 45.8	„	„	
87 II 1	8 02.5	600(?)	„	Haze } not measured
2	8 12.3	251	„	Interrupted by haze }
				March 16, 1923.
88 I 1	7 40.4	600	Ö.	
2	7 52.9	„	„	
88 II 1	8 07.0	„	„	
2	8 19.7	„	„	
89 II 1	8 36.4	„	„	
2	8 50.9	760±	„	$t^0 = 0^0.0$ C

Table 1. Continued.

Plate, Field and Exposure	Sid. Time of Middle	Duration	Observer	Remarks
	h m			
March 16, 1923. Continued.				
89 I 1	9 05.9	600^s	Ö.	
2	9 20.4	„	„	
90 I 1	9 36.6	„	„	
2	9 51.6	„	„	
90 II 1	10 04.5	„	„	
2	10 17.5	„	„	
91 I 1	11 05.4	620±	L.	
2	11 19.9	602	„	
91 II 1	11 39.0	720	„	
2	11 56.7	600	„	
92 I 1	12 20.0	„	„	
2	12 35.0	„	„	
92 II 1	12 51.1	„	„	
2	13 04.9	„	„	
March 18, 1923.				
93 I 1	7 45.5	600	Ö.	
2	7 57.6	„	„	
93 II 1	8 12.4	„	„	
2	8 26.6	600±	„	$t^0 = + 1^0.2$ C
94 II 1	8 44.6	600	„	
2	8 57.6	„	„	
94 I 1	9 12.1	„	„	
2	9 26 5	755	„	
95 I 1	9 52.1	605	„	
2	10 04.9	540	„	Interrupted by clouds.
March 19, 1923.				
96 I 1	7 51.3	600	Ö.	*
2	8 02.6	606±	„	
96 II 1	8 17.9	600	„	*
2	8 32.0	600(?)	„	
97 II 1	8 50.4	800	„	* $t^0 = — 0^0.8$ C
2	9 04.7	600	„	
97 I 1	9 17.7	„	„	* The exposures marked with * have a partial superposition with a 12 mg. star.
2	9 30.7	„	„	
98 I 1	9 50.4	„	„	*
2	10 03.4	„	„	
98 II 1	10 17.7	„	„	*
2	10 30.6	„	„	
99 I 1	11 10.2	„	L.	*
2	11 26.1	„	„	
99 II 1	11 42.5	„	„	*
2	11 58.7	720	„	
100 I 1	12 21.5	600	„	*
2	12 35.6	600±	„	
100 II 1	12 51.9	600	„	*
2	13 06.0	„	„	
March 20, 1923.				
101 I 1	8 12.3	600	Ö.	Clouds interrupted } not measured
2	8 21.0	146	„	

Table 1. Continued.

Plate, Field and Exposure	Sid. Time of Middle	Duration	Observer	Remarks
				March 21, 1923.
	h m			
102 I 1	8 14.4	600s	Ö.	
2	8 27.3	602	„	
102 II 1	8 39.7	600	„	
2	8 52.0	„	„	
101 II 1	9 07.8	„	„	
2	9 23.8	„	„	
103 II 1	9 37.7	„	„	Haze, clouds pass. } not measured
2	9 56.0	„	„	Haze, brightness varying considerably } not measured

those days when it was possible to obtain less than 4 reliable exposures were entirely rejected; so were rejected the observations of March 6 (4 exposures, last hazy), March 15 (4 exposures, last two hazy), March 20 (only 2 exposures); next was rejected every exposure during which the appearance of *haze* was noted, as on March 12 (last exposure) and March 21 (2 last exposures); the interruption by *clouds* seemed to offer no reason for rejection, as the disappearance in this case is usually almost instantaneous and hardly influences the difference of brightness of Neptune and the near comparison stars. On account of moonlight and fogged background were rejected 2 exposures on March 5, although the sky was perfectly clear. All exposures of January 23 were also not measured, though taken at apparently perfect conditions; the reason was that because of an error of recording the right order of the plates was unknown, and the plates could not be used for our chief purpose — the investigation of the variability and period of rotation. Therefore out of the total number of 168 exposures 23 were judged as not worth of measurement, and only the remaining 145 were measured. After measurement no rejection took place, and all these 145 exposures were used with equal weight, as will be shown later on.

2. Reduction of the Measures.

Table 2 contains the data for the comparison stars used, together with the coordinates of Neptune.

Table 2. Comparison Stars.

Denotation	B. D.	Magn.	1923.0 α	1923.0 δ	1855.0 α	1855.0 δ	Distance from Neptune Dec. 18	Distance from Neptune Febr. 13	Distance from Neptune March 16	Magnit. adopted (zero-point arbitrary)	Remarks
			h m		h m		mm	mm	mm		
m	16°1930	8.0	9 11	+16°.3	9 06.9	+16°35′	—	19.4	8.9	9.457	
p	17 2053	8.0	9 13	17 .0	9 09.6	17 19	—	16.9	10.3	9.196	Variable (eclipsing ?)
r	16 1956	8.2	9 18	16 .1	9 14.7	16 24	13.0	7.0	17.3	8.757	
s	15 2013	8.5	9 12	15 .4	9 08.2	15 42	—	17.1	12.6	9.557	
t	15 2011	8.5	9 12	15 .3	9 07.9	15 37	—	18.8	14.5	8.919	
z	15 2049	8.0	9 23	14 .8	9 18.9	15 8	11.2	—	—	8.853	
w	15 2048	8.2	9 23	15 .2	9 18.8	15 34	5.5	23.2	—	9.471	
α	14 2095	7.2	9 23	14 .6	9 19.0	14 55	13.9	—	—	9.099	Gött. Act. 1369;m=7.99
i	15 2055	8.5	9 24	15 .5	9 20.4	15 48	7.9	—	—	9.735	
Neptune, Dec. 18			9 22	15 .6							
„ Febr. 13			9 16	16 .0							
„ March 16			9 13	16 .3							

The first column of this table gives the letter by which the star is denoted in the following discussion; the second and third columns — the number and magnitude according to the B. D. The 8th, 9th and 10th columns give the distance of the star from Neptune for three principal dates of observation; the distances were directly measured on the plate and are expressed in mm; a vacant place in the column of distance indicates that the star was out of the field (of about 50 mm diameter) and could not be used. The 11th column contains the finally adopted magnitudes of the stars, reckoned from an arbitrary zero-point and derived from the photographs themselves; the method of deriving these magnitudes will be explained below. The star *p* proved to be a variable; its variation of a range of about 0.4 mg. was observed only on 1 day, March 19, when it showed a minimum during 4 hours; on all other days it remained practically constant, with a mean square deviation of only ± 0.06 mg.; it was therefore used as a comparison star on all days except March 19; the magnitude adopted for *p* refers to the normal state, the minimum not being taken into account [1]).

The correction for varying distance from the focus was applied as explained in the first paper [2]). Besides irregularities produced by occasional curvature of the plate, there should be

1) For particulars concerning this star consult the *Appendix*.
2) *Loc. cit.* pp. 13—17.

expected a systematical error in the brightness depending on the distance from the centre and due chiefly to optical distorsion; indeed near the edge of the field the extrafocal images became elliptical; nevertheless our method of measuring diameters in two perpendicular directions proved to be excellent from this standpoint also, since this source of error was authomatically eliminated: photographs of the North Polar Sequence and measures of the comparison stars used in the present investigation indicated that after applying the correction for diameter there remained no residual systematic error as great as 0.01 st. mg. for distances varying from 0 to 25 mm from the centre of the field; such a result could be expected *a priori* since the two perpendicular diameters give a measure of the area of the ellipse (the excentricity being small); on the other hand, this area represents the reciprocal of the surface brightness.

The correction for atmospherical absorption was computed on the assumption of a constant coefficient of absorption, γ, throughout all measures; the value $\gamma = 0.50$ st. mg. per unit of air-mass was adopted. Table 3 was computed which allowed of finding the differential absorption directly from the differences in right ascension and declination for a given hour-angle.

Table 3.

Differential Absorption for $\delta = +13^\circ \ldots + 17^\circ$ and $\varphi = +58^\circ.4$

Hour-Angle	$\pm 0^h$	$\pm 1^h$	$\pm 2^h$	$\pm 3^h$	$\pm 4^h$
Differential Absorption (st. mg.) for $\Delta\delta = +1^\circ$	—0.010	—0.011	—0.013	—0.017	—0.026
Differential Absorption (st. mg.) for $\Delta\alpha = +1^m$	0.0000	$\mp$0.0005	$\mp$0.0011	$\mp$0.0021	$\mp$0.0038

The convertion of the microphotometer readings into stellar magnitudes was made with the aid of data furnished by 7 extrafocal photographs of the North Polar Sequence made for another purpose [1]) on plates of the same sort and emulsion; the circumstances under which these photographs were taken and developed correspond very nearly to the average conditions for the photographs of Neptune and the same diaphragm was used. As the data for the N. P. S. will appear *in extenso* in a future publication, we shall give here only the final result. Table 4

1) Photometry of globular clusters and spiral nebulae.

gives the stellar magnitude, m, corresponding to a given photographic density, Δ (difference of image and background); the zero-point of magnitudes is quite arbitrary. The magnitudes of the N. P. S. used in deriving this table were adopted according to Fr. H. Seares [1]).

Table 4.

Δ	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.60	0.70	0.80	0.90	1.00	1.10
m	(10.89)	(10.70)	(10.54)	10.40	10.28	10.17	10.06	9.96	9.85	9.64	9.47	9.30	9.15	9.00	8.87

Δ	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00	2.10	2.20	2.30	2.40	2.50	2.60	2.70	2.80	2.90
m	8.75	8.63	8.51	8.39	8.28	8.14	8.00	7.86	7.72	7.58	7.45	7.33	7.19	7.05	6.91	6.78	6.64	6.50

The curve represented by the function $m = f(\Delta)$ is a pseudo-hyperbola. On a few days a systematic deviation was perceptible, which was eliminated by taking instead of the preceding formula the following:

$$m' = k\,f(\Delta) = km,$$

k being a constant factor. It may be remarked here that for the whole series of photographs of Neptune there could be detected no trace of variation in k; therefore k was assumed equal to 1 and the magnitudes were read directly from an extension of table 4 (interpolated for every 0.01 of Δ).

The exposures of the N. P. S. ranged from 10 to 90 minutes; the photographs were centred on α Ursae Minoris and the following stars were used:

5; 6; 8; 10; 12; 14; 2*r*; 4*r*; 6*r*; 8*r*.

The r (red) stars gave a systematic deviation from the mean curve of —0.006 st. mg., which is negligible, so that the colour-sensitiveness of the system objective — plate was essentially the same in the present observations as in the adopted magnitudes of the N. P. S.

Table 5 contains the result of measurement of the plates. The first column gives the denotation of the star; n means Neptune, and n_0 refers to the concluded brightness of the planet. The second column gives the mean diameter, in 0.001 mm; for Neptune it is usually the average of 8, and for the comparison stars — of 4 separate measures. The next two columns contain the corrections for diameter and absorption expressed

1) *Transactions of the International Astronomical Union*, vol. I (1922), p. 71.

Table 5.

Negative 47, II.

	d	Corr.		1. Image				2. Image			
		diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	458	+0.009	+0.005	0.78	9.316	+0.16	+7	0.63	9.576	—0.10	—5
z	467	+0.052	+ .009	1.12	8.789	+ .06	—3	0.97	8.889	— .04	+1
α	467	+ .052	+ .012	0.99	8.956	+ .14	+5	0.86	9.146	— .05	0
i	464	+ .038	+ .002	0.55	9.710	+ .02	—7	0.54	9.730	.00	+5
r	422	— .159	— .007	1.40	8.676	+ .08	—1	1.29	8.806	— .05	0
Mean	—	—	—	—	—	**+0.092**	±0.014	—	—	**—0.048**	±0.014
n	456	0.000	0.000	0.96	9.060	—	—	0.83	9.260	—	—
n_0	—	—	—	**9.152**				**9.212**			

Negative 47, I.

	d	Corr.		1. Image				2. Image			
		diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	475	—0.013	+0.005	0.60	9.648	—0. 18	+ 3	0.66	9.548	—0.08	—3
z	479	+ .005	+ .009	0.94	9.076	— . 22	— 1	1.07	8.896	— .04	+1
α	474	— .018	+ .011	0.73	9.427	— . 33	—12	0.87	9.207	— .11	— 6
i	485	+ .031	+ .002	0.46	9.900	— . 16	+ 5	0.54	9.740	— .00	+5
r	460	— .080	— .007	1.14	8.907	— . 15	+ 6	1.26	8.767	— .01	+4
Mean	—	—	—	—	—	**—0.208**	±0.018	—	—	**—0.046**	±0.018
n	478	0.000	0.000	0.78	9.330	—	—	0.95	9.080	—	—
n_0	—	—	—	**9.122**				**9.034**			

Negative 52, II.

	d	Corr.		1. Image				2. Image			
		diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	425	+0.062	+0.007	0.89	9.101	+0. 37	+4	0.95	9.011	+0.46	+10
z	430	+ .088	+0.013	1.29	8.540	+0. 31	—2	1.32	8.510	+ .34	— 3
α	429	+ .083	+0.015	1.14	8.720	+0. 38	+5	1.13	8.730	+ .37	+ 1
i	429	+ .083	+0.004	0.66	9.450	+0. 28	—5	0.70	9.380	+ .35	— 1
r	398	— .078	—0.013	1.54	8.441	+0. 32	—1	1.52	8.461	+ .30	— 6
Mean	—	—	—	—	—	**+0.332**	±0.015	—	—	**+0.364**	±0.015
n	413	0.000	0.000	1.13	8.830	—	—	1.14	8.820	—	—
n_0	—	—	—	**9.162**				**9.184**			

Negative 52, I.

	d	Corr.		1. Image				2. Image			
		diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	461	+0.014	+0.006	0.73	9.400	+0. 07	—1	0.74	9.380	+0. 09	+ 2
z	460	+ .009	+ .011	1.09	8.860	—0. 01	—9	1.13	8.810	+0. 04	— 3
α	462	+ .019	+ .014	0.99	8.987	+0. 11	+3	0.93	9.077	+0. 02	— 5
i	463	+ .023	+ .003	0.58	9.654	+0. 08	0	0.55	9.724	+0. 01	— 6
r	443	— .070	— .011	1.40	8.591	+0. 17	+9	1.42	8.571	+0. 19	+12
Mean	—	—	—	—	—	**+0.084**	±0.021	—	—	**+0.070**	±0.021
n	458	0.000	0.000	1.03	8.960	—	—	1.06	8.920	—	—
n_0	—	—	—	**9.044**				**8.990**			

Table 5. Continued.

Negative 53, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	484	+0.022	+0.006	0.63	9.562	—0. 09	+11	0.60	9.612	—0 .14	0
z	476	— .013	+ .012	0.96	9.059	—0. 21	— 1	0.98	9.029	—0 .18	—4
α	480	+ .004	+ .012	0.77	9.334	—0. 23	— 3	0.82	9.254	—0 .15	—1
i	487	+ .036	+ .002	0.40	10.022	—0. 29	— 9	0.46	9.892	—0 .16	—2
r	461	— .080	— .009	1.12	8.939	—0. 18	+ 2	1.22	8.819	—0 .06	+8
Mean	—	—	—	—	—	**—0.200**	±0.018	—	—	**—0.138**	±0.018
n	479	0.000	0.000	0.84	9.240	—	—	0.81	9.290	—	—
n_0	—	—	—	**9.040**				**9.152**			

Negative 53, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	458	+0.058	+0.005	0.69	9.427	+0. 04	+8	0.66	9.477	—0. 01	+2
z	463	+0.082	+ .008	1.02	8.880	—0. 03	+1	1.03	8.870	—0. 02	+1
α	463	+0.082	+ .011	0.81	9.197	—0. 10	—6	0.83	9.167	—0. 07	—4
i	459	+0.062	+ .002	0.52	9.746	—0. 01	+3	0.55	9.686	+0. 05	+8
r	417	—0.139	— .005	1.24	8.844	—0. 09	—5	1.24	8.844	—0. 09	—6
Mean	—	—	—	—	—	**—0.038**	±0.017	—	—	**—0.028**	±0.017
n	446	0.000	0.000	0.82	9.270	—	—	0.90	9.150	—	—
n_0	—	—	—	**9.232**				**9.122**			

Negative 54, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	426	+0.041	+0.004	0.82	9.225	+0. 25	—1	0.84	9.195	+0. 28	+ 6
z	436	+ .092	+ .008	1.28	8.550	+0. 30	+4	1.26	8.580	+0. 27	+ 5
α	436	+ .092	+ .010	1.02	8.868	+0. 23	—3	1.04	8.848	+0. 25	+ 3
i	428	+ .051	+ .001	0.67	9.468	+0. 27	+1	0.57	9.648	+0. 09	—13
r	394	— .123	— .005	1.50	8.518	+0. 24	—2	1.47	8.558	+0. 20	— 2
Mean	—	—	—	—	—	**+0.258**	±0.017	—	—	**+0.216**	+0.017
n	418	0.000	0.000	1.10	8.870	—	—	1.06	8.920	—	—
n_0	—	—	—	**9.128**				**9.136**			

Negative 54, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
w	444	+0.019	+0.004	0.83	9.237	+0. 23	+ 4	0.82	9.247	+0. 22	+1
z	439	— .005	+ .008	1.32	8.607	+0. 25	+ 6	1.28	8.647	+0. 21	0
α	437	— .015	+ .010	1.09	8.885	+0. 22	+ 3	1.08	8.905	+0. 20	—1
i	444	+ .019	+ .001	0.57	9.680	+0. 05	—14	0.62	9.590	+0. 14	—7
r	437	— .015	— .005	1.38	8.550	+0. 21	+ 2	1.43	8 490	+0. 27	+6
Mean	—	—	—	—	—	**+0.193**	+0.019	—	—	**+0.208**	±0.019
n	440	0.000	0.000	1.05	8.940	—	—	1.04	8.950	—	—
n_0	—	—	—	**9.133**				**9.158**			

Table 5. Continued.

Negative 55, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
w	461	—0.005	+0.002	0.53	9.793	—0. 32	—4	0.61	9.623	—0. 15	— 6
z	467	+ .023	+ .008	0.92	9.089	—0. 24	+4	1.01	8.959	—0. 11	— 2
a	468	+ .028	+ .011	0.77	9.311	—0. 21	+7	0.85	9.191	—0. 09	0
i	454	— .037	+ .000	0.43	10.037	—0. 30	—2	0.59	9.697	+0. 04	+13
r	459	— .014	— .003	0.95	9.097	—0. 34	—6	1.09	8.897	—0. 14	— 5
Mean	—	—	—	—	—	**—0.282**	±0.013	—	—	**—0.090**	±0.013
n	462	0.000	0.000	0.76	9.370	—	—	0.86	9.210	—	—
n_0	—	—	—	**9.088**				**9.120**			

Negative 55, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
w	389	—0.048	+0.002	0.69	9.536	—0. 06	—4	0.69	9.536	—0. 06	— 4
z	392	— .032	+ .010	1·06	8.942	—0. 09	—7	1.14	8.842	+0. 01	+ 3
a	388	— .054	+ .012	1.00	9.042	+0. 06	+8	0.97	9.092	+0. 01	+ 3
i	(391)	(— 0.049)	— .001	0.61	9.670	+0. 06	+ 8	0.62	9.660	+0. 07	+ 9
r	409	+ .059	— .002	1.09	8.823	—0. 06	—4	1.04	8.893	—0. 13	—11
Mean	—	—	—	—	—	**—0.018**	±0.022	—	—	**- 0.020**	±0.022
n	398	0.000	0.000	0.89	9.170	—	—	0.91	9.140	—	—
n_0	—	—	—	**9.152**				**9.120**			

Negative 64, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
r	490	+0.013	+0.002	1.29	8.625	+0. 13	+4	1.26	8.665	+0. 09	0
w	505	+0.079	+ .029	0.65	9.452	+0. 02	—6	0.72	9.332	+0. 14	+ 5
t	467	—0.088	+ .004	1.18	8.854	+0. 06	—2	1.21	8.824	+0. 09	0
s	461	—0.114	+ .001	0.75	9.503	+0. 05	—4	0.71	9.563	—0. 01	—10
m	464	—0.101	— .016	0.84	9.357	+0. 10	+1	0.85	9.347	+0. 11	+ 2
p	470	—0.075	— .023	1.04	9.048	+0. 15	+6	1.02	9.068	+0. 13	+ 4
Mean	—	—	—	—	—	**+0.085**	±0.013	—	—	**+0.092**	±0.013
n	487	0.000	0.000	1.02	8·970	—	—	1.01	8.990	—	—
n_0	—	—	—	**9.055**				**9.082**			

Table 5. Continued.

Negative 64, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
r	462	+0.023	+0.002	1.61	8.245	+0. 51	+1	1.36	8.535	+0. 22	—2
w											
t	448	—0.042	+0.003	1.53	8.402	+0. 52	+2	1.31	8.662	+0. 26	+2
s	450	—0.033	+0.002	0.96	9.093	+0. 46	—4	0.85	9.263	+0. 29	+5
m	(442)	(—0.117)	—0.013					0.94	9.220	+0. 24	0
p	430	—0.126	—0.020	1.38	8.676	+0. 52	+2	1.11	9.006	+0. 19	—5
Mean	—	—	—	—	—	**+0.502**	±0.011	—	—	**+0.240**	±0.011
n	457	0.000	0.000	1.22	8.730	—	—	1.12	8.850	—	—
n_0	—	—	—			**9.232**				**9.090**	

Negative 65, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
r	427	+0.025	—0.001	1.55	8.316	+0. 44	—3	1.56	8.296	+0. 46	—4
w											
t	404	— .091	+0.004	1.46	8.527	+0. 39	—8	1.53	8.447	+0. 47	—3
s	405	— .086	+ .003	1.07	8.993	+0. 56	+9	1.09	8.963	+0. 59	+9
m	393	— .147	— .008	1.15	8.965	+0. 49	+2	1.20	8.905	+0. 55	+5
p	393	— .147	— .013	1.34	8.740	+0. 46	—1	1.33	8.750	+0. 45	—5
Mean	—	—	—	—	—	**+0.468**	±0.019	—	—	**+0.504**	±0.019
n	422	0.000	0.000	1.30	8.630	—	—	1.36	8.560	—	—
n_0	—	—	—			**9.098**				**9.064**	

Negative 65, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
r	478	+0.050	0.00[illegible]	1.44	8.410	+0. 35	+ 5	1.39	8.470	+0. 29	—6
w	484	+0.078	+0.016	0.72	9.346	+0. 12	—18	0.80	9.206	+0. 27	—8
t	448	—0.087	+0.005	1.37	8.632	+0. 29	— 1	1.42	8.572	+0. 35	0
s	451	—0.073	+0.004	0.86	9.279	+0. 28	— 2	0.90	9.219	+0. 34	—1
m	446	—0.091	—0.009	1.01	9.090	+0. 37	+ 7	1.05	9.040	+0. 42	+7
p	463	—0.018	—0.016	1.16	8.834	+0. 36	+ 6	1.22	8.764	+0. 43	+8
Mean	—	—	—	—	—	**+0.295**	±0.022	—	—	**+0.350**	±0.022
n	467	0.000	0.000	1.14	8.820	—	—	1.16	8.800	—	—
n_0	—	—	—			**9.115**				**9.150**	

Table 5. Continued.

Negative 66, I

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
r	464	+0.033	—0.001	1.44	8.428	+0. 33	—3	1.44	8.428	+0. 33	— 6
w	459	+0.009	+0.007	0.92	9.104	+0. 37	+1	0.93	9.094	+0· 38	— 1
t	448	—0.042	+0.007	1.37	8.585	+0. 33	—3	1.36	8.595	+0. 32	— 7
s	447	—0.047	+0.006	0.95	9.121	+0. 44	+8	0.99	9.061	+0. 50	+11
m	447	—0.047	—0.003	0.98	9.080	+0. 38	+ 2	1.02	9.020	+0. 44	+ 5
p	461	+0.019	—0.010	1.08	8.891	+0. 31	—5	1.13	8.821	+0. 38	— 1
Mean	—	—	—	—	—	**+0.360**	±0.016	—	—	**+0.392**	±0.016
n	457	0.000	0.000	1.24	8.700	—	—	1.23	8.710	—	—
n_0	—	—	—		**9.060**				**9.102**		

Negative 67, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
r	457	+0.014	—0.005	1.51	8.371	+0. 39	— 5	1.56	8.311	+0. 45	+ 3
w	445	—0.042	+0.002	1.18	8.810	+0. 66	+22	1.04	8.990	+0. 48	+ 6
t	477	+0.108	+0.017	1.43	8.345	+0. 57	+13	1.34	8.455	+0. 46	+ 4
s	472	+0.085	+0.015	0.80	9.200	+0. 36	— 8	0.84	9.140	+0. 42	0
m	474	+0.094	+0.003	0.87	9.103	+0. 35	— 9	0.85	9.133	+0. 32	—10
p	466	+0.057	—0.010	1.04	8.903	+0. 29	—15	1.11	8.813	+0. 38	— 4
Mean	—	—	—	—	—	**+0.437**	±0.030	—	—	**+0.418**	±0.030
n	454	0.000	0.000	1.24	8.700	—	—	1.28	8.650	—	—
n_0	—	—	—		**9.137**				**9.068**		

Negative 67, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
r	425	—0.020	—0.006	1.76	8.086	+0. 67	+11	1.60	8.306	+0. 45	+5
w	380	—0.244	0.000	1.31	8.866	+0. 61	+ 5	1.12	9.094	+0. 38	—2
t	431	+0.010	+0.020	1.47	8.400	+0. 52	— 3	1.32	8.580	+0. 34	—6
s	440	+0.055	+0.018	0.94	9.017	+0. 54	— 2	0.91	9.067	+0. 49	+9
m	455	+0.129	+0.004	0.90	9.017	+0. 44	—11	0.83	9.127	+0. 33	—7
p	460	+0.154	—0.011	1.17	8.647	+0. 55	— 1	1.06	8.777	+0. 42	+ 2
Mean	—	—	—	—	—	**+0.555**	±0.019	—	—	**+0.402**	±0.019
n	429	0.000	0.000	1.35	8.570	—	—	1.23	8.710	—	—
n_0	—	—	—		**9.125**				**9.112**		

Table 5. Continued.

Negative 68, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
r	437	—0.015	—0.009	1.43	8.494	+0. 26	— 2	1.36	8.584	+0. 17	— 5
w	(441)	+0.004	— .004	0.94	9.090	+0. 38	+10	0.81	9.290	+0. 18	— 4
t	444	+0.019	+ .026	1.25	8.645	+0. 27	— 1	1.21	8.695	+0. 22	0
s	446	+0.029	+ .024	0.78	9.277	+0. 28	0	0.81	9.237	+0. 32	+10
m	457	+0.083	+ .007	0.81	9.200	+0. 26	— 2	0.75	9.300	+0. 16	— 6
p	458	+0.087	— .013	0.98	8.956	+0. 24	— 4	0.99	8.946	+0. 25	+ 3
Mean	—	—	—	—	—	**+0.282**	±0.015	—	—	**+0.222**	±0.015
n	440	0.000	0.000	1.20	8.750	—	—	1.17	8.790	—	—
n_0	—	—	—		**9.032**				**9.012**		

Negative 68, I.

		Corr.		1. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.
r	487	+0.031	—0.008	1.21	8.717	+0. 04	0
w	476	— .018	— .006	0.68	9.524	—0. 05	—9
t	496	+ .071	+ .028	1.06	8.821	+0. 10	+6
s	495	+ .067	+ .026	0.66	9.447	+0. 11	+7
m	490	+ .045	+ .010	0.71	9.395	+0. 06	+2
p	489	+ .041	— .017	0.85	9.206	—0. 01	—5
Mean	—	—	—	—	—	**+0.042**	±0.017
n	480	0.000	0.000	0.90	9.150	—	—
n_0	—	—	—		**9.192**		

Negative 70, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
r	458	+0.043	+0.002	1.35	8.525	+0. 23	— 5	1.32	8.565	+0. 19	— 5
w	455	+ .029	+ .024	0.76	9.317	+0. 15	—13	0.75	9.337	+0. 13	—11
t	431	— .086	+ .004	1.36	8.642	+0. 28	0	1.39	8.602	+0. 32	+ 8
s	430	— .090	+ .002	0.88	9.268	+0. 29	+ 1	0.86	9.298	+0. 26	+ 2
m	438	— .052	— .009	1.10	8.931	+0. 53	+25	0.94	9.151	+0. 31	+ 7
p	452	+ .014	— .020	1.01	8.996	+0. 20	— 8	1.04	8.956	+0. 24	0
Mean	—	—	—	—	—	**+0.280**	±0.029	—	—	**+0.242**	±0.029
n	449	0.000	0.000	1.08	8.900	—	—	1.15	8.810	—	—
n_0	—	—	—		**9.180**				**9.052**		

Table 5. Continued.

Negative 70, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0-m	Dev.	*Δ*	*m*	m_0-m	Dev.
r	392	+0.056	+0.002	1.65	8.152	+0. 61	+ 4	1.57	8.252	+0. 51	— 1
w											
t	371	— .062	+ .004	1.39	8.578	+0. 34	—23	1.46	8.498	+ 0.42	—10
s	374	— .045	+ .003	1.14	8.862	+0. 69	+12	1.00	9.042	+ 0.51	— 1
m	361	— .118	— .010	1.30	8.758	+0. 70	+13	1.26	8.808	+ 0.65	+13
p	367	— .084	— .017	1.34	8.681	+0. 52	— 5				
Mean	—	—	—	—	—	**+0.572**	±0.037	—	—	**+0.522**	±0.037
n	382	0.000	0.000	1.43	8.470	—	—	1.38	8.530	—	—
n_0	—	-	—			**9.042**				**9.052**	

Negative 71, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0-m	Dev.	*Δ*	*m*	m_0-m	Dev.
r	511	+0.069	0.000	1.35	8.501	+0. 26	+ 3	1.59	8.221	+0. 54	—2
w											
t	477	— .078	+0.005	1.33	8.660	+0. 26	+ 3	1.66	8.270	+0. 65	+9
s	474	— .091	+ .004	0.86	9.297	+0. 26	+ 3	1.06	9.007	+0. 55	—1
m	451	— .190	— .008	1.01	9.188	+0. 27	+ 4	1.25	8.888	+0. 57	+1
p	458	— .160	— .014	1.05	9.114	+0. 08	—15	1.37	8.724	+0. 47	—9
Mean	—	—	—	—	—	**+0.226**	±0.022	—	—	**+0.556**	±0.022
n	495	0.000	0.000	1.08	8.900	—	—	1.38	8.530	—	—
n_0	—	—	—			**9.126**				**9.086**	

Negative 71, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0-m	Dev.	*Δ*	*m*	m_0-m	Dev.
r	518	+0.017	—0.004	1.33	8.577	+0. 18	+1	1.43	8.457	+0. 30	+8
w	540	+ .108	+ .012	0.75	9·270	+0. 20	+3	0.78	9.210	+0. 26	+4
t	495	— .079	+ .006	1.24	8.773	+0. 14	—3	1.28	8.723	+0. 20	—2
s	485	— .121	+ .005	0.79	9.436	+0. 12	—5	0.80	9.416	+0. 14	—8
m	486	— .116	— .006	0.89	9.292	+0. 16	—1	0.88	9.302	+0. 15	—7
p	495	— .079	— .013	1.09	8.972	+0. 22	+5	1.14	8.912	+0. 28	+6
Mean	—	—	—	—	—	**+0.170**	±0.015	—	—	**+0.222**	±0.015
n	514	0.000	0.000	1.16	8.800	—	—	1.08	8.900	—	—
n_0	—	—	—			**8.970**				**9.122**	

Table 5. Continued.

Negative 72, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
r	446	+0.014	—0.001	1.68	8.157	+0. 60	+2	1.68	8.157	+0. 60	—1
w	456	+ .063	+ .008	0.98	8.959	+0. 51	—7	1.03	8.889	+0. 58	—3
t	433	— .048	+ .007	1.59	8.331	+0. 59	+1	1.63	8.281	+0. 64	+3
s	424	— .092	+ .006	1.07	8.996	+0. 56	—2	1.07	8.996	+0. 56	—5
m	424	— .092	— .003	1.22	8.825	+0. 63	+5	1.24	8.795	+0. 66	+5
p	437	— .029	— .010	1.36	8.599	+0. 60	+2	1.38	8.569	+0. 63	+2
Mean	—	—	—	—	—	**+0.582**	±0.011	—	—	**+0.612**	±0.011
n	443	0.000	0.000	1.45	8.450	—	—	1.36	8.560	—	—
n_0	—	—	—	**9.032**				**9.172**			

Negative 73, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
r	547	+0.012	—0.004	1.16	8.792	—0. 03	+3	1.19	8.752	+0. 01	+8
w											
t	512	—0.126	+0.015	1.06	9.031	—0. 11	—5	1.10	8.981	—0. 06	+1
s	516	— .110	+ .014	0.68	9.596	—0. 04	+2	0.62	9.706	—0. 15	—8
m											
p	530	—. 055	— .010	0.88	9.245	—0. 05	+1	0.87	9.265	—0. 07	0
Mean	—	—	—	—	—	**—0.056**	±0.017	—	—	**—0.067**	±0.017
n	544	0.000	0.000	0.81	9.290	—	—	0.90	9.150	—	—
n_0	—	—	—	**9.234**				**9.083**			

Negative 73, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
r	572	+0.042	—0.005	1.07	8.873	—0. 12	+2	1.09	8.843	—0. 09	+6
w	580	+ .072	0.000	0.57	9.628	—0. 16	—2	0.57	9.628	—0. 16	—1
t	535	— .099	+ .017	1.04	9.032	—0. 11	+3	1.00	9.082	—0. 16	—1
s	523	— .145	+ .017	0.59	9.788	—0. 23	—9	0.62	9.738	—0. 18	—3
m	534	— .103	+ .004	0.71	9.549	—0. 09	+5	0.66	9.639	—0. 18	—3
p	552	— .034	— .011	0.80	9.345	—0. 15	—1	0.82	9.315	—0. 12	+3
Mean	—	—	—	—	—	**—0.143**	±0.012	—	—	**—0.148**	±0.012
n	561	0.000	0.000	0.83	9.260	—	—	0.90	9.150	—	—
n_0	—	—	—	**9.117**				**9.002**			

Table 5. Continued.

Negative 74, I.

	d	Corr. diam.	Corr. abs.	1. Image Δ	1. Image m	1. Image m_0-m	1. Image Dev.	2. Image Δ	2. Image m	2. Image m_0-m	2. Image Dev.
r	458	—0.041	—0.007	1.33	8.638	+0. 12	—3	1.35	8.618	+0. 14	— 4
w	446	— .096	— .003	0.89	9.269	+0. 20	+5	0.95	9.179	+0. 29	+11
t	477	+ .046	+ .025	1.12	8.779	+0. 14	—1	1.16	8.729	+0. 19	+ 1
s	482	+ .069	+ .023	0.73	9.328	+0. 23	+8	0.72	9.348	+0. 21	+ 3
m	490	+ .105	+ .007	0.70	9.358	+0. 10	—5	0.74	9.288	+0. 17	— 1
p	477	+ .046	— .012	0.91	9.106	+0. 09	—6	0.91	9.106	+0. 09	— 9
Mean	—	—	—	—	—	**+0.147**	±0.017	—	—	**+0.182**	±0.017
n	467	0.000	0.000	1.08	8.900	—	—	1.10	8.870	—	—
n_0	—	—	—			**9.047**				**9.052**	

Negative 74, II.

	d	Corr. diam.	Corr. abs.	1. Image Δ	1. Image m	1. Image m_0-m	1. Image Dev.	2. Image Δ	2. Image m	2. Image m_0-m	2. Image Dev.
r	435	—0.029	—0.009	1.36	8.598	+0. 16	0	1.32	8.648	+0. 11	—5
w											
t	447	+0.029	+0.030	1.12	8.791	+0. 13	—3	1.20	8.691	+0. 23	+7
s	443	+ .010	+ .028	0.75	9.352	+0. 20	+4	0.70	9.432	+0. 12	—4
m	464	+ .112	+ .011	0.73	9.297	+0 16	0	0.74	9.277	+0. 18	+2
p	465	+ .116	— .014	0.90	9.048	+0. 15	—1	0.92	9.018	+0. 18	+2
Mean	—	—	—	—	—	**+0.160**	±0.012	—	—	**+0.164**	±0.012
n	441	0.000	0.000	1.00	9.000	—	—	1.05	8.940	—	—
n_0	—	—	—			**9.160**				**9.104**	

Negative 75, I.

	d	Corr. diam.	Corr. abs.	1. Image Δ	1. Image m	1. Image m_0-m	1. Image Dev.	2. Image Δ	2. Image m	2. Image m_0-m	2. Image Dev.
t	534	0.000	+0.013	0.95	9.067	—0. 15	+ 3	0.94	9.077	—0. 16	0
s	537	+ .012	+ .012	0.60	9.616	—0. 06	+12	0.56	9.696	—0. 14	+ 2
m	546	+ .048	+ .001	0.62	9.561	—0. 10	+ 8	0.66	9.491	—0. 03	+13
p	541	+ .028	— .010	0.72	9.422	—0. 23	— 5	0.76	9.352	—0. 16	0
r	517	— .068	— .003	0.98	9.101	—0. 34	—16	0.99	9.091	—0. 33	—17
Mean	—	—	—	—	—	**—0.176**	±0.033	—	—	**—0.164**	±0.033
n	534	0.000	0.000	0.81	9.290	—	—	0.84	9.240	—	—
n_0	—	—	—			**9.114**				**9.076**	

Table 5. Continued.

Negative 75, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
t	494	—0.026	+0.017	1.02	8.979	—0. 06	—2	1.00	9.009	—0. 09	— 2
s	489	— .047	+ .015	0.69	9.522	+0. 03	+7	0.69	9.522	+0. 03	+10
m	513	+ .056	+ .003	0.65	9.501	—0. 04	0	0.60	9.581	—0. 12	— 5
p	518	+ .077	— .010	0.81	9.223	—0. 03	+1	0.81	9.223	—0. 03	+ 4
r	482	— .077	— .004	1.17	8.871	—0. 11	—7	1.17	8.871	—0. 11	— 4
Mean	—	—	—	—	—	**—0.042**	±0.017	—	—	**—0.066**	±0.017
n	500	0.000	0.000	0.90	9.150	—	—	0.90	9.150	—	—
n_0	—	—	—	**9.108**				**9.084**			

Negative 76, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
	441	0.000	+0.020	0.90	9.130	—0. 21	—21	0.92	9.100	—0. 18	—9
s	454	+0.063	+ .019	0.66	9.458	+0. 10	+10	0.53	9.708	—0. 15	—6
m	458	+0.082	+ .005	0.70	9.383	+0. 07	+ 7	0.60	9.553	—0. 10	—1
p	453	+0.058	— .011	0.84	9.193	+0. 00	0	0.83	9.213	—0. 02	+7
r	425	—0.078	— .006	1.28	8.734	+0. 02	+ 2	1.27	8.754	+0. 00	+9
Mean	—	—	—	—	—	**—0.004**	±0.031	—	—	**—0.090**	±0.031
n	441	0.000	0.000	1.00	9.000	—	—	1.01	8.990	—	—
n_0	—	—	—	**8.996**				**8.900**			

Negative 76, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
t	515	+0.073	+0.021	0.91	9.046	—0. 13	+ 9	1.00	8.906	+0. 01	+ 4
s	506	+0.034	+ .019	0.52	9.757	—0. 20	+ 2	0.60	9.587	—0. 03	0
m	507	+ .039	+ .005	0.54	9.726	—0. 27	— 5	0.68	9.456	0. 00	+ 3
p	487	— .047	— .011	0.69	9.548	—0. 35	—13	0.81	9.348	—0. 15	—12
r	485	— .056	— .005	1.12	8.911	—0. 15	+ 7	1.26	8.741	+0. 02	+ 5
Mean	—	—	—	—	—	**—0.220**	±0.024	—	—	**—0.030**	±0.024
n	498	0.000	0.000	0.83	9.260	—	—	0.94	9.090	—	—
n_0	—	—	—	**9.040**				**9.060**			

Negative 77, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
t	515	+0.004	+0.011	1.04	8.935	—0. 02	+ 3	1.23	8.695	+0. 22	—1
s	513	— .004	+ .010	0.55	9.744	—0. 19	—14	0.74	9.394	+0. 16	—7
m	511	— .012	— .002	0.73	9.434	+0. 02	+ 7	0.92	9.134	+0. 32	+9
p	515	+ .004	— .008	0.84	9.244	—0. 05	0	1.03	8.964	+0. 23	0
r	521	+ .029	+ .005	1.15	8.776	—0. 02	+ 3	1.37	8.516	+0. 24	+1
Mean	—	—	—	—	—	**—0.052**	±0.021	—	—	**+0.234**	±0.021
n	514	0.000	0.000	0.95	9.080	—	—	1.13	8.830	—	—
n_0	—	—	—	**9.028**				**9.064**			

Table 5. Continued.

Negative 77, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0-m	Dev.	*Δ*	*m*	m_0-m	Dev.
t	470	+0.066	+0.010	1.10	8.794	+0. 12	—8	1.13	8.754	+0. 16	— 2
s	459	+ .014	+ .009	0.79	9.297	+0. 26	+6	0.69	9.467	+0. 09	— 9
m	451	— .023	— .001	0.87	9.224	+0. 23	+3	0.90	9.174	+0. 28	+10
p	450	— .028	— .008	1.00	9.036	+0. 16	—4	0.99	9.056	+0. 14	— 4
r	478	+ .103	+ .005	1.28	8.542	+0. 22	+2	1.30	8.522	+0. 24	+ 6
Mean	—	—	—	—	—	**+0.198**	±0.020	—	—	**+0.182**	±0.020
n	456	0.000	0.000	1.03	8.960	—	—	1.04	8.950	—	—
n_0	—	—	—			**9.158**				**9.132**	

Negative 81, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0-m	Dev.	*Δ*	*m*	m_0-m	Dev.
t	470	—0.092	+0.011	1.14	8.901	+0. 02	—1	1.18	8.851	+0. 07	—1
s	477	— .061	+ .010	0.72	9.491	+0. 07	+4	0.71	9.501	+0. 06	—2
m	481	— .044	— .001	0.75	9.435	+0. 02	—1	0.80	9.345	+0. 11	+3
p	489	— .009	— .007	0.91	9.156	+0. 04	+1	0.94	9.106	+0. 09	+1
r	502	+ .048	+ .005	1.17	8.737	+0. 02	—1	1.21	8.687	+0. 07	—1
Mean	—	—	—	—	—	**+0.034**	±0.003	—	—	**+0.080**	±0.003
n	491	0.000	0.000	0.98	9.030	—	—	1.10	8.870	—	—
n_0	-	—	—			**9.064**				**8.950**	

Negative 81, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0-m	Dev.	*Δ*	*m*	m_0-m	Dev.
t	421	—0.010	+0.011	1.32	8.610	+0. 30	+ 4	1.37	8.550	+0. 36	+ 6
s	424	+ .005	+ .010	0.81	9.275	+0. 28	+ 2	0.84	9.225	+0. 33	+ 3
m	412	— .056	— .001	0.90	9.207	+0. 25	— 1	0.99	9.077	+0. 38	+ 8
p	416	— .035	— .007	1.13	8.872	+0. 32	+ 6	1.08	8.942	+0. 25	— 5
r	441	+ .091	+ .004	1.24	8.605	+0. 15	—11	1.27	8.575	+0. 18	—12
Mean	—	—	—	—	—	**+0.260**	±0.022	—	—	**+0.300**	±0.022
n	423	0.000	0.000	1.12	8.850	—	—	1.14	8.820	—	—
n_0	—	—	—			**9.110**				**9.120**	

Negative 82, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0-m	Dev.	*Δ*	*m*	m_0-m	Dev.
t	498	+0.035	+0.010	0.98	8.985	—0. 07	— 5	1.12	8.805	+0. 11	— 7
s	495	+0.022	+ .009	0.63	9.559	—0. 00	+ 2	0.69	9.459	+0. 10	— 8
m	473	— .074	+ .000	0.75	9.464	—0. 01	+ 1	0.94	9.164	+0. 29	+11
p	474	— .070	— .007	0.98	9.107	+0. 09	+11	1.07	8.987	+0. 21	+ 3
r	519	+ .127	+ .002	1.00	8.871	—0. 10	— 8	1.26	8.551	+0. 21	+ 3
Mean	—	—	—	—	—	**—0.018**	±0.022	—	—	**+0.184**	±0.022
n	490	0.000	0.000	0.91	9.140	—	—	1.04	8.950	—	—
n_0	—	—	—			**9.122**				**9.134**	

Table 5. Continued.

Negative 82, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	506	—0.058	+0.011	1.10	8.917	0. 00	+ 8	1.01	9.037	—0. 12	—8
s	502	— .074	+ .010	0.60	9.704	—0. 15	— 7	0.67	9.584	—0. 03	+1
m	510	— .041	+ .001	0.75	9.430	+0. 03	+11	0.74	9.440	+0. 01	+5
p	521	+ .004	— .007	0.76	9.373	—0. 18	—10	0.89	9.173	+0. 02	+6
r	534	+ .058	+ .001	1.08	8.841	—0. 08	0	1.06	8.861	—0. 10	—6
Mean	—	—	—	—	—	**—0.076**	±0.023	—	—	**—0.044**	±0.023
n	520	0.000	0.000	0.93	9.110	—	—	0.96	9.060	—	—
n_0	—	—	—	**9.034**				**9.016**			

Negative 83, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	511	+0.083	+0.018	0.93	9.009	—0. 09	— 5	0.78	9.229	—0. 31	— 7
s	504	+ .052	+ .016	0.64	9.504	+0. 05	+ 9	0.45	9.894	—0. 34	—10
m	498	+ .026	+ .004	0.60	9.610	—0. 15	—11	0.56	9.690	—0. 23	+ 1
p											
r	491	— .004	— .006	1.23	8.720	+0. 04	+ 8	1.13	8.840	—0. 08	+16
Mean	—	—	—	—	—	**—0.038**	±0.036	—	—	**—0.240**	±0.036
n	492	0.000	0.000	0.85	9.230	—	—	0.70	9.470	—	—
n_0	—	—	—	**9.192**				**9.230**			

Negative 84, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	478	—0.013	+0.011	1.06	8.922	—0. 00	+ 1	1.18	8.772	+0. 15	+ 8
s	475	— .027	+ .010	0.68	9.517	+0. 04	+ 5	0.70	9.487	+0. 07	0
m	476	— .022	— .001	0.66	9.563	—0. 11	—10	0.65	9.583	—0. 13	—20
p	478	— .013	— .007	0.89	9.190	+0. 01	+ 2	0.97	9.070	+0. 13	+ 6
r	493	+ .053	+ .005	1.16	8.742	+0. 02	+ 3	1.26	8.622	+0. 14	+ 7
Mean	—	—	—	—	—	**—0.008**	±0.027	—	—	**+0.072**	±0.027
n	481	0.000	0.000	1.01	8.990	—	—	1.01	8.990	—	—
n_0	—	—	—	**8.982**				**9.062**			

Negative 84, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	448	+0.010	+0.010	1.22	8.710	+0. 21	0	1.13	8.810	+0. 11	+ 8
s	445	— .005	+ .009	0.73	9.416	+0. 14	— 7	0.68	9.496	+0. 06	+ 3
m	431	— .072	.000	0.97	9.122	+0. 33	+12	0.71	9.522	—0. 07	—10
p	431	— .072	— .007	1.15	8.889	+0. 31	+10	1.00	9.079	+0. 12	+ 9
r	463	+ .082	+ .003	1.16	8.715	+0. 04	—17	1.08	8.815	—0. 06	— 9
Mean	—	—	—	—	—	**+0.206**	±0.031	—	—	**+0.032**	±0.031
n	446	0.000	0.000	1.09	8.880	—	—	1.03	8.960	—	—
n_0	—	—	—	**9.086**				**8.992**			

Table 5. Continued.

Negative 85, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
t	487	+0.022	+0.010	1.15	8.778	+0. 14	+ 4	1.16	8.768	+0. 15	+6
s	482	0.000	+ .009	0.78	9.321	+0. 24	+14	0.69	9.481	+0. 08	—1
m	468	—0.062	0.000	0.85	9.292	+0. 16	+ 6	0.82	9.332	+0. 12	+3
p	466	—0.071	— .007	0.89	9.248	—0. 05	—15	0.94	9.118	+0. 08	—1
r	499	+0.075	+ .002	1.13	8.753	+0. 00	—10	1.13	8.753	+0. 00	—9
Mean	—	—	—	—	—	**+0.098**	±0.028	—	—	**+0 086**	±0.028
n	482	0.000	0.000	1.04	8.950	—	—	0.97	9.050	—	—
n_0	—	—	—	**9.048**				**9.136**			

Negative 85, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
t	498	—0.026	+0.011	1.05	8.955	—0. 04	+ 2	0.95	9.095	—0. 18	— 7
s	495	— .038	+ .010	0.70	9.498	+0. 06	+12	0.69	9.518	+0. 04	+15
m	492	— .051	+ .001	0.65	9.610	—0. 15	— 9	0.63	9.640	—0. 18	— 7
p	515	+ .047	— .007	0.81	9.250	—0. 05	+ 1	0.75	9.350	—0. 15	— 4
r	525	+ .089	0.000	1.04	8.861	—0. 10	— 4	1.05	8.851	—0. 09	+ 2
Mean	—	—	—	—	—	**—0.056**	±0.025	—	—	**—0.112**	±0.025
n	504	0.000	0.000	0.83	9.260	—	—	0.90	9.150	—	—
n_0	—	—	—	**9.204**				**9.038**			

Negative 86, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
t	506	—0.017	+0.013	0.91	9.144	—0. 23	+11	0.94	9.094	—0. 18	+ 5
s	507	— .013	+ .012	0.47	9.911	—0. 35	— 1	0.55	9.751	—0. 19	+ 4
m	498	— .050	+ .002	0.53	9.838	—0. 38	— 4	0.59	9.708	—0. 25	— 2
p	509	— .004	— .008	0.66	9.552	—0. 36	— 2	0.76	9.382	—0. 19	+ 4
r	520	+ .042	— .002	0.87	9.160	—0. 40	— 6	0.91	9.100	—0. 34	—11
Mean	—	—	—	—	—	**—0.344**	±0.020	—	—	**—0.230**	±0.020
n	510	0.000	0.000	0.68	9.500	—	—	0.79	9.320	—	—
n_0	—	—	—	**9.156**				**9.090**			

Negative 86, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	m_0—*m*	Dev.	*Δ*	*m*	m_0—*m*	Dev.
t	469	+0.061	+0.014	0.97	8.975	—0. 06	+ 5	0.89	9.095	—0. 18	— 1
s	462	+ .028	+ .013	0.56	9.679	—0. 12	— 1	0.47	9.869	—0. 31	—14
m	452	— .019	+ .002	0.72	9.457	0. 00	+11	0.72	9.457	0. 00	+17
p	450	— .028	— .009	0.79	9.357	—0. 16	— 5	0.82	9.307	—0. 11	+ 6
r	474	+ .084	— .003	0.98	8.949	—0. 19	— 8	0.93	9.029	—0. 27	—10
Mean	—	—	—	—	—	**—0.106**	±0.031	—	—	**—0.174**	+0.031
n	456	0.000	0.000	0.79	9.320	—	—	0.83	9.260	—	—
n_0	—	—	—	**9.214**				**9.086**			

Table 5. Continued.

Negative 88, I.

	d	Corr. diam.	Corr. abs.	1. Image Δ	m	m_0-m	Dev.	2. Image Δ	m	m_0-m	Dev.
t	494	+0.035	+0.010	1.07	8.865	+0. 05	+15	0.94	9.045	−0. 13	−7
s	494	+ .035	+ .009	0.50	9.806	−0. 25	−15	0.61	9.576	−0. 02	+4
m	492	+ .026	− .002	0.58	9.656	−0. 20	+ 9	0.63	9.566	−0. 11	−5
p	484	− .009	− .008	0.82	9.287	−0. 09	− 3	0.83	9.277	−0. 08	−2
r	462	− .106	+ .006	1.28	8.750	+0. 01	− 9	1.29	8.740	+0. 02	+8
Mean	—	—	—	—	—	**−0.096**	±0.029	—	—	**−0.064**	±0.029
n	486	0.000	0.000	0.85	9.230	—	—	0.88	9.180	—	—
n_0	—	—	—			**9.134**				**9.116**	

Negative 88. II.

	d	Corr. diam.	Corr. abs.	1. Image Δ	m	m_0-m	Dev.	2. Image Δ	m	m_0-m	Dev.
t	446	−0.028	+0.010	1.29	8.658	+0. 26	−5	1.28	8.668	+0. 25	−3
s	442	−0.047	+ .009	0.88	9.218	+0. 34	+3	0.90	9.188	+0. 37	+9
m	457	+ .024	− .001	0.89	9.147	+0. 31	0	0.86	9.187	+0. 27	−1
p	473	+ .099	− .008	1.07	8.819	+0. 38	+7	1.01	8.899	+0. 30	+2
r	427	− .118	+ .005	1.49	8.513	+0. 24	−7	1.46	8.553	+0. 20	−8
Mean	—	—	—	—	—	**+0.307**	±0.018	—	—	**+0.278**	±0.018
n	452	0.000	0.000	1.13	8.830	—	—	1.14	8.820	—	—
n_0	—	—	—			**9.137**				**9.098**	

Negative 89, II.

	d	Corr. diam.	Corr. abs.	1. Image Δ	m	m_0-m	Dev.	2. Image Δ	m	m_0-m	Dev.
t	425	+0.026	+0.010	1.35	8.534	+0. 38	−9	1.45	8.414	+0. 50	−14
s	427	+ .036	+ .009	0.97	9.005	+0. 55	+8	1.12	8.805	+0. 75	+11
m	431	+ .056	0.000	1.00	8.944	+0. 51	+ 4	1.19	8.704	+0. 75	+11
p	423	+ .015	− .007	1.26	8.672	+0. 53	+6	1.46	8.432	+0. 77	+13
r	404	− .082	+ .003	1.58	8.379	+0. 38	−9	1.63	8.319	+0. 44	−20
Mean	—	—	—	—	—	**+0.470**	±0.039	—	—	**+0.642**	±0.039
n	420	0.000	0.000	1.23	8.710	—	—	1.43	8.470	—	—
n_0	—	—	—			**9.180**				**9.112**	

Negative 89, I.

	d	Corr. diam.	Corr. abs.	1. Image Δ	m	m_0-m	Dev.	2. Image Δ	m	m_0-m	Dev.
t	513	+0.008	+0.010	1.05	8.922	0. 00	−4	1.08	8.882	+0. 04	−1
s	517	+ .025	+ .009	0.65	9.526	+0. 03	−1	0.66	9.506	+0. 05	0
m	505	− .025	0.000	0.80	9.325	+0. 13	+9	0.73	9.445	+0. 01	−4
p	491	− .084	− .007	0.95	9.171	+0. 02	−2	0.97	9.141	+0. 05	0
r	501	− .042	+ .002	1.25	8.730	+0. 03	−1	1.29	8.680	+0. 08	+3
Mean	—	—	—	—	—	**+0.042**	±0.011	—	—	**+0.046**	±0.011
n	511	0.000	0.000	1.00	9.000	—	—	0.97	9.050	—	—
n_0	—	—	—			**9.042**				**9.096**	

Table 5. Continued.

Negative 92, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	500	-0.075	+0.023	0.90	9.052	—0. 13	+ 5	0.87	9.102	—0. 18	+ 4
s	501	+ .080	+ .021	0.48	9.789	—0. 23	— 5	0.50	9.749	—0. 19	+ 3
m	500	+ .075	+ .005	0.49	9.790	—0. 33	—14	0.43	9.920	—0. 46	—24
p											
r	470	— .058	— .012	1.20	8.820	—0. 06	+13	1.19	8.830	—0. 07	+15
Mean	—	—	—	—	—	**—0.185**	±0.048	—	—	**—0.222**	±0.048
n	483	0.000	0.000	0.76	9.370	—	—	0.75	9.390	—	—
n_0	—	—	—		**9.185**				**9.168**		

Negative 92, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	421	—0.035	+0.027	1.08	8.908	+0. 01	+ 1	1.03	8.968	—0. 05	— 6
s	417	— .055	+ .025	0.60	9.670	—0. 11	—11	0.62	9.640	—0. 08	— 9
m	441	+ .065	+ .007	0.70	9.398	+0. 06	+ 6	0.75	9.318	+0. 14	+13
p	431	+ .015	— .017	0.91	9.142	+0. 05	+ 5	0.91	9.142	+0. 05	+ 4
r	403	— .125	— .013	1.29	8.778	—0. 02	— 2	1.28	8.788	—0. 03	— 4
Mean	—	—	—	—	—	**—0.002**	±0.024	—	—	**+0.006**	±0.024
n	428	0.000	0.000	0.94	9.090	—	—	0.95	9.080	—	—
n_0	—	—	—		**9.088**				**9.086**		

Negative 93, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	517	+0.008	+0.011	1.16	8.781	+0. 14	+13	1.19	8.741	+0. 18	+ 9
s	519	+ .017	+ .010	0.59	9.633	—0. 08	— 9	0.72	9.413	+0. 14	+ 5
m	510	— .021	— .001	0.75	9.412	+0. 04	+ 3				
p	506	— .037	— .008	0.84	9.285	—0. 09	—10	0.89	9.215	—0. 02	—11
r	510	— .021	+ .006	1.25	8.705	+0. 05	+ 4	1.26	8.695	+0. 06	— 3
Mean	—	—	—	—	—	**+0.012**	±0.029	—	—	**+0.090**	±0.029
n	515	0.000	0.000	0.93	9.110	—	—	0.99	9.020	—	—
n_0	—	—	—		**9.122**				**9.110**		

Negative 93, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	*m*	m_0-m	Dev.	Δ	*m*	m_0-m	Dev.
t	450	—0.024	+0.011	1.26	8.693	+0. 23	+4	1.31	8.633	+0. 29	— 2
s	450	— .024	+ .010	0.81	9.304	+0. 25	+6	0.89	9.184	+0. 37	+ 6
m	467	+ .056	— .001	0.79	9.265	+0. 19	0	0.89	9.115	+0. 34	+ 3
p	467	+ .056	— .008	0.97	9.002	+0. 19	0	1.14	8.772	+0. 42	+11
r	449	— .028	+ .005	1.30	8.653	+0. 10	—9	1.32	8.633	+0. 12	—19
Mean	—	—	—	—	—	**+0.192**	±0.027	—	—	**+0.308**	±0.027
n	455	0.000	0.000	1.11	8.860	—	—	1.19	8.760	—	—
n_0	—	—	—		**9.052**				**9.068**		

Table 5. Continued.

Negative 96, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	479	—0.095	+0.011	0.83	9.344	—0. 43	— 5	0.87	9.284	—0. 37	— 3
s	474	— .087	+ .010	0.44	10.057	—0. 50	—12	0.49	9.947	—0. 39	— 5
m	495	+ .004	— .001	0.55	9.747	—0. 29	+ 9	0.56	9.717	—0. 26	+ 8
p	492	— .008	— .008	0.53	9.806	(—0. 61)	(—23)	0.51	9.846	(—0. 65)	(—31)
r	459	— .152	+ .004	1.07	9.058	—0. 30	+ 8	1.05	9.088	—0. 33	— 1
Mean	—	—	—	—	—	**—0.380**	±0.028	—	—	**—0.337**	±0.028
n	494	0.000	0.000	0.74	9.400	—	—	0.70	9.470	—	—
n_0	—	—	—	**9.020**				**9.133**			

Negative 97, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	456	—0.005	+ .010	1.21	8.735	+0. 18	— 5	1.04	8.945	—0. 03	— 2
s	458	+ .005	+ .009	0.84	9.226	+0. 33	+10	0.69	9.476	+0. 08	+ 9
m	464	+ .033	0.000	0.81	9.257	+0. 20	— 3	0.65	9.527	—0. 07	— 6
p	462	+ .023	— .007	0.88	9.164	(+0. 03)	(—20)	0.59	9.644	(—0. 45)	(—44)
r	447	— .047	+ .002	1.41	8.545	+0. 21	— 2	1.22	8.775	—0. 02	— 1
Mean	—	—	—	—	—	**+0.230**	±0.022	—	—	**—0.010**	±0.022
n	457	0.000	0.000	1.08	8.900	—	—	0.92	9.120	—	—
n_0	—	—	—	**9.130**				**9.110**			

Negative 97, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	528	+0.033	+0.010	0.70	9.427	—0. 51	— 2	0.72	9.397	—0. 48	+ 3
s	519	— .004	+ .009	0.38	10.095	—0. 54	— 5	0.34	10.185	—0. 63	—12
m	510	— .041	0.000	0·42	10.061	- 0. 60	—11	0.41	10.081	—0. 62	—11
p	520	0.000	— .007	0.49	9.877	(—0. 68)	(—19)	0.52	9.817	(—0. 62)	(—11)
r	517	— .012	+ .002	0.96	9.070	—0. 31	+18	0.96	9.070	—0. 31	+20
Mean	—	—	—	—	—	**—0.490**	±0.046	—	—	**—0.510**	±0.046
n	520	0.000	0.000	0.59	9.660	—	—	0.64	9.570	—	—
n_0	—	—	—	**9.170**				**9.060**			

Negative 98, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	464	+0.038	+0.011	0.93	9.061	—0. 14	— 3	0.97	9.001	—0. 08	0
s	452	— .028	+0.010	0.56	9.738	—0. 18	— 7	0.56	9.738	—0. 18	—9
m	464	+ .038	+ .001	0.66	9.501	—0. 04	+ 7	0.63	9 551	—0. 09	0
p	461	+ .014	— .007	0.69	9.483	(—0. 29)	(—18)	0.72	9.433	(—0. 24)	(—15)
r	445	— .061	0.000	1.17	8.851	—0. 09	+ 2	1.25	8.751	+0. 01	+9
Mean	—	—	—	—	—	**—0.112**	±0.022	—	—	**—0.085**	±0.022
n	458	0.000	0.000	0.79	9.320	—	—	0.86	9.210	—	—
n_0	—	—	—	**9.208**				**9.125**			

Table 5. Continued.

Negative 98, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	$m_0—m$	Dev.	*Δ*	*m*	$m_0—m$	Dev.
t	422	—0.054	+0.012	1.11	8.902	+0. 02	— 3	1.13	8.872	+0. 05	+ 1
s	422	— .054	+ .011	0.70	9.513	+0. 04	— 1	0.71	9.493	+0. 06	+ 2
m	439	+ .030	+ .001	0.72	9.409	+0. 05	0	0.69	0.459	0. 00	— 4
p	439	+ .030	— .007	0.78	9.307	(—0.11)	(—16)	0.78	9.307	(—0.11)	(—15)
r	409	— .119	— .001	1.36	8.680	+0. 08	+ 3	1.34	8.700	+0. 06	+ 2
Mean	—	—	—	—	—	**+0.048**	±0.009	—	—	**+0.042**	±0.009
n	433	0.000	0.000	0.98	9.030	—	—	1.03	8.960	—	—
n_0	—	—	—	**9.078**				**9.002**			

Negative 99, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	$m_0—m$	Dev.	*Δ*	*m*	$m_0—m$	Dev.
t	519	+0.046	+0.014	1.04	8.890	+0. 03	+ 1	1.04	8.890	+0. 03	0
s	504	— .017	+ .013	0.69	9.494	+0. 06	+ 4				
m	506	— .008	+ .002	0.72	9.446	+0. 01	— 2	0.71	9.456	0. 00	— 3
p	489	— .080	— .009	0.76	9.459	(—0.26)	(—28)	0.69	9.579	(—0.33)	(—41)
r	487	— .088	— .003	1.27	8.761	0. 00	— 3	1.32	8.701	+0. 06	+ 3
Mean	—	—	—	—	—	**+0.025**	±0.011	—	—	**+0.030**	±0.011
n	508	0.000	0.000	0.92	9.120	—	—	0.91	9.140	—	—
n_0	—	—	—	**9.145**				**9.170**			

Negative 99, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	$m_0—m$	Dev.	*Δ*	*m*	$m_0—m$	Dev.
t	439	+0.025	+0.018	1.05	8.897	+0. 02	— 7	1.12	8.807	+0. 11	— 8
s	441	+ .035	+ .016	0.71	9.399	+0. 16	+ 7	0.75	9.339	+0. 22	+ 3
m	454	+ .097	+ .003	0.79	9.220	+0. 24	+15	0.87	9.100	+0. 36	+17
p	439	+ .025	— .011	0.94	9.076	+0. 12	+ 3	1.02	8.956	+0. 24	+ 5
r	404	— .148	— .005	1.26	8.833	—0. 08	—17	1.37	8.703	+0. 05	—14
Mean	—	—	—	—	—	**+0.092**	±0.036	—	—	**+0.192**	±0.036
n	434	0.000	0.000	1.06	8.920	—	—	1.10	8.870	—	—
n_0	—	—	—	**9.012**				**9.062**			

Negative 100, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	*Δ*	*m*	$m_0—m$	Dev.	*Δ*	*m*	$m_0—m$	Dev.
t	539	+0.053	+0.023	0.84	9 164	—0. 25	+ 9	0.84	9.164	—0. 25	+ 8
s	542	+ .065	+ .021	0.43	9.914	—0. 36	— 2	0.43	9.914	—0. 36	— 3
m	540	+ .057	+ .005	0.43	9.938	—0. 48	—14	0.39	10.018	—0. 56	—23
p	529	+ .012	— .014	0.60	9.642	—0. 45	—11	0.66	9.542	—0. 35	— 2
r	514	— .049	— .009	1.12	8.908	—0. 15	+19	1.13	8.888	—0. 13	+20
Mean	—	—	—	—	—	**—0.338**	±0.044	—	—	**—0.330**	±0.044
n	526	0.000	0.000	0.67	9.520	—	—	0.71	9.450	—	—
n_0	—	—	—	**9.182**				**9.120**			

Table 5. Continued.

Negative 100, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	479	—0.044	+0.028	0.84	9.256	—0. 34	+2	0.85	9.246	—0. 33	+3
s	486	— .013	+ .026	0.44	9.967	—0. 41	—5	0.47	9.897	—0. 34	+2
m	498	+ .039	+ .007	0.50	9.804	—0. 35	+1	0.48	9.844	—0. 39	—3
p	495	+ .026	— .017	0.62	9.601	—0. 41	—5	0.60	9.631	—0. 44	—8
r	456	— .145	— .012	1.08	9.057	—0. 30	+6	1.07	9.067	—0. 31	+5
Mean	—	—	—	—	—	**—0.362**	±0.015	—	—	**—0.362**	±0.015
n	489	0.000	0.000	0.75	9.390	—	—	0.71	9.450	—	—
n_0	—	—	—	**9.028**				**9.088**			

Negative 102, I.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	514	+0.025	+0.011	0.97	9.014	—0. 10	+ 2	0.94	9.054	—0. 14	— 1
s	512	+ .017	+ .010	0.54	9.743	—0. 19	— 7	0.60	9.613	—0. 06	+ 7
m	520	+ .051	— .001	0.56	9.670	—0. 21	— 9	0.51	9.780	—0. 32	—19
p	503	— .021	— .007	0.82	9.298	—0. 10	+ 2	0.81	9.318	—0. 12	+ 1
r	485	— .097	+ .004	1.27	8.763	—0. 01	+11	1.26	8.773	—0. 02	+11
Mean	—	—	—	—	—	**—0.122**	±0.030	—	—	**—0.126**	±0.030
n	508	0.000	0.000	0.91	9.140	—	—	0.97	9.050	—	—
n_0	—	—	—	**9.018**				**8.924**			

Negative 102, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	473	—0.078	+0.010	1.06	8.988	—0. 07	+13	1.02	9.038	—0. 12	+ 8
s	471	— .087	+ .009	0.58	9.758	—0. 20	0				
m	494	+ .013	0.000	0.51	9.817	—0. 36	—16	0.52	9.797	—0. 34	—14
p	500	+ .039	— .007	0.71	9.418	—0. 22	— 2	0.72	9.408	—0. 21	— 1
r	450	— .179	+ .003	1.23	8.886	—0. 13	+ 7	1.23	8.886	—0. 13	+ 7
Mean	—	—	—	—	—	**—0.196**	±0.033	—	—	**—0.200**	±0.033
n	491	0.000	0.000	0.89	9.170	—	—	1.90	9.150	—	—
n_0	—	—	—	**8.974**				**8.950**			

Negative 101, II.

		Corr.		1. Image				2. Image			
	d	diam.	abs.	Δ	m	m_0-m	Dev.	Δ	m	m_0-m	Dev.
t	451	—0.051	+0.010	0.90	9.191	—0. 27	—10	0.95	9.121	—0. 20	—9
s	460	— .009	+ .009	0.59	9.660	—0. 10	+ 7	0.59	9.660	—0. 10	+1
m	473	+ .051	0.000	0.54	9.719	—0. 26	— 9	0.60	9.589	—0. 13	—2
p	477	+ .069	— .007	0.74	9.338	—0. 14	+ 3	0.76	9.308	—0. 11	0
r	439	— .106	+ .002	1.22	8.836	—0. 08	+ 9	1.27	8.774	—0. 02	+9
Mean	—	—	—	—	—	**—0.170**	±0.023	—	—	**—0.112**	±0.023
n	462	0.000	0.000	0.80	9.300	—	—	0.82	9.270	—	—
n_0	—	—	—	**9.130**				**9.158**			

in stellar magnitudes; these corrections are those which should be added to the magnitude of Neptune; with respect to the comparison stars these quantities represent *deviations* and must therefore be *subtracted* from the observed magnitude. For each of the two neighbouring images of 1 negative the same mean correction for diameter and absorption was adopted. Next follows, separately for the two images, Δ — the mean difference between the photographic density of the stellar image and the surrounding background of the plate, expressed in units of the microphotometer wedge; this difference is derived: for the comparison stars from 2 settings on the middle of the extrafocal image and 4 settings on different points of the background; for Neptune from 4 settings on the image and 8 points of the background. The number of the settings on the background was twice the number of those made on the image because all measures of the background near the two neighbouring images were joined into one general mean.

The following column after Δ gives m — the magnitude of the star if it were at the same zenith distance and had the same diameter as Neptune; this quantity was found by taking from table 4 the value of m corresponding to the measured Δ and by subtracting the corrections for diameter and absorption. The next columns contain: $m_0—m$ or the correction which must be applied to the observed magnitude to reduce it to the mean value given in the 11^{th} column of table 2; and the deviation of this difference from the mean difference of all comparison stars measured; a $+$ deviation means that the star was measured *brighter* than on the average.

Below each column of comparison stars is given the mean difference $m_0—m$; in forming the mean *all stars received equal weight* and no measured image was rejected whatever the deviation might be; an exception was made only for the star p on March 19, when it showed variability, as mentioned above. These rejected images of p are given in parentheses. Certain images of the comparison stars were however not measured, the reason of rejection being usually a dust-particle or any other defect on the image; a number of images of w and m could also not be used on the February photographs because they fell too near the veiled edge of the plate or were partly screened by the boundary of the field. In all cases when an image was for some reason not measured a vacant place appears in the table.

Besides the mean difference, m_0—m, its probable error is given; the p. e. was computed from all deviations of both images of the corresponding negative.

By adding the mean difference, m_0—m, to the observed magnitude of Neptune the *concluded magnitude* of Neptune, n_0, was obtained; the zero-point of this magnitude is evidently the same as for the scale of comparison stars in table 2.

The magnitudes of the comparison stars were derived in the following way. The observations were joined into groups according to the combinations of comparison stars used, and mean values of the magnitudes m of table 5 were determined. These groups and mean values were:

I group (December, 20 observations)

star	*w*	*a*	*z*	*i*	*r*
mean m	9.423	9.068	8.822	9.704	8.725

II group (February, 23 obs.)

star	*r*	*w*	*t*	*s*	*m*	*p*
mean m	8.492	9.222	8.650	9.295	9.189	8.937

IIa (February, star *w* not measured; 6 observations)

star	*r*	*t*	*s*	*m*	*p*
mean m	8.432	8.565	9.173	9.088	8.898

III (22. February and March, 68 observations)

star	*t*	*s*	*m*	*p*	*r*
mean m	8.919	9.555	9.454	9.190	8.764

IIIa (March 19 and occasional photographs where *p* was not measured; 17 observations)

star	*t*	*s*	*m*	*r*
mean m	9.087	9.734	9.673	8.852.

All these groups include 134 observations; the remaining 11 observations were not used in the derivation of the magnitudes of the comparison stars, because they occasionally contained one or another star not measured and would therefore give too many groups with a small number of observations within each and introduce thus unnecessary complication.

Were these 11 observations also included, they would hardly alter the definitive magnitudes by a few thousandths of a stellar magnitude (of course, a more considerable shift of the zero-point of the scale would be produced, but this is of no consequence for our purposes).

The scales of magnitude in the different groups differ by certain constant values, which must be attributed to the varying average transparency of the atmosphere, the distance from the focus and unknown circumstances of development. Therefore all these magnitudes must be reduced to a uniform zero-point — say, to the zero of the most numerous group III; then the other 4 groups require each a certain constant correction; these corrections together with the definitive magnitudes of the 9 comparison stars give together 13 unknowns which were determined from a least-square solution of the 25 equations furnished by the 25 mean magnitudes given above; the weights were assumed equal to the number of observations. In this way the definitive magnitudes contained in the 11^{th} column of table 2 were derived.

The uniformity of the system of magnitudes adopted depends chiefly on the number of stars common to the different groups; the small groups II_a and III_a are of little importance since they refer to the same epochs as the groups II and III respectively; therefore only three chief groups shall attract our attention — the I, II and III. The December group is connected with the other two groups through the star *r*, and with the February group through *w*; all 5 stars of the March group occur also in February. Thus the February and March systems of magnitude are practically identical, and only the December group stands somewhat apart, the zero-point being based on only two stars, *r* and *w*; the uncertainty in this case however hardly exceeds 0.005 st. mg. and in any case is less than 0.01 mg.

3. Discussion of Results.

Table 6 gives the final results for Neptune. The first column gives the sidereal time corrected for light-time and change of apparent position; the latter correction corresponds to the perspective change of the central meridian of the rotating planet, and was computed as follows. From a preliminary discussion of the observational data it was obvious that the observed light variation might be accounted for by a rotation period of about $7.^h8$; the position of Neptune's axis of rotation was assumed according to Arthur

Newton[1]: $\alpha = 19^h\ 17^m$; $\delta = +38^\circ.3$ (north pole). With these data the following corrections were found:

December 18. Corr. for light-time $= -1^m.7$; corr. for change of position[2]) $= +3.^m0$; total . . . . . . $+1^m.3$

February 13. Corr. for light-time $= +1^m.7$; corr. for change of position $= +1^m.0$; total . . . . $+2^m.7$

March 16. Corr. for light-time $= 0^m.0$; corr. for change of position $= 0^m.0$; total . . . . $0^m.0$

Actually the following corrections were applied:

for December	16—18	$+1^m.0$
„ February	12—13	$+3^m.0$
„ „	22	$+2^m.0$
„ March	5	$+1^m.0$
„ „	12—21	$0^m.0$

These corrections are small and have only a conventional character.

The second column gives the magnitude of Neptune corrected for the distance from the earth; no correction for the phase-angle was made, and the change of the distance from the sun is too insignificant to be taken into account. The correction for distance used was:

December	16—18	—0.015	st. mg.
February	12—22	+0.015	„
March	5	+0.010	„
„	12—13	+0.005	„
„	16—21	0.000	„

The general mean magnitude from all 145 observations results as

$$\bar{m}_0 = 9.101 \pm 0.004 \text{ (p. e.)},$$

with an average deviation of ± 0.0645 (or a probable dev. $= \pm 0.0434$); this is a little too large and may alone give rise to suspicions of variability. The suspicion is strengthened to conviction when the individual values from day to day are scrutinized.

The period of variation was determined in the following way. The individual values for each day were plotted and the

1) *Popular Astronomy* XXX p. 166.

2) Allowing for the *retrograde* sense of rotation.

Table 6.

m_0 = magnitude of Neptune reduced to $\log \varrho = 1.467$, ϱ being the distance from the earth (zero-point of magnitudes arbitrary)
t = sidereal time corrected for light-time (reduced to $\log \varrho = 1.467$) and change of apparent position.

t	m_0	Phase of Rotation $P_I = 7^h.7269$	Phase of Rotation $P_{II} = 7^h.857$	Magnitude from mean Light-Curve I	Magnitude from mean Light-Curve II	Magnitude from mean Light-Curve superposed I+II	Dev. × 1000 Obs.-Comp. I	Dev. × 1000 Obs.-Comp. II	Dev. × 1000 Obs.-Comp. I+II
				1922. December 16.					
h		h	h						
8.01	9.137	0.29	0.15	9.167	9.143	9.209	−30	−6	−72
8.30	.197	0.58	0.44	.129	.102	.130	+68	+95	+67
8.60	.107	0.88	0.74	.123	.102	.124	−16	+5	−17
8.89	.019	1.17	1.03	.091	.081	.071	−72	−62	−52
				December 18.					
6.83	.147	0.75	7.69	.126	.130	.155	+21	+17	−8
7.05	.169	0.97	0.05	.119	.152	.170	+50	+17	−1
7.32	9.029	1.24	0.32	.073	.108	.080	−44	−79	−51
7·55	8.975	1.47	0.55	.035	.102	.036	−60	−127	−61
7.95	9.025	1.87	0.95	.089	.083	.071	−64	−58	−46
8.20	.137	2.12	1.20	.129	.089	.117	+8	+48	+20
.50	.217	2.42	1.50	.105	.139	.143	+112	+78	+74
.78	.107	2.70	1.78	.101	.119	.119	+6	−12	−12
.22	.113	3.14	2.22	.083	.047	.029	+30	+66	+84
.51	.121	3.43	2.51	.110	.080	.089	+11	+41	+32
9.81	.118	3.73	2.81	.140	.139	.178	−22	−21	−60
10.04	.143	3.96	3.04	.155	.115	.169	−12	+28	−26
10.99	.073	4.91	3.99	.119	.142	.160	−46	−69	−87
11.22	.105	5.14	4.22	.154	.124	.177	−49	−19	−72
11.44	.137	5.36	4.44	.124	.090	.113	+13	+47	+24
11.70	.105	5.62	4.70	.124	.078	.101	−19	+27	+4
				1923. February 12.					
6.28	.070	7.47	7.59	.099	.100	.098	−29	−30	−28
6.60	.097	0.06	0.05	.131	.152	.182	−34	−55	−85
6.86	.247	0.32	0.31	.166	.108	.173	+81	+139	+74
7.10	.105	0.56	0.55	.130	.102	.131	−25	+3	−26
7 49	.113	0.95	0.94	.120	.084	.103	−7	+29	+10
7.70	.079	1.16	1.15	.093	.085	.077	−14	−6	+2
7.95	.130	1.41	1.40	.045	.119	.063	+85	+11	+67
8.19	.165	1.65	1.64	.046	.140	.085	+119	+25	+80
8.88	.075	2.34	2.33	.107	.063	.069	−32	+12	+6
9.26	.117	2.72	2.71	.099	.134	.132	+18	−17	−15
11.63	.152	5.09	5.08	.160	.141	.200	−8	+11	−48
11.84	.083	5.30	5.29	.126	.156	.181	−43	−73	−98
12.09	.140	5.55	5.54	.124	.124	.147	+16	+16	−7
12.31	.127	5.77	5.76	.124	.070	.093	+3	+57	+34
12.57	.047	6.03	6.02	.078	.054	9.031	−31	−7	+16
12.86	.027	6.32	6.31	.033	.062	8.994	−6	−35	+33
13.12	.207	6.58	6.57	.086	.093	9.078	+121	+114	+129

Table 6. Continued.

t	m_0	Phase of Rotation $p_I = 7^h.7269$	Phase of Rotation $p_{II} = 7^h.857$	Magnitude from mean Light-Curve I	Magnitude from mean Light-Curve II	Magnitude from mean Light-Curve superposed I+II	Dev. × 1000 Obs.-Comp. I	Dev. × 1000 Obs.-Comp. II	Dev. × 1000 Obs.-Comp. I+II
				February 13.					
h		h	h						
6.63	9.195	0.91	0.51	9.122	9.101	9.122	+ 73	+ 94	+ 73
6.85	.067	1.13	0.73	.100	.103	.102	— 33	— 36	— 35
7.10	.057	1.38	0.98	.061	.081	.041	— 4	— 24	+ 16
7.31	.067	1.59	1.19	.035	.088	.022	+ 32	— 21	+ 45
7.71	.141	1.99	1.59	.119	.144	.162	+ 22	— 3	— 21
7.98	9.101	2.26	1.86	.113	.093	.105	— 12	+ 8	— 4
8.24	8.985	2.52	2.12	.104	.031	.034	—119	— 46	— 49
8.45	9.137	2.73	2.33	.097	.063	.059	+ 40	+ 74	+ 78
9.35	.047	3.63	3.23	.125	.089	.113	— 78	— 42	— 66
9.68	.187	3.96	3.56	.155	.130	.184	+ 32	+ 57	+ 3
11.52	.249	5.80	5.40	.124	.147	.170	+125	+102	+ 79
11.72	.098	6.00	5.60	.091	.102	9.092	+ 7	— 4	+ 6
11.95	.132	6.23	5.83	.034	.062	8.995	+ 98	+ 70	+137
12.15	.017	6.43	6.03	.050	.054	9.003	— 33	— 37	+ 14
12.52	.062	6.80	6.40	.096	.071	.066	— 34	— 9	— 4
12.75	.067	7.03	6.63	.101	.098	.098	— 34	— 31	— 31
12.97	.175	7.25	6.85	.094	.104	.097	+ 81	+ 71	+ 78
13.18	.119	7.46	7.06	.098	.099	.096	+ 21	+ 20	+ 23
				February 22.					
11.25	.129	5.17	1.13	.149	.084	.132	— 20	+ 45	— 3
11.47	.091	5.39	1.35	.123	.111	.133	— 32	— 20	— 42
11.70	.123	5.62	1.58	.124	.143	.166	— 1	— 20	— 43
11.92	.099	5.84	1.80	.121	.115	9.135	— 22	— 16	— 36
12.18	9.011	6.10	2.06	.049	.031	8.969	— 38	— 20	+ 42
12.39	8.915	6.31	2.27	.033	.055	8.987	—118	—140	— 72
12.63	9.055	6.55	2.51	.083	.080	9.062	— 28	— 25	— 7
12.86	.075	6.78	2.74	.095	.135	.129	— 20	— 60	— 54
				March 5.					
7.46	.038	2.67	2.07	.102	.030	.031	— 64	+ 8	+ 7
7.64	.074	2.85	2.25	.075	.052	.026	— 1	+ 22	+ 48
7.91	.168	3.12	2.52	.080	.086	.065	+ 88	+ 82	+103
8.14	.142	3.35	2.75	.103	.136	.138	+ 39	+ 6	+ 4
				March 12.					
8.05	9.069	1.28	5.66	.069	.088	9.056	0	— 19	+ 13
8.28	8.955	1.51	5.89	.031	.058	8.988	— 76	—103	— 33
8.54	9.115	1.77	6.15	.067	.054	9.020	+ 48	+ 61	+ 95
8.78	.125	2.01	6.39	.123	.070	.092	+ 2	+ 55	+ 33
9.12	.127	2.35	6.73	.107	.102	.108	+ 20	+ 25	+ 19
9.34	.139	2.57	6.95	.104	.103	.106	+ 35	+ 36	+ 33
9.62	.039	2.85	7.23	.075	.084	.058	— 36	— 45	— 19
9.85	.021	3.08	7.46	.074	.070	.043	— 53	— 49	— 22
11.77	.197	5.00	1.52	.142	.140	.181	+ 55	+ 57	+ 16
11.97	.235	5.20	1.72	.143	.129	.171	+ 92	+106	+ 64

Table 6. Continued.

t	m_0	Phase of Rotation $P_{\rm I}$ = =$7^h.7269$	$P_{\rm II}$ = =$7^h.857$	Magnitude from mean Light-Curve I	II	superposed I+II	Dev. × 1000 Obs.-Comp. I	II	I+II
				March 13.					
h		h	h						
8.23	8.987	2.27	6.27	9.112	9.059	9.070	—125	— 72	—83
8.45	9.067	2.49	6.49	.104	.084	.087	— 37	— 17	—20
8.72	9.091	2.76	6.76	.094	.103	.096	— 3	— 12	— 5
8.95	8.997	2.99	6.99	.062	.103	.065	— 65	—106	—68
9.36	9.053	3.40	7.40	.108	.069	.076	— 55	— 16	—23
9.58	.141	3.62	7.62	.124	.109	.132	+ 17	+ 32	+ 9
9.84	.209	3.88	0.02	.161	.152	.212	+ 48	+ 57	— 3
10.14	.043	4.18	0.32	.104	.108	.111	— 61	— 65	—68
10.50	.161	4.54	0.68	.112	.104	.115	+ 49	+ 57	+46
10.76	.095	4.80	0.94	.114	.084	.097	— 19	+ 11	— 2
11.00	.219	5.04	1.18	.150	.088	.137	+ 69	+131	+82
11.21	.091	5.25	1.39	.135	.117	.151	— 44	— 26	—60
				March 16.					
7.67	.134	4.17	6.99	.106	.102	.107	+ 28	+ 32	+27
7.88	.116	4.38	7.20	.102	.087	.088	+ 14	+ 29	+28
8.12	.137	4.62	7.44	.114	.069	.082	+ 23	+ 68	+55
8.33	.098	4.83	7.65	.115	.118	.132	— 17	— 20	—34
8.61	.180	5.11	0.08	.160	.152	.211	+ 20	+ 28	—31
8.85	.112	5.35	0.32	.124	.108	.131	— 12	+ 4	—19
9.10	.042	5.60	0 57	.124	.102	.125	— 82	— 60	—83
9.34	.096	5.84	0.81	.121	.099	.119	— 25	— 3	—23
9.61	.024	6.11	1.08	.048	.082	.029	— 24	— 58	— 5
9.86	.042	6.36	1.33	.036	.108	.043	+ 6	— 66	— 1
10.07	.078	6.57	1.54	.085	.141	.125	— 7	— 63	—47
10.29	.092	6.79	1.76	.096	.122	.117	— 4	— 30	—25
11.09	.080	7.59	2.56	.107	.088	.094	— 27	— 8	—14
11.33	.176	0.11	2.80	.139	.139	.177	+ 37	+ 37	— 1
11.65	.092	0.43	3.12	.150	.099	.148	— 58	— 7	—56
11.94	.128	0.72	3.41	.127	.108	.134	+ 1	+ 20	— 6
12.33	.185	1.11	3.80	.105	.142	.146	+ 80	+ 43	+39
12.58	.168	1.36	4.05	.054	.138	.091	+114	+ 30	+77
12.85	.088	1.63	4.32	.042	.110	.051	+ 46	— 22	+37
13.08	.086	1.86	4.55	.086	.078	.063	0	+ 8	+23
				March 18.					
7.76	.122	5.91	0.09	.114	.152	.165	+ 8	— 30	—43
7.96	.110	6.11	0.29	.048	.111	.058	+ 62	— 1	+52
8.21	.052	6.36	0.54	.036	.102	.037	+ 16	— 50	+15
8.44	.068	6.59	0.77	.087	.101	.087	— 19	— 33	—19
8.74	.082	6.89	1.07	.099	.081	.079	— 17	+ 1	+ 3
8.96	.128	7.11	1.29	.101	.102	.102	+ 27	+ 26	+26
9.20	.082	7.35	1.53	.094	.141	.134	— 12	— 59	—52
9.44	.120	7.59	1.77	.107	.120	.126	+ 13	0	— 6
9.87	.178	0.29	2.20	.167	.044	.110	+ 11	+134	+68
10.08	.038	0.50	2.41	.132	.070	.101	— 94	— 32	—63

Table 6. Continued.

t	m_0	Phase of Rotation $P_I =$ $=7^h.7269$	Phase of Rotation $P_{II} =$ $= 7^h.857$	Magnitude from mean Light-Curve I	Magnitude from mean Light-Curve II	Magnitude from mean Light-Curve superposed I+II	Dev. × 1000 Obs.-Comp. I	Dev. × 1000 Obs.-Comp. II	Dev. × 1000 Obs.-Comp. I+II
			March 19.						
h		h	h						
7.85	9.172	6.82	0.61	9.097	9.103	9.099	+ 75	+ 69	+ 73
8.04	.115	7.01	0.80	.101	.100	.100	+ 14	+ 15	+ 15
8.30	.020	7.27	1.06	.094	.081	.074	— 74	— 61	— 54
8.53	.133	7.50	1.29	.101	.102	.102	+ 32	+ 31	+ 31
8.84	.130	0.08	1.60	.134	.144	.177	— 4	— 14	— 47
9.08	.110	0.32	1.84	.166	.100	.165	— 56	+ 10	— 55
9.30	.170	0.54	2.06	.130	.031	.060	+ 40	+139	+110
9.51	.060	0.75	2.27	.126	.055	.080	— 66	+ 5	— 20
9.84	.208	1.08	2.60	.109	.095	.103	+ 99	+113	+105
10.06	.125	1.30	2.82	.065	.139	.103	+ 60	— 14	+ 22
10.30	.078	1.54	3.06	.032	.110	.041	+ 46	— 32	+ 37
10.51	.002	1.75	3.27	.064	.090	.053	— 62	— 88	— 51
11.17	.145	2.41	3.93	.105	.142	.146	+ 40	+ 3	— 1
11.44	.170	2.68	4.20	.102	.127	.128	+ 68	+ 43	+ 42
11.71	.012	2.95	4.47	.062	.085	.046	— 50	— 73	— 34
11.98	.062	3.22	4.74	.093	.084	.076	— 31	— 22	— 14
12.36	.182	3.60	5.12	.121	.146	.166	+ 61	+ 36	+ 16
12.59	.120	3.83	5.35	.156	.152	.207	— 36	— 32	— 87
12.86	.028	4.10	5.62	.114	.097	.110	— 86	— 69	— 82
13.10	.088	4.34	5.86	.101	.060	.060	— 13	+ 28	+ 28
			March 21.						
8.24	9.018	1.12	1.85	.102	.097	9.098	— 84	— 79	— 80
8.46	8.924	1.34	2.07	.058	.030	8.987	—134	—106	— 63
8.66	8.974	1.54	2.27	.032	.055	8.986	— 58	— 81	— 12
8.87	8.950	1.75	2.48	.064	.076	9.039	—114	—126	— 89
9.13	9.130	2.01	2.74	.123	.135	.157	+ 7	— 5	— 27
9.40	9.158	2.28	3.01	.111	.121	.121	+ 47	+ 37	+ 27

points joined by straight lines; in this way curves of variation for each day separately were obtained; although these curves were without doubt considerably deformed by observational errors, if separated by a 1, 2 or 3 days interval they generally presented a sufficient number of common features for the identification of their maxima and minima.

Generally a shift of the later curve by $0^h.4$—$0^h.8$ backwards per day led to very satisfactory agreement. Let us denote this shift by x; then, if P is the period, and k — an even number, we have

$$kP = 24^h - x.$$

From a comparison of different curves it appeared that $k = 3$ is evidently the only acceptable value; this gives

$$P = 8^h - \frac{x}{3}, \text{ or a period near } 7^h.8.$$

To determine more precisely the relative shifts of the different curves, copies of them made on transparent paper were superposed upon one another and shifted along the t — axis till the difference between both curves became a minimum; sometimes the same pair of curves gave two shifts with minimum deviation; in this case both shifts were noted. The results of such a comparison are given below.

Dates		Shift	Remarks	x	Weight
December	16—18	$2x = 1^h.42$	very good	$0^h.71$	8
February	12—13	$x = 0\ .44$	very good	0 .44	2
„	„ „	$x = 0\ .70$	bad	0 .70	0.5
March	12—13	$x = 0\ .70$	good	0 .70	1
„	16—18	$2x = 1\ .48$	good	0 .74	4
„	„ „	$2x = 0\ .80$	acceptable	0 .40	2
„	16—19	$3x = 1\ .33$	good	0 .44	9
„	„ „	$3x = 2\ .60$	good	0 .87	9
„	18—19	$x = 0\ .48$	very good	0 .48	1

The weight here was assumed equal to the square of the interval in days, multiplied by 2 or 1 when the coincidence was noted as "very good" or "good" respectively, and by 0.5 in the remaining cases.

From an inspection of the values of x obtained it appears that they may be divided into two distinct groups, the first with $x \geqslant 0^h.70$ and the other with $x < 0^h.5$; the weighted mean of the first group gives $x = 0^h.78$, and the mean of the second group —$x = 0^h.44$; these values correspond to two different periods:

$$P_{\text{I}} = 7^h.740 \text{ and}$$
$$P_{\text{II}} = 7^h.853 \text{ (units of sidereal time).}$$

With the purpose in view to decide which period is the right, and which — the wrong one, both periods were corrected by successive approximations and subjected to the test of all observations; and the surprising result was obtained that *both* periods correspond to a doubtlessly real variation of brightness. The most natural explanation of this result is that Neptune, like

Jupiter and Saturn, rotates not as a solid body but with different angular velocity in different zones; our bifurcation of the period of light-variation is then readily accounted for; e. g. we may suppose that the major part of the visible surface of Neptune belongs to two different zones — say, the quickly rotating equatorial zone and the slower temperate zone. With the position of Neptune's axis adopted above the angle between the line of sight and Neptune's equator during the period of observation becomes -29^0, so that practically only one of the two temperate zones could be visible; this circumstance must have added to the uniformity of the second period.

The accurate values of the periods and the light-curves were determined quite independently for both periods, on the assumption that only the period under question existed. Such a method is justified for a sufficiently long and numerous series of observations: in this case with respect to the first period the variations caused by the second may be regarded as accidental errors, and vice versa, so that the mean light-curve obtained will correspond to the period adopted, as if the other variation did not exist.

To determine each period, the phase of rotation was computed with the first approximation given above and for the three following groups of days preliminary light curves were constructed:

I. group: December 16 and 18, mean date ass. Dec. 18.
II. „ : February 12—22, mean date ass. Febr. 13.
III. „ : March 5—21, mean date March 16.

The relative shift of the preliminary light-curves gave the correction of the period.

For the first period ($P_{\mathrm{I}} = 7^{\mathrm{h}}.74$) the three light-curves showed high similarity, and gave for the correction of the period:

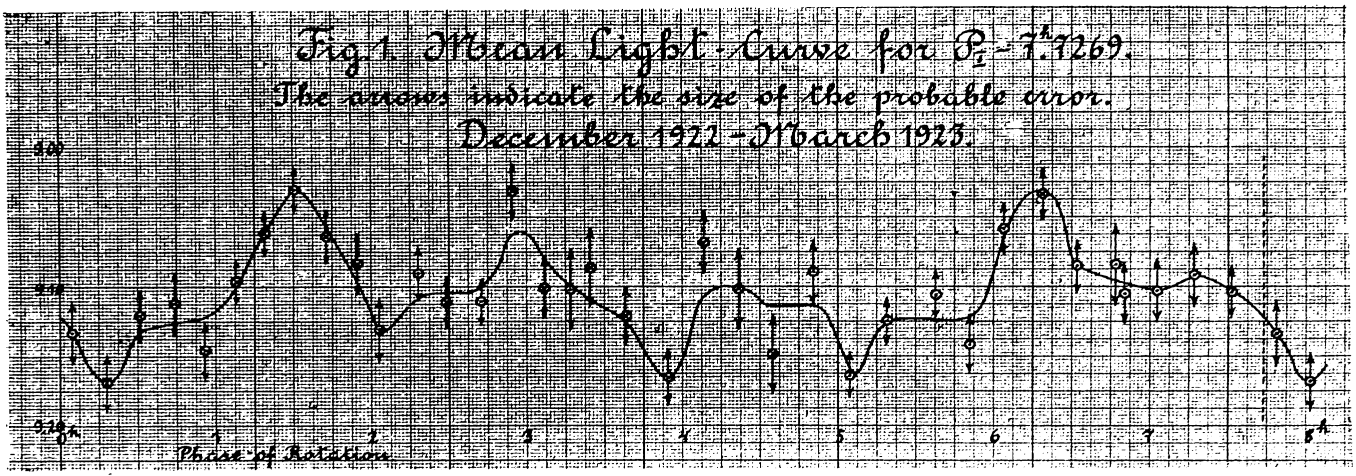
from the February—March groups . . . $-0^{\mathrm{h}}.016$ (interval 31 days)
„ „ December—March „ . . . $-0^{\mathrm{h}}.0131$ („ 88 „).

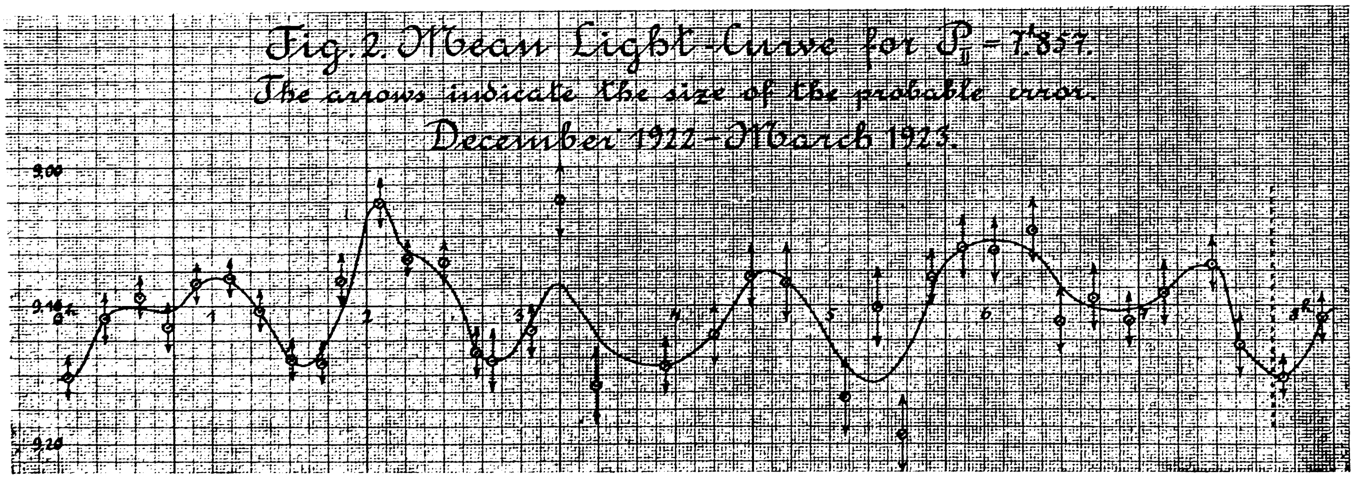
The last value, being of greater weight, was adopted; this gives for the first period

$P_{\mathrm{I}} = 7^{\mathrm{h}}.7269 \pm 0^{\mathrm{h}}.0007$ . . . . (in units of sidereal time);

the probable error is roughly estimated.

As to the second period, it may be noted that our first approximation is remarkably near the value found by Maxwell Hall in 1915[1]: $7^h.835$ (M. T.) $= 7^h.857$ (Sid. T.); this period was therefore adopted as the first approximation, instead of our value found above ($7^h.853$). The light-curves for February and March determined with this period were similar and indicated a cor-





rection of $-0^h.003$; the two days of December, however, seem to have been chiefly under the influence of the first period, so that the comparison with the other two groups gave indeterminate results; the best correction obtained was $+0^h.002$, with an uncertainty of the same order; therefore the final value of the second period was adopted unchanged:

$$P_{II} = 7^h.857 \pm 0^h.002 \quad . \; . \; . \; . \quad \text{(units of sid. time)}.$$

1) *Monthly Notices* **75**, pp. 626—628.

The *phase of rotation* for each observation corresponding to the two periods found is given in the 3[d] and 4[th] columns of table 6; the zero of phase is chosen arbitrarily (0^h, December 16).

To determine the mean light-curves for each period average values of the observed magnitude were computed for every $0^h.2$ interval of the phase of rotation; if only 1 observation was found in the corresponding interval, it was joined with the near-

Table 7.

Normal Points of the Light-Curve for $P_I = 7^h.7269$.

Phase of Rotation Limits	Phase of Rotation Mean	Mean Magn.	*n*	Deviations × 100
h h	h			
0.00—0.19	0.08	9.134	3	—4 +4 —0
0.20—0.39	0.30	.168	4	—3 +8 +1 —6
0.40—0.59	0.52	.120	5	+8 —2 —3 —8 +5
0.60—0.79	0.74	.112	3	+4 +2 —5
0.80—0.99	0.93	.146	4	—4 +2 —3 +5
1.00—1.19	1.13	.096	6	—8 —2 —3 +9 +11 —8
1.20—1.39	1.32	.062	6	—3 —0 +1 +11 +6 —14
1.40—1.59	1.51	.030	6	—6 +10 +4 —8 +5 —6
1.60—1.79	1.71	.064	5	+ 10 +5 +2 —6 —11
1.80—1.99	1.91	.084	3	—6 +6 +0
2.00—2.19	2.05	.131	3	+1 —1 —0
2.20—2.39	2.30	.090	5	—2 +1 +4 —10 +7
2.40—2.59	2.48	.111	5	+11 —13 +3 —4 +4
2.60—2.79	2.71	.110	6	—0 +1 +3 —7 —2 +6
2.80—2.99	2.91	.031	4	+4 +1 —3 —2
3.00 —3.19	3.11	.101	3	+1 +7 —8
3.20—3.39	3.28	.102	2	+4 —4
3.40—3.59	3.42	.087	2	+3 —3
3.60—3.79	3.64	.122	4	—0 —8 +2 +6
3.80—3.99	3.91	.165	4	—2 +2 +4 —4
4.00—4.19	4.15	.068	3	—2 +7 —4
4.20—4.39	4.36	.102	2	+1 —1
4.40—4.79	4.58	.149	2	+1 —1
4.80—4.99	4.85	.089	3	—2 +1 +1
5.00—5.19	5.08	.164	6	—6 —1 —4 +3 +6 +2
5.20—5.39	5.31	.125	6	+1 —4 —3 +11 —3 —1
5.40—5.79	5.63	.107	5	+3 —0 +2 +2 —6
5.80—5.99	5.85	.142	4	+11 —4 —5 —2
6.00—6.19	6.07	.058	5	—1 +4 —5 —3 +5
6.20—6.39	6.32	.034	5	—1 +10 —12 +1 +2
6.40—6.59	6.54	.085	5	+12 —7 —3 —1 —2
6.60—6.79	6.78	.084	2	— 1 +1
6.80—6.99	6.84	.105	3	—4 —2 +7
7.00—7.19	7.05	.103	3	—4 +2 +1
7.20—7.39	7.29	.092	3	+8 —1 —7
7.40—7.72	7.52	.104	5	—3 +2 —2 +2 +2

est other interval; in this way *normal points* of the light-curves were obtained. Tables 7 and 8 contain the result.

The normal points from these tables were plotted and smooth curves drawn; these curves are represented on fig. 1 and 2. In drawing the curves the probable errors of the normal points were taken into account; the probable deviation of

Table 8.

Normal Points of the Light-Curve for $P_{II} = 7^h.857$.

Phase of Rotation: Limits	Phase of Rotation: Mean	Mean Magn.	n	Deviations × 100
h h	h			
0.00—0.19	0.07	9.152	6	—2 +1 —6 +6 +3 —3
0.20—0.39	0.31	.108	5	—8 +14 —6 +0 +0
0.40—0.59	0.53	.094	6	+10 —12 +1 +10 —5 —4
0.60—0.79	0.71	.115	5	—1 —5 +5 —5 +6
0.80—0.99	0.90	.084	6	—6 +3 —3 +1 +1 +3
1.00—1.19	1.11	.080	8	—6 —0 —1 +5 +14 —6 +0 —6
1.20—1.39	1.31	.104	6	+3 —1 —1 —6 +2 +3
1.40—1.59	1.52	.138	7	+8 —1 +0 —2 +6 —6 —6
1.60—1.79	1.71	.142	6	—4 +2 +9 —5 —2 —1
1.80—1.99	1.84	.082	4	+2 +2 +3 —6
2.00—2.19	2.08	.026	5	—4 —2 +1 +14 —10
2.20—2.39	2.27	.066	8	+5 +1 +7 —15 +1 +11 —1 —9
2.40—2.59	2.50	.069	6	+5 —1 +10 +1 —3 —12
2.60—2.79	2.71	.134	5	—2 —6 +1 +7 —0
2.80—2.99	2.81	.140	3	—2 +4 —2
3.00—3.19	3.06	.118	4	+2 —3 —4 +4
3.20—3.39	3.25	.024	2	+2 —2
3.40—3.59	3.48	.158	2	+3 —3
3.80—4.19	3.94	.143	4	—7 +4 +0 +2
4.20—4.39	4.25	.121	3	—2 —3 +5
4.40—4.59	4.49	.078	3	+6 +1 —7
4.60—4.79	4.72	.084	2	+2 —2
4.80—4.99	—	—	0	— — —
5.00—5.19	5.10	.167	2	—2 +2
5.20—5.39	5.32	.102	2	—2 +2
5.40—5.59	5.47	.194	2	—5 +6
5.60—5.79	5.66	.080	4	+5 +2 —1 —5
5.80—5.99	5.86	.058	3	+7 —10 +3
6.00—6.19	6.07	.060	3	—1 —4 +6
6.20—6.39	6.32	.046	3	—2 +8 —6
6.40—6.59	6.49	.112	3	+10 —5 —4
6.60—6.79	6.71	.095	3	—3 +3 —0
6.80—6.99	6.94	.111	4	+6 +3 —11 +2
7.00—7.39	7.16	.091	3	+3 —5 +2
7.40—7.59	7.47	.070	4	0 —5 —2 +7
7.60—7.85	7.65	.129	3	+3 +1 —3

1 observed magnitude was computed according to the formula

$$\pm 0.674 \sqrt{\frac{\Sigma (\text{Dev.})^2}{N-\nu}},$$

where $N = 145$ is the total number of observations, and ν — the number of normal points ($\nu = 36$ for the first, and 35 for the second curve); this gave for the probable deviation from a normal magnitude the value ± 0.040 for the first, and ± 0.041 for the second curve; the first value was adopted for both curves and the probable error of 1 normal point came out as follows:

n =	2	3	4	5	6	7	8
p. e. =	± 0.029	± 0.023	± 0.020	± 0.018	± 0.016	± 0.015	± 0.014.

The probable error of each normal point is represented on the figures by arrows. The curves were smoothed so that very small oscillations within the limits of the probable error were made to disappear and certain improbably abrupt changes of brightness were softened.

The first conclusion which may be drawn from an inspection of the curves is that both periods correspond to a doubtlessly real variation, the first within a range of 0.14 st. mg., the second — within 0.13 st. mg. The internal agreement of the normal points is somewhat better for the first curve than for the second, which is probably partly due to the circumstance that the observations are more evenly distributed over the first period. The second curve shows a curious feature: it has six approximately equidistant maxima, which may correspond on the planet to six white spots separated from one another by 60° in longitude.

The 5^{th} and 6^{th} columns of table 6 contain the magnitude read from the curves of fig. 1 or 2 for the corresponding phase of rotation; the 8^{th} and 9^{th} columns of the same table give the deviation of the observed magnitude from the values read from the curves.

If both periods are real, it is obvious that the actual variation cannot be explained by a single light-curve but must be the result of superposition of both curves; since the range of variation is very small, we may compute the magnitude resulting from superposition by simply adding the deviations from the mean magnitude caused by each curve separately. Let m_1 and

m_2 be the magnitudes at a given moment according to curve I or II respectively, and let $\overline{m}$ be the mean magnitude of Neptune; then $m_1-\overline{m}$ and $m_2-\overline{m}$ will represent the deviations from the mean caused by each curve separately; the total deviation will be $(m_1-\overline{m})+(m_2-\overline{m})$, and the magnitude resulting from superposition is

$$(m_1-\overline{m})+(m_2-\overline{m})+\overline{m}=m_1+m_2-\overline{m}.$$

Column 7 of table 6 gives the magnitude computed according to this formula with $\overline{m}=9.101$, and the last column the deviation of the observed from the computed magnitude.

Table 9.

Distribution of Deviations: Observation-Computation.

Dev. St. Magn.	Number of Deviations from			
	Mean Magn.	Curve I	Curve II	Superposed I+II
±0.00	10	11	12	16
.01	15	22	19	16
.02	22	23	25	24
.03	20	19	20	20
.04	17	13	13	11
.05	6	11	5	14
.06	9	14	17	9
.07	9	7	12	13
.08	13	9	5	12
.09	3	4	2	3
.10	5	2	3	4
.I1	4	3	5	1
.12	4	6	0	0
.13	1	1	4	1
14	2	0	3	1
.15	3	0	0	0
.16	0	0	0	0
.17	0	0	0	0
18	2	0	0	0
Total	145	145	145	145
Σ (Dev.)^2	0.5989	0.4111	0.4483	0.3675
Mean Square Dev.	±0.0645	±0.0534	±0.0558	±0.0506

The degree of closeness by which each curve represents the observations may be estimated from the data of table 9; the considerable improvement introduced by the superposition of the two curves is obvious.

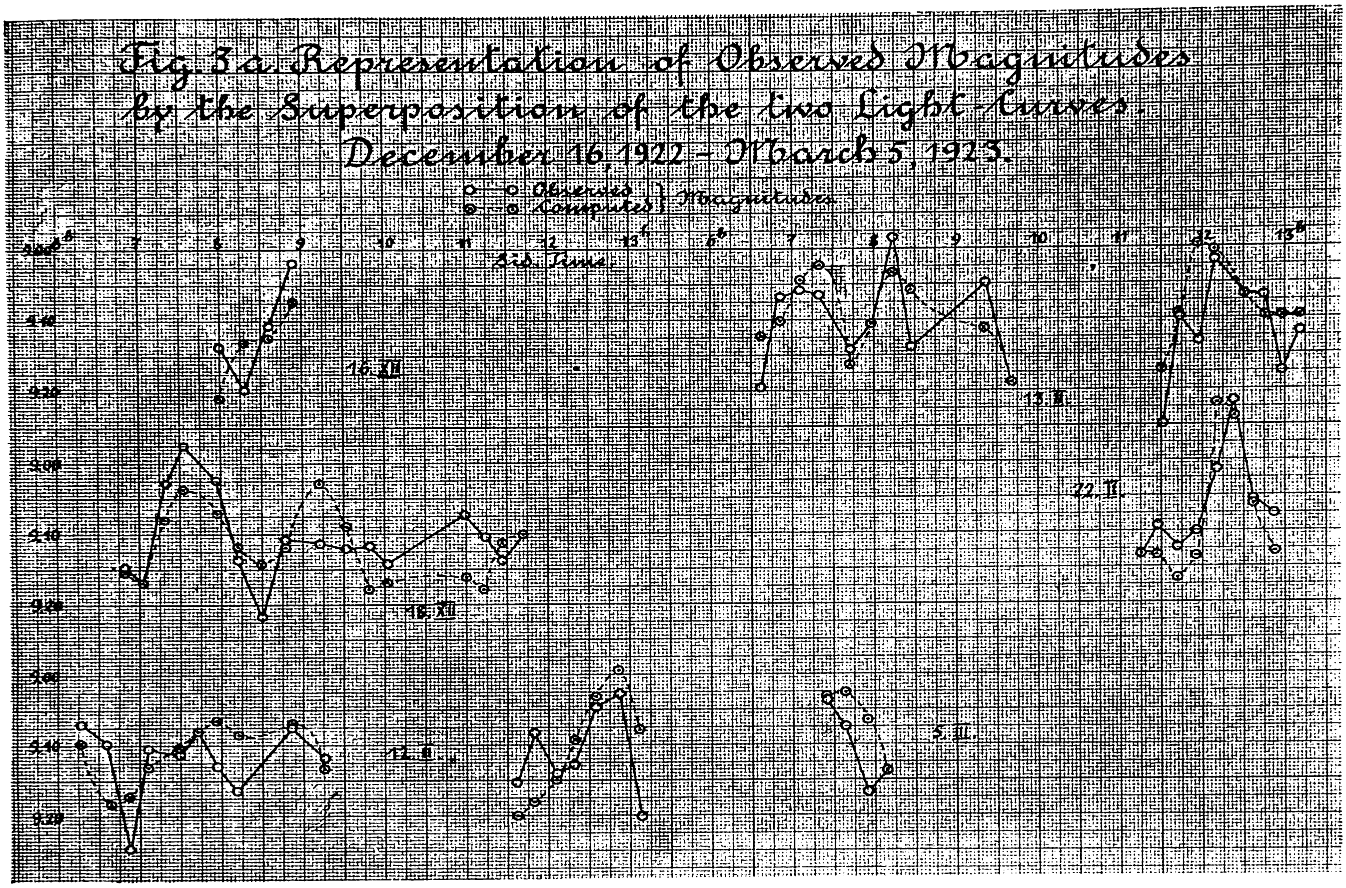


Fig. 3a. Representation of Observed Magnitudes by the Superposition of the two Light-Curves. December 16, 1922 – March 5, 1923.

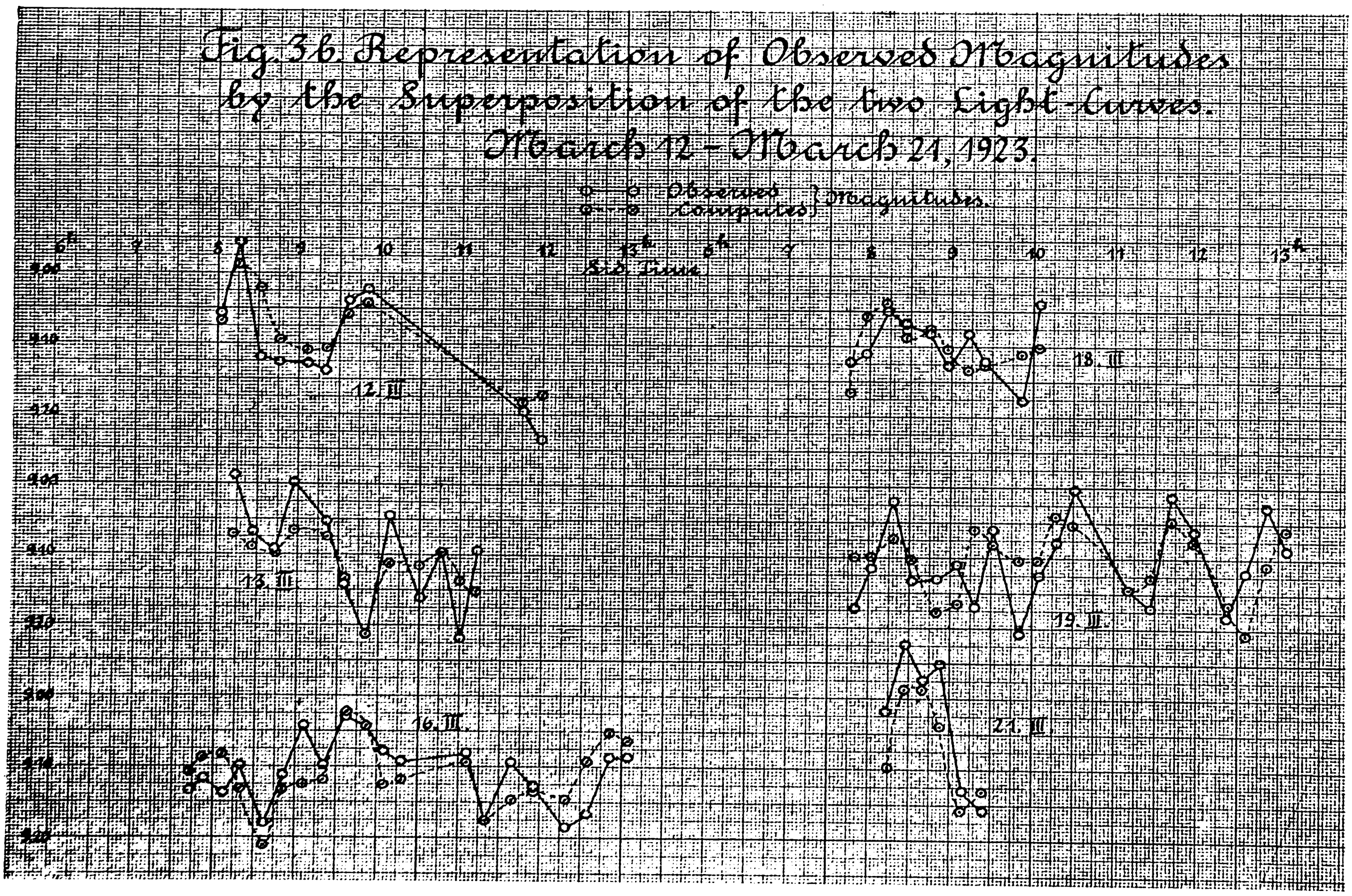


Fig. 3b. Representation of Observed Magnitudes by the Superposition of the two Light-Curves. March 12 – March 21, 1923.

On fig. 3a and 3b the theoretical curves of variation resulting from the superposition of curves I and II are traced for each evening of observation together with the individual observed points; the theoretical curves are represented schematically, their ordinates being exact only for the very moments of observation, whereas the intermediate variation is sometimes substituted simply by a straight line; for purposes of comparison of observation with theory such a simplified treatment is quite legitimate. A careful examination of the figures indicates that there is not a single day out of the 12 days of observation which does not reveal the principal features of the theoretical curve. The agreement of theory with observation would be even much closer, if on certain days — e. g. on March 21 — all observed magnitudes were changed by the same constant amount; such a correction would correspond to a variation in the sun's radiation or to changes in the general brightness of the planet produced e. g. by changes in the polar region turned towards the earth.

That real irregularities in the light-variation of Neptune have contributed to the observed deviations seems highly probable from the following. From the standpoint of accuracy of measurement the different periods of observation were not quite equivalent, the observations of March being less accurate than those of February or December; this is revealed by the behaviour of the comparison stars which in March show a greater average deviation; a possible explanation may be sought in the greater age of the plates, they being considerably more "veiled" in March than previously.

In table 5 we find for each negative separately the probable error of the mean of the system of comparison stars derived from their internal agreement; we may assume that the mean error of one measured magnitude of Neptune is proportional to this probable error; then an excess of the observed mean deviation over the expected deviation at some epoch may be regarded as a measure of changes on the light-curve itself. The following table may give some information on this subject.

	December	February	March
Mean p. e. of the System of Comp. St.	± 0.018	± 0.021	± 0.027
Mean sq. dev. Obs.-Comp. for Neptune	± 0.051	± 0.055	± 0.049

	December	February	March
n	20	43	82
Mean sq. dev. of Neptune to be expected	± 0.033	± 0.037	(± 0.049)
Quadratic Excess of mean sq. dev.	± 0.039	± 0.041	(± 0.000)

In this table the "mean square deviation to be expected" was computed on the assumption that in the March group the observed mean deviation is entirely due to accidental errors of observation; this assumption gave for the ratio (mean sq. dev. of Neptune): (mean p. e. of comp. stars) the value $\frac{0.049}{0.027}$. From the last line of the table it appears that in December and February a variability with a mean square deviation ± 0.04 st. mg. remained unexplained by our mean curves.

Table 10 gives the average algebraïc deviation of the observed brightness of Neptune from the theoretical curve; the data of this table may be of some use in the question of variability of the sun.

Table 10.

Date	1922 Dec. 16	1922 Dec. 18	1923 Febr. 12	1923 Febr. 13	1923 Febr. 22	1923 March 5
Average Dev.	-0.018	-0.012	$+0.008$	$+0.019$	-0.027	$+0.041$
n	4	16	17	18	8	4
p. e.	± 0.019	± 0.010	± 0.009	± 0.009	± 0.013	± 0.019

Date	1923 March 12	1923 March 13	1923 March 16	1923 March 18	1923 March 19	1923 March 21
Average Dev.	$+0.020$	-0.016	-0.003	-0.001	$+0.002$	-0.041
n	10	12	20	10	20	6
p. e.	± 0.012	± 0.011	± 0.009	± 0.012	± 0.009	± 0.015

The deviations are on the average greater than should be expected from their probable errors (computed on the assumption of a p. e. $= \pm 0.038$ for a single observation; this includes accidental variations in the brightness of Neptune mentioned above); it must be remembered, however, that the result is liable to be influenced by systematic errors or variations in the light-curves.

Before concluding this section a few words must be said on a systematical source of error which could have some influence on our results. If Neptune differed much in colour from the mean colour of the comparison stars, an effect of differential absorption due to the difference in the coefficients of absorption would arise; such an effect must reveal itself chiefly at great hour-angles. To prove whether a sensible source of error of this kind existed, the mean magnitude and deviation for the 19 observations made at an hour-angle greater than 3^h were computed. The result was:

mean magnitude $= 9.096 \pm 0.011$ or by 0.005 ± 0.011 less than the general mean; mean deviation from the theoretical curve $= + 0.010 \pm 0.010$.

These values are small and entirely within the limits of the probable error and therefore the suspected effect may be neglected in the present series of observations.

4. Comparison with other Observational Series.

In the first paper there are 26 observations of sufficient accuracy, made on March 22, 23 and 24, 1922 [1]) which may serve as a first independent test of the results arrived at in the present investigation. The data for these observations are found in table 11.

The assumption was made that during March 1922 the light-curves corresponding to the two periods were the same as found later for the period December 1922—March 1923; although during a year's interval changes in the surface features determining the light-curve of the planet may be expected *à priori*, it will be shown that in the present case our assumption is excellently supported by observational evidence. With our hypothesis the only thing to be sought is a plausible correction of the periods. It was found that a correction of $+ 0^h.0009$ applied to both periods led to good agreement; this correction is fairly within the range of the probable errors assigned to the periods in the preceding section, $\pm 0^h.0007$ and $\pm 0^h.0020$ respectively, and corresponds to a correction of the phase of rotation equal to 1 hour after a year's interval. The periods finally adopted were therefore:

$$\left.\begin{aligned} P_{\text{I}} &= 7^h.7278 \pm 0^h.0002 \\ P_{\text{II}} &= 7^h.8579 \pm 0^h.0002 \end{aligned}\right\} \text{units of sidereal time.}$$

1) T.P. 25_3, p. 33.

Table 11.

Sid. Time	Magn. Obs.	Phase of Rot. I	Magn. I —9.101	Resid. from I	Phase of Rot. II	Magn. II —9.101	Resid. from II	Magn. I+II	Resid. from I+II Obs.-Comp.
				March 22, 1922.					
h		h			h				
8.5	+0.034	4.7	+0.013	+0.021	3.7	+0.038	—0.004	+0.051	—0.017
9.0	+ .122	5.2	+ .042	+ .080	4.2	+ .026	+ .096	+ .068	+ .054
9.2	+ .088	5.4	+ .023	+ .065	4.4	— .005	+ .093	+ .018	+ .070
9.5	+ .038	5.7	+ .023	+ .015	4.7	— .023	+ .061	.000	+ .038
9.8	— .056	6.0	— .010	— .046	5.0	+ .026	— .082	+ .016	— .072
10.2	+ .032	6.4	— .063	+ .095	5.4	+ .046	— .014	— .017	+ .049
10.6	— .062	6.8	— .005	— .057	5.8	— .037	— .025	— .042	— .020
10.8	— .056	7.0	.000	— .056	6.0	— .047	— .009	— .047	— .009
11.1	+ .008	7.3	— .008	+ .016	6.3	— .040	+ .048	— .048	+ .056
11.5	— .003	7.7	+ .017	— .020	6.7	.000	— .003	+ .017	— .020
11.7	+ .027	0.2	+ .060	— .033	6.9	+ .003	+ .024	+ .063	— .036
12.0	+ .019	0.5	+ .031	— .012	7.2	— .014	+ .033	+ .017	+ .002
				March 23, 1922.					
8.6	+ .038	5.6	+ .023	+ .015	4.2	+ .006	+ .032	+ .029	+ .009
8.8	+ .011	5.8	+ .023	— .012	4.4	— .005	+ .016	+ .018	— .007
11.0	+ .053	0.3	+ .067	— .014	6.6	— .005	+ .058	+ .062	— .009
11.6	— .056	0.9	+ .022	— .078	7.2	— .014	— .042	+ .008	— .064
11.8	— .041	1.1	+ .006	— .047	7.4	— .032	— .009	— .026	— .015
12.1	— .034	1.4	— .054	+ .020	7.7	+ .031	— .065	— .023	— .011
12.4	+ .013	1.7	— .045	+ .058	0.1	+ .052	— .039	+ .007	+ .006
12.7	+ .017	2.0	+ .021	— .004	0.4	+ .001	+ .016	+ .022	— .005
				March 24, 1922.					
8.8	— .001	6.6	— .013	+ .012	4.8	— .009	+ .008	— .022	+ .021
9.1	+ .050	6.9	— .002	+ .052	5.1	+ .043	+ .007	+ .041	+ .009
9.3	+ .023	7.1	.000	+ .023	5.3	+ .056	— .033	+ .056	— .033
9.6	— .005	7.4	— .006	+ .001	5.6	+ .001	— .006	— .005	.000
9.9	— .060	0.0	+ .021	— .081	5.9	— .044	— .016	— .023	— .037
10.1	— .015	0.2	+ .060	— .075	6.1	— .047	+ .032	+ .013	— .028

The phases of rotation computed with these periods are given in the 3ᵈ and 6ᵗʰ columns of table 11; in this computation the zero phase of rotation was assumed to take place on March 16, 1923, at $3^h.50$ for $P_{\rm I}$, and at $0^h.68$ for $P_{\rm II}$ (see table 6); this date was adopted as representing the middle of the most numerous group of March observations on which our light-curves chiefly depend.

The 9ᵗʰ column gives the computed brightness, representing the deviation from the mean magnitude caused by the superposition of both curves; the mean algebraïc of these deviations in table 11 is not zero but equal to +0.010, which is explained by the circumstance that not the whole light-curve is represented;

the observed magnitudes in column 2 of table 11 are reduced to the same zero as those of column 9; the magnitudes of the 2[d] column represent therefore the deviations given in table 18, p. 33 of T.P. 25_3 after adding to them the constant correction $+0.010$ st. mg.

The last column of table 11 gives the residuals: observation — computation; as may be judged from these residuals, the agreement is excellent, the mean square deviation being only ± 0.035 stellar magnitudes, corresponding to a probable error of 1 magnitude $= \pm 0.024$ st. mg. Figure 4 illustrates the agreement between theory and observation even more clearly.

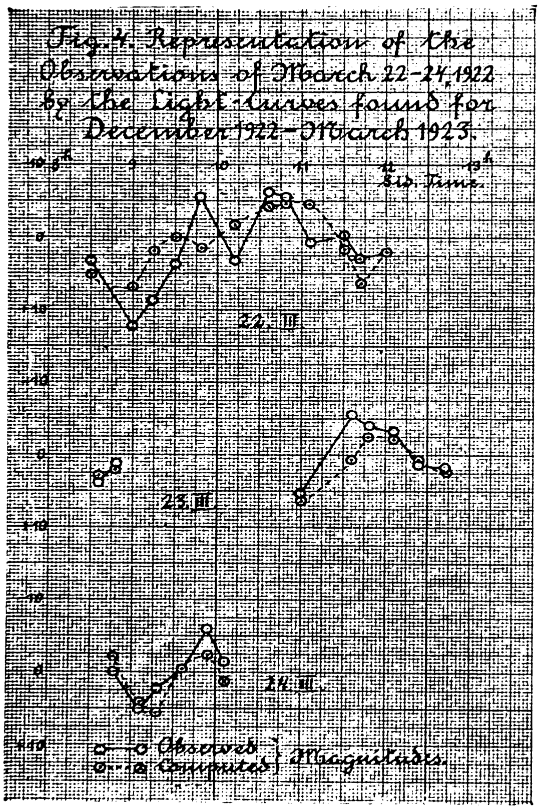


Fig. 4. Representation of the Observations of March 22-24, 1922 by the Light-Curves found for December 1922—March 1923.

The fact of agreement which is found for the observations of March, 1922, is of especial importance as the light-curves used were derived from an altogether different series of measures. On the other hand we arrive at the conclusion that the light-curves of Neptune may retain their general features unchanged during as long an interval as 1 year.

For purposes of testing the question of variability and period of rotation it is advisable to use only observations sufficiently numerous and made during a relatively short interval of time — say, separated by no greater an interval than 6 months; among the different photometric measures of Neptune there are apparently only 3 old series of observation which answer these conditions:

the series of G. Müller[1]) in 1884—1885, containing 72 observations, of which however a great part were made at low altitudes;

the series of measures by J. M. Baldwin[2]), containing 32

1) *Publ. d. Astroph. Obs. zu Potsdam.* B. VIII, pp. 284—287.

2) *Monthly Notices*, **68**, pp. 614—620.

observations of excellent quality, made at Potsdam between January and April 1908;

the already mentioned series by Maxwell Hall[1]) on Jamaica in 1915, who found a period of rotation almost exactly coinciding with our P_{II}.

The first two series were discussed by J. M. Baldwin[2]), but the period used by him, $7^h.92$ (M. T.) is evidently wrong, and so we must not wonder that no variation was found. Here we shall try the applicability of the periods found in the present paper to these photometric series.

In the series of Müller it appeared safe to use only observations made not too near the horizon; therefore 16 observations with $z \geqslant 70^0$ were rejected; 4 other observations where only 1 comparison star was measured were not used either, so that there remained a total of 52 observations made at more than 20^0 altitude and attached to two comparison stars, the same throughout the whole series. Table 12 contains the data for these observations.

Table 12.
Observations of G. Müller in 1884/85.

Date and M. T.	Observ. Magn. (Deviation) St. Mg.	Phase of Rotation		Magn. from Hand-Drawn Curve			Residual Obs.-Comput. × 100		
		$P_I = 7^h.7067$	$P_{II} = 7^h.8363$	I	II	superposed I+II	I	II	I+II
1884									
h		h	h						
Sept. 12, 11.42	+0.18	3.71	3.58	+0.03	+0.02	+0.06	+15	+16	+12
„ 14, 11.17	— .09	5.22	4.32	— .06	— .07	— .12	— 3	— 2	+ 3
„ 15, 10.83	— .07	5.76	4.47	— .05	— .07	— .11	— 2	0	+ 4
„ 17, 11.10	— .10	0.09	5.72	+ .02	— .04	— .01	—12	— 6	— 9
„ 21, 10.20	+ .06	2.71	6.78	.00	+ .01	+ .02	+ 6	+ 5	+ 4
„ 24, 9.58	— .14	4.73	7.64	— .04	+ .03	.00	—10	—17	—14
„ 26, 11.18	+ .02	0.38	2.38	.00	+ .05	+ .06	+ 2	— 3	— 4
„ 30, 10.82	.00	3.54	3.99	+ .03	— .06	— .02	— 3	+ 6	+ 2
Oct. 29, 7.65	+ .11	2.77	7.22	.00	+ .03	+ .04	+11	+ 8	+ 7
„ 29, 9.10	+ .01	4.22	0.84	— .02	— .03	— .04	+ 3	+ 4	+ 5
„ 29, 9.88	— .02	5.00	1.62	— .06	— .02	— .07	+ 4	0	+ 5
„ 31, 7.78	— .01	4.65	0.50	- .04	+ .02	— .01	+ 3	— 3	0
„ 31, 9.25	+ .01	6.12	1.97	— .02	+ .02	+ .01	+ 3	— 1	0
„ 31, 10.07	+ .09	6.94	2.79	+ .05	+ .09	+ .15	+ 4	0	— 6
„ 31, 11.18	— .06	0.35	3.90	.00	— .04	— .03	— 6	— 2	— 3

1) *Monthly Notices*, **75**, 626—628.
2) Loc. cit.

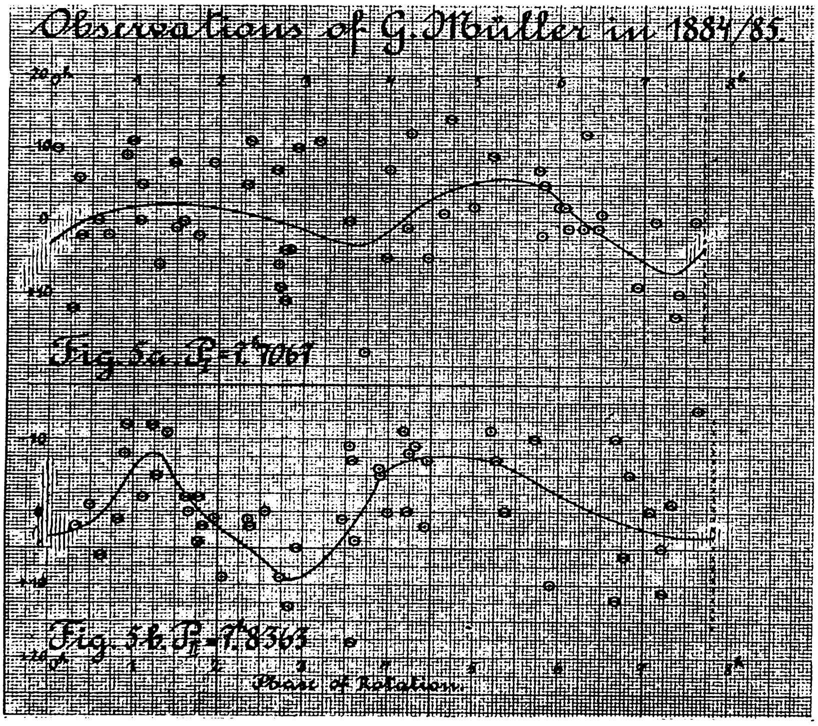
Table 12. Continued.

Date and M. T.		Observ. Magn. (Deviation) St. Mg.	Phase of Rotation $P_I =$ $=7^h.7067$	Phase of Rotation $P_{II}=$ $=7^h.8363$	Magn. from Hand-Drawn Curve I	Magn. from Hand-Drawn Curve II	Magn. from Hand-Drawn Curve superposed I+II	Residual Obs.-Comput. × 100 I	Residual Obs.-Comput. × 100 II	Residual Obs.-Comput. × 100 I+II
1884	h		h	h						
Nov. 1,	8.08	−0.05	5.83	1.29	−0 04	−0.08	−0.11	−1	+3	+6
„ 1,	9.63	+.13	7.38	2.84	+.07	+.09	+.17	+6	+4	−4
„ 1,	11.02	.00	1.07	4.23	−.02	−.07	−.08	+2	+7	+8
„ 2,	10.55	−.08	1.48	4.25	−.02	−.07	−.08	−6	−1	0
„ 4,	7.88	.00	0.57	2.56	−.02	+.06	+.05	+2	−6	−5
„ 4,	8.80	+.01	1.49	3.48	−.02	+.03	+.02	+3	−2	−1
„ 7,	7.45	+.04	2.78	3.61	.00	+.01	+.02	+4	+3	+2
„ 13,	6.80	+.10	7.41	5.90	+.07	−.02	+.06	+3	+12	+4
„ 19,	7.62	+.02	5.80	1.83	−.04	+.01	−.02	+6	+1	+4
„ 19,	10.23	+.02	0.70	4.44	−.02	−.07	−.08	+4	+9	+10
„ 19,	12.47	−.10	2.94	6.68	+.01	+.01	+.03	−11	−11	−13
Dec. 1,	8.63	−.08	1.95	0.90	−.02	−.04	−.05	−6	−4	−3
„ 2,	6.08	+.12	0.28	6.68	+.01	+.01	+.03	+11	+11	+9
„ 2,	7.57	+.02	1.77	0.33	−.02	+.02	+.01	+4	0	+1
„ 16,	7.68	−.01	6.50	7.32	+.01	+.03	+.05	−2	−4	−6
1885										
Jan. 8,	5.37	+.06	1.30	0.63	−.02	.00	−.01	+8	+6	+7
„ 8,	6.80	+.09	2.73	2.06	.00	+.02	+.03	+9	+7	+6
„ 9,	6.02	+.04	2.83	1.77	.00	.00	+.01	+4	+4	+3
„ 9,	7.17	+.05	3.98	2.92	+.01	+.09	+.11	+4	−4	−6
„ 12,	8.15	.00	7.61	5.37	+.05	−.07	−.01	−5	+7	+1
„ 12,	9.85	.00	1.60	7.07	−.02	+.03	+.02	+2	−3	−2
„ 17,	9.93	−.02	6.08	1.77	−.02	.00	−.01	0	−2	−1
„ 19,	6.55	+.05	4.46	7.21	−.04	+.03	.00	+9	+2	+5
„ 19,	8.40	−.12	6.31	1.23	.00	−.08	−.07	−12	−4	−5
„ 19,	10.72	−.09	0.92	3.55	−.02	+.02	+.01	−7	−11	−10
„ 20,	8.35	.00	7.14	1.67	+.06	−.02	+.05	−6	+2	−5
Febr. 3,	6.65	−.05	2.34	6.84	−.01	+.02	+.02	−4	−7	−7
„ 3,	8.57	−.12	4.26	0.93	−.02	−.05	−.06	−10	−7	−6
„ 6,	8.13	+.01	6.46	1.96	+.01	+.02	+.04	0	−1	−3
„ 6,	10.35	−.11	0.97	4.18	−.02	−.07	−.08	−9	−4	−3
„ 7,	6 80	−.02	6.01	1.12	−.03	−.08	−.10	+1	+6	+8
„ 7,	9.60	−.05	1.10	3.92	−.02	−.04	−.05	−3	1	0
„ 7,	10.88	−.11	2.38	5.20	−.01	−.07	−.07	−10	−4	−4
„ 11,	9.00	−.07	4.02	5.28	.00	−.06	−.05	−7	−1	−2
„ 12,	6.80	−.07	2.70	3.58	.00	+.02	+.03	−7	−9	−10
„ 24,	7.53	+.01	6.29	2.36	−.01	+.05	+.05	+2	−4	−4
March 10,	7.53	−.11	3.19	1.40	+.03	−.06	−.02	−14	−5	−9
Mean		−0.01								

The second column of this table gives the deviation obs. — mean; this is the deviation from the mean magnitude given by Müller (loc. cit.) but taken with the opposite sign, so that these deviations represent stellar magnitudes reckoned from a certain mean magnitude; the mean of the magnitudes in the second column is not zero but equals — 0.01, which is explained by the circumstance that here not all observations of Müller were used. The 3[d] and 4[th] columns give the phase of rotation for the two periods, reckoned from an arbitrary zero (0^h on Sept. 12, 1884); the periods adopted are those given at the beginning of this section; in units of mean time they are respectively

$$P_{\mathrm{I}} = 7^h.7067 \text{ and } P_{\mathrm{II}} = 7^h.8363.$$

The observed magnitudes were plotted on fig 5a and 5b with the phases of rotation as abscissae and curves were drawn from



hand. The first glance at these figures indicates a conspicuous variation corresponding to both periods; the range is especially great for the second period, attaining 0.18 stellar magnitudes, whereas for the first period the range is only about 0.12 st. mg.; the agreement of the individual points for P_{I} is also bad, which is evidently due to the disturbing influence of the more important second variation.

The 5[th] and 6[th] columns of table 12 contain the magnitude read from the hand-drawn curves on fig. 5, and the 7[th] column — the result of superposition of both variations, computed from

$$m_{\mathrm{I}} + m_{\mathrm{II}} + 0.01,$$

$m = -0.01$ being the average magnitude.

The last three columns give the residuals from the I and II curves and from the superposition of these curves respectively. Table 13 gives the distribution of the residuals.

Table 13.
Distribution of Residuals for Müller's Observations.

Resid. O.-C. st. mg.	Number of Residuals from			
	Mean Magn.	I	II	superpos. I+II
±0.00	2	2	4	4
.01	9	2	5	4
.02	5	7	6	4
.03	4	8	6	6
.04	3	8	10	8
.05	3	1	2	6
.06	5	7	5	6
.07	4	3	5	3
.08	2	1	1	2
.09	2	3	2	3
.10	5	3	0	3
.11	3	3	3	0
.12	1	2	1	1
.13	2	0	0	1
.14	1	1	0	1
.15	0	1	0	0
.16	0	0	1	0
.17	0	0	1	0
.18	0	0	0	0
.19	1	0	0	0
Σ (Resid.)^2	0.2756	0.2333	0.1996	0.1895
Mean Sq. Resid.	±0.073	±0.067	±0.062	±0.060

The data of this table indicate that the observations are considerably improved by the superposition of the two variations. The light-curves are of course different from those found for 1922—23.

The observations of J. M. Baldwin were treated in the same manner as those of G. Müller. Table 14 gives a summary of the observations, fig. 6a and 6b represent them graphically with curves drawn from hand.

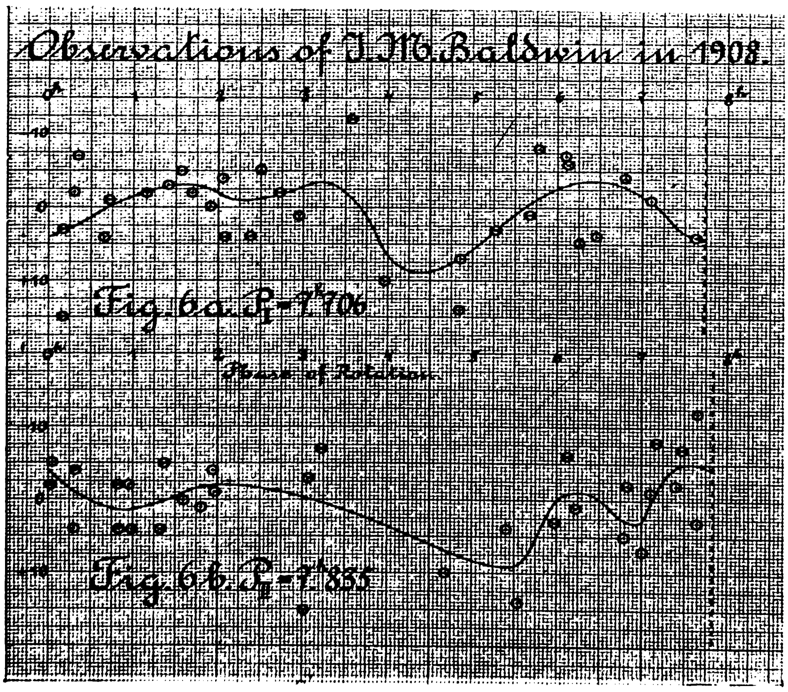


Table 14.
Observations of J. M. Baldwin.

Date and G. M. T.	Observ. Magn. (Dev. from Mean)	Phase of Rotation		Magn. from Hand-Drawn Curve			Residual Obs.-Comput. × 100		
		$P_{I} = 7^h.706$	$P_{II} = 7^h.835$	I	II	superposed I+II	I	II	I+II
1908 h		h	h						
Jan. 25, 6.13	—0.06	6.13	6.13	—0.03	—0.01	—0.04	— 3	— 5	— 2
„ 25, 7.10	— .01	7.10	7.10	— .01	.00	— .01	0	— 1	0
„ 25, 9.77	— .04	2.06	1.93	— .01	— .02	— .03	— 3	— 2	— 1
Febr. 3, 10.20	— .02	2.73	6.82	— .02	+ .03	+ .01	0	— 5	— 3
„ 3, 11.05	— .12	3.58	7.67	— .02	— .05	— .07	—10	— 7	— 5
„ 9, 11.30	— .03	1.41	3.06	— .03	.00	— .03	0	— 3	0
„ 10, 7.40	— .07	6.10	7.48	— .03	— .05	— .08	— 4	— 2	+ 1
„ 10, 8.08	— .04	6.78	0.33	— .03	— .01	— .04	— 1	— 3	0
„ 10, 9.72	— .01	0.71	1.97	.00	— .02	— .02	— 1	+ 1	+ 1
„ 14, 7.37	.00	1.89	1.60	— .03	— .01	— .04	+ 3	+ 1	+ 4
„ 19, 8.70	+ .04	7.63	5.40	+ .06	+ .09	+ .15	— 2	— 5	—11
March 2, 9.87	+ .10	3.97	4.68	+ .06	+ .07	+ .13	+ 4	+ 3	— 3
„ 2, 10.73	+ .14	4.83	5.54	+ .07	+ .09	+ .16	+ 7	+ 5	— 2
„ 2, 11.17	+ .03	5.27	5.98	+ .03	.00	+ .03	0	+ 3	0
„ 16, 9.12	+ .15	0.16	3.02	+ .03	— .01	+ .02	+12	+16	+13
„ 16, 9.32	— .07	0.36	3.22	+ .02	.00	+ .02	— 9	— 7	— 9
„ 22, 9.35	+ .01	5.68	6.23	.00	— .01	— .01	+ 1	+ 2	+ 2
„ 22, 9.92	+ .05	6.25	6.80	— .03	+ .03	.00	+ 8	+ 2	+ 5
„ 24, 9.78	+ .03	0.17	7.64	+ .03	— .05	— .02	0	+ 8	+ 5
„ 24, 10.27	+ .04	0.66	0.30	.00	— .01	— .01	+ 4	+ 5	+ 5
„ 24, 10.78	— .02	1.17	0.81	— .03	+ .01	— .02	+ 1	— 3	0
„ 25, 9.03	— .02	0.30	7.39	+ .02	— .04	— .02	— 4	+ 2	0
„ 25, 10.42	— .02	1.69	0.94	— .04	+ .01	— .03	+ 2	— 3	+ 1
„ 25, 10.80	+ .04	2.07	1.32	— .01	.00	— .01	+ 5	+ 4	+ 5
„ 26, 9.00	— .02	1.15	0.02	— .03	— .02	— .05	+ 1	0	+ 3
„ 26, 10.35	— .05	2.50	1.37	.00	.00	.00	— 5	— 5	— 5
„ 26, 10.80	+ .01	2.95	1.82	— .03	— .01	— .04	+ 4	+ 2	+ 5
„ 27, 8.52	— .05	1.56	0.04	— .04	— .02	— .06	— 1	— 3	+ 1
„ 27, 9.32	+ .04	2.36	0.84	.00	+ .01	+ .01	+ 4	+ 3	+ 3
Apr. 26, 8.47	+ .07	4.85	7.00	+ .07	+ .01	+ .08	0	+ 6	— 1
„ 28, 7.65	— .08	5.79	7.17	— .01	— .01	— .02	— 7	— 7	— 6
„ 28, 8.32	+ .04	6.46	0.00	— .03	+ .01	— .02	+ 7	+ 3	+ 6
Mean	0.00								

The periods adopted here are those of the preceding section; the definitive periods derived in this section would introduce but little difference in the phase of rotation.

As in the case of Müller's series, the observations of Baldwin show clearly a variation with *both* periods, the range being 0.14 mg. for the first, and 0.15 mg. for the second period. Thus these observations also confirm our results. Table 15 gives the distribution of residuals for the different hypotheses. As in our observations and those of Müller, the best representation is here obtained by the superposition of the light-curves corresponding to the two periods.

Table 15.
Distribution of Residuals for the Observations of J. M. Baldwin.

Residual St. Mg.	Number of Residuals from Mean Magn.	Curve I	Curve II	superposed I+II
±0.00	1	6	1	6
.01	4	6	3	6
.02	5	2	6	3
.03	3	3	9	4
.04	7	6	1	1
.05	3	2	6	7
.06	1	0	1	2
.07	3	3	3	0
.08	1	1	1	0
.09	0	1	0	1
.10	1	1	0	0
.11	0	0	0	1
.12	1	1	0	0
.13	0	0	0	1
.14	1	0	0	0
.15	1	0	0	0
.16	0	0	1	0
Σ (Res.)^2	0.1150	0.0723	0.0777	0.0688
Mean Sq. Resid.	±0.061	±0.048	±0.050	±0.047

The observations of Maxwell Hall made in 1915 were also plotted with our first period; the points so obtained were distributed at random and no curve could be traced; it appears, therefore, that the considerable oscillation observed by Maxwell Hall, which attained a range of over 0.4 magn., was entirely due to a great disturbance in the zone rotating with the second (slower) period; the small variation produced by the first period was masqued by the great variation from the other.

Summary.

1. It has been shown that the light of Neptune is variable, and that its variability consists of two superposed oscillations with periods (units of mean time)

$$P_{\mathrm{I}} = 7^{\mathrm{h}}.7067 \pm 0^{\mathrm{h}}.0002 \text{ and}$$
$$P_{\mathrm{II}} = 7^{\mathrm{h}}.8363 \pm 0^{\mathrm{h}}.0002 \text{ respectively;}$$

these periods are supported by the whole observational evidence available at present, i. e.: a) by 145 photographic observations made at Tartu on 12 nights between December 1922 — March 1923, from which the character of the variation and the periods were derived; b) by 26 photographic observations made at Tartu on 3 nights in March 1922; these observations fitted perfectly into the light-curves derived from the above mentioned 145 observations, and gave a correction of the periods; c) by 52 pho tometric observations of G. Müller in the opposition of 1884/85, all at an altitude $>20^0$; d) by 32 photometric observations of J. M. Baldwin in 1908; e) by 35 observations of Maxwell Hall in 1915, which gave only the second period. These 290 observations contain *all* existing series of accurate measures with a number of observations not less than 20 during one opposition [1]).

2. The variability has the only reasonable explanation in the rotation of the planet, and to Maxwell Hall belongs the priority of first determining photometrically the period of rotation of Neptune; his period found in 1915, $7^h.835$ is in excellent agreement with our second period of rotation.

3. Like Jupiter and Saturn, Neptune rotates not as a solid body, but with different angular speed in different zones: the two periods found correspond evidently to two principal zones occupying the major part of the visible hemisphere, e. g. the equatorial zone and the southern temperate zone (inclination of Neptune's equator to the line of sight $= -29^0$ during the period of observation); if the analogy between the great outer planets is drawn farther, the shorter period must correspond to the equatorial zone; the difference in the periods, $0^h.13 = 7^m.8$ is of the same order of magnitude as observed for Jupiter and Saturn.

4. The range of variation for the different series of observation was:

1922—1923 . . .	0.14 mg.	for the first, and	0.13	for the second period;
1915 . . .		—	$>$ 0. 4	„ „ „ „ ;
1908 . . .	0.14	for the first, and	0.15	„ „ „ „ ;
1884—1885 . . .	0.12	„ „ „ „	0.18	„ „ „ „ ;

through interference of both oscillations the range might be increased, so that in 1922—23 a range of 0.27, in 1908 — of 0.29 and in 1884—1885 — of 0.30 magnitudes could occur.

Appendix.

Variability of BD $+17^0$2053.

This star used as comparison star for Neptune showed on March 19, 1923, a marked variation; for $3^1/_2$ hours it was from

1) The most numerous series of E. C. Pickering is the series of 1897/98 when 16 observations during one opposition were made; the mean error was ± 0.10 with the meridian photometer; this series was not considered here, for the small number of observations and the relatively great mean deviation would hardly give a decisive answer to the question of variability.

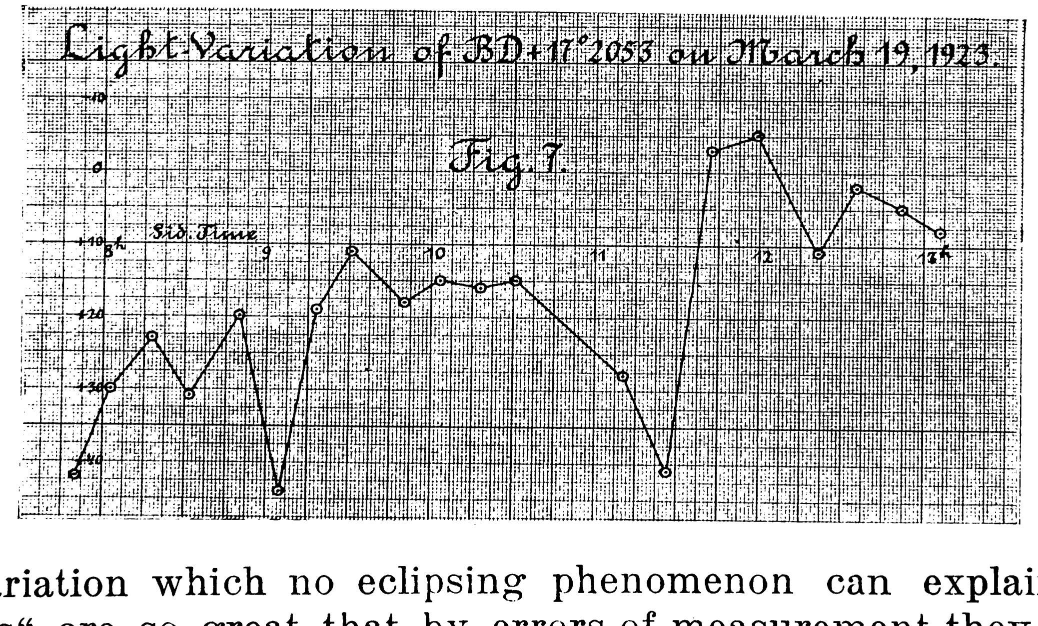
0.2 to 0.4 mg. below its normal brightness and rose then almost suddenly to the usual magnitude. On other days (Febr. 12, 13 and 22; March 5, 12, 13, 16, 18 and 21) no trace of a variation of such a size could be found; the 100 observations on these days covering about 25 hours of uninterrupted observation gave a mean square deviation of only ± 0.059 st. mg. The variation on March 19 is illustrated by the following table:

March 19, 1923.

Sid. Time	$7^h.85$	8.05	8.30	8.53	8.84	9.08	9.30	9.51	9.84	10.06
Deviation of Magn. from the Mean	+0.42	+0.30	+0.23	+0.31	+0.20	+0.44	+0.19	+0.11	+0.18	+0.15

Sid. Time	$10^h.30$	10.51	11.17	11.44	11.71	11.98	12.36	12.59	12.86	13.10
Deviation of Magn. from the Mean	+0.16	+0.15	+0.28	+0.41	—0.03	—0.05	+0.11	+0.02	+0.05	+0.08

Fig. 7 represents the variation graphically. The star might be taken for an Algol variable but for the strange "jumps" in



the variation which no eclipsing phenomenon can explain; the "jumps" are so great that by errors of measurement they cannot be accounted for.

The spectrum of this star is A_0, according to the Henry Draper Catalogue.