Discussion of photo-electric observations in blue light of the eclipsing variable TT Herculis made by G. Westerhout and W. N. Brouw

Genderen, A.M. van

TABLE 2 (*continued*)

J.D. hel. −243 0000	phase φ	phase ψ	*SPg*	*SPv*	*SCI*	J.D. hel. −243 0000	phase φ	phase ψ	*SPg*	*SPv*	*SCI*
			m	m	m				m	m	m
5639.255	0.604	0.53	8.20	7.85	0.35	5660.304	0.800	0.87	8.47	7.99	0.48
.278	.613	.54	8.15	7.81	.34	.341	.814	.88	8.55	8.02	.53
40.293	.009	.70	8.62	8.10	.52	61.408	.230	.05	8.77	8.24	.53
.381	.043	.71	8.71	8.15	.56	64.209	.320	.49	8.30:	7.88:	.42:
41.288	.396	.85	7.74	7.53	.21	65.360	.768	.67	8.31	7.90	.41
.394	.437	.87	7.51	7.36	.15	68.363	.937	.15	8.76	8.19	.57
42.211	.755	.00	8.47	7.96	.51	69.205	.265	.28	8.39	7.99	.40
.425	.839	.04	8.65	8.11	.54	72.319	.478	.78	7.66	7.50	.16
43.295	.177	.17	8.79	8.23	.56	77.212	.383	.55	8.36	7.97	.39
.472	.246	.20	8.44	8.03	.41	78.408	.848	.74	8.51	8.02	.49
44.352	.589	.34	8.32	7.90	.42	81.222	.944	.19	8.83	8.22	.61
46.442	.403	.67	8.20	7.86	.34	82.204	.326	.35	8.27	7.93	.34
47.213	.703	.79	8.21	7.82	.39	83.202	.715	.50	8.43	7.95	.48
.238	.713	.80	8.21	7.81	.40	85.202	.494	.82	7.69	7.50	.19
52.264	.669	.60	8.19	7.84	.35	86.218	.889	.98	8.73	8.15	.58
54.282	.455	.92	7.55	7.41	.14	87.398	.349	.17	7.93:	7.65	.28:
55.411	.895	.10	8.78	8.18	.60	88.202	.662	.30	8.47	7.99	.48
56.255	.223	.23	8.56	8.09	.47	89.208	.053	.46	8.70	8.15	.55
.407	.282	.25	8.32	7.89	.43	91.207	.832	.77	8.50	7.98	.52
57.236	.605	.38	8.39	7.93	.46	.261	.853	.78	8.50	7.99	.51
.350	.650	.40	8.38	7.94	.44	5692.332	0.270	0.95	8.74	8.23	0.51

DISCUSSION OF PHOTO-ELECTRIC OBSERVATIONS IN BLUE LIGHT OF THE ECLIPSING VARIABLE TT HERCULIS MADE BY G. WESTERHOUT AND W. N. BROUW

BY A. M. VAN GENDEREN

TT Herculis, a variable of the β Lyrae type, was observed photo-electrically in blue light at the Leiden Observatory during twenty nights in 1951 and during two nights in 1961.
The elements for primary minimum are: Min I = J. D. Hel. 2434525.25721 + ^{d}.9120800 *E*. The light-curve is shown in Figure 2.
The rectification of the light-curve and the computation of the geometrical elements met with serious difficulties.

1. *Introduction*

TT Herculis has been investigated by R. B. BALDWIN (1940), who computed the geometrical and physical elements from his visual light-curve, obtained with a wedge photometer. In 1954 A. R. HOGG and G. E. KRON (1955) observed photo-electric light-curves in blue and yellow light. They did not succeed in finding a reasonable value for the reflection coefficient A_1 or in deriving orbital elements.

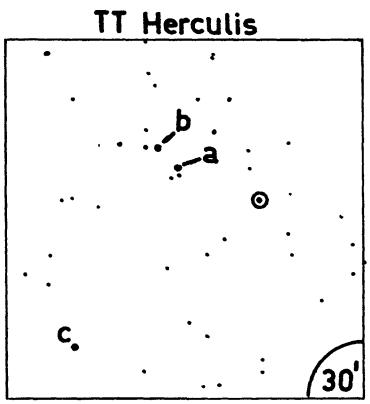
LUIZET (1909), KORDYLEWSKI (1930), MCLAUGHLIN (1927, 1928, 1929, 1930), LAUSE (1935, 1938) and TSESEVICH (1946, 1954), observed the variable and determined ephemerides.

SANFORD (1937) obtained a radial-velocity curve and a spectroscopic orbit. The above-mentioned investigations suggest that the hot star is of spectral type A and the cool one of type G or K.

2. *Observations*

The observations at the Leiden Observatory in 1951 were made in blue light with the 18″ Zunder-

FIGURE 1



man reflector by G. WESTERHOUT. Unfortunately it is not known which blue filter has been used.

During twenty nights from April to August 797 observations were obtained. The comparison star used was BD + 16° 3066 ("c"). To get more epochs of primary minimum from photo-electric observations W. N. BROUW measured two minima in 1961 with the same instrument, but with comparison star "b". Some data about the variable and the comparison stars are given in Table 1.

The observations were made as follows: sky – comparison star – sky – variable star – sky – comparison star, etc.

The time needed for one such set varied from $1\frac{1}{2}$ to $2\frac{1}{2}$ minutes.

TABLE 1

Data about the variable and comparison stars

Star	α 1951	δ 1951	B.D. No	B.D.*m*	Sp(reference)
	h m s	° ′	°		
TT Her	16 52 11.4	+ 16 54.4	+ 17 3117	9.0	A
a	16 52 40.2	+ 16 57.3	+ 17 3118	9.1	Go (AGK)*
b	16 52 48.4	+ 16 58.7	+ 17 3119	8.7	Ko (AGK)
c	16 53 18.2	+ 16 42.5	+ 16 3066	9.1	F8 (AGK)

* *Astronomische Gesellschaft Katalog*

3. *Reductions*

The differences "star minus sky" were read from the Brown recorder charts with an accuracy of about .5 per cent, and the magnitude differences $m_v - m_c$ were derived in three decimals.

The time was measured in seconds and has been computed in five decimals of a Julian Day, after reduction to the sun had been applied.

Corrections for differential extinction were computed for the observations made with comparison star "c". The maximum correction was $^m.010$. The extinction coefficients resulted from the observed intensity changes of the comparison star during the night, with the assumption that the response of the electronic equipment to light-intensity is linear. Only for four nights we could compute the extinction coefficient k by the method of least squares, k being given by the formula $m_i = m_o + k \sec z$, where m_o is the "no-atmosphere" magnitude. The weighted mean value of m_o from these four determinations was used to compute the extinction coefficient for all 797 observations.

TABLE 2

Weights of the observations in the various nights

date		*p*	date		*p*
April	17	44	May	29	17
„	22	17	„	30	25
„	24	28	June	7	44
„	25	14	„	8	17
„	30	5	July	7	25
May	2	23	„	15	19
„	10	13	„	21	25
„	11	21	„	26	6
„	21	28	„	27	12
„	25	51	August	7	9

Weights for each night have been computed from the differences between successive observations of the comparison star. These weights were defined as: $p = \frac{1}{100\,\mu^2}$, μ being the mean error derived from the comparison star. The weights have been listed in Table 2.

4. *The ephemeris*

To compute the ephemeris we used all the epochs of primary minimum published before (Table 3), and four photo-electric epochs from Leiden, two observed in 1951 (nos. 48, 49) and two in 1961 (nos. 51, 52). The weights assigned to the non-photo-electric minima are the same as those given by BALDWIN.

The weights of the five photo-electric minima (nos. 48–52) have been computed as follows: the mean error corresponding with unit weight of the column $(O' - C')$ given by BALDWIN is defined as:

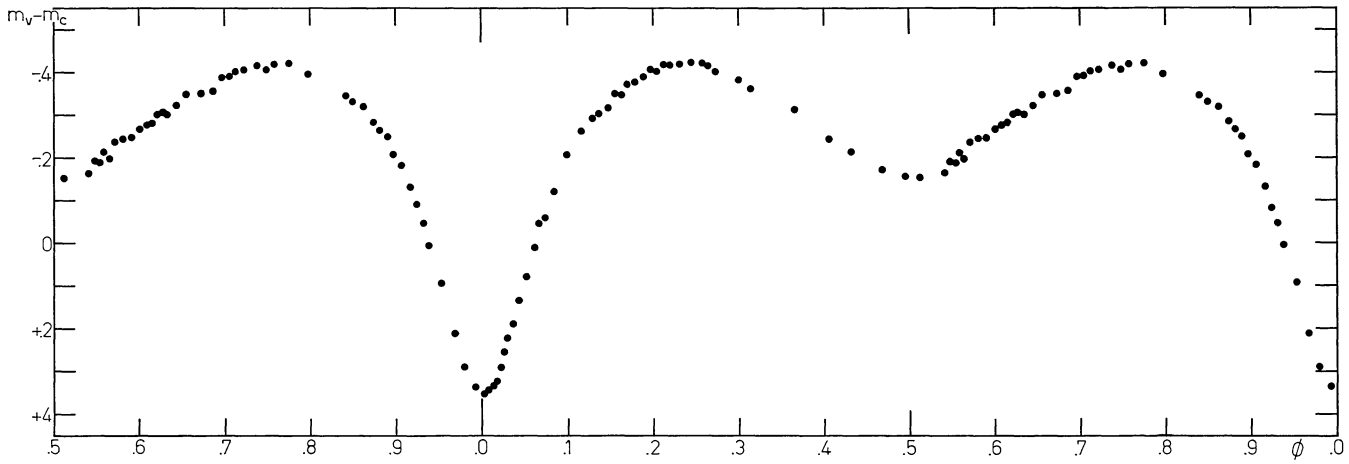
$$\varepsilon = \pm \sqrt{\frac{[p\,(O' - C')^2]}{n - 1}} = \pm {}^d.0082.$$

The mean error of each epoch of primary minimum is: m.e. $= \sqrt{\frac{\varepsilon^2}{p_i}}$.

When we know the mean error of the photo-electric epochs we can compute their weights p_i (second column of Table 3). Our own epochs and their mean errors were computed with the method of HERTZSPRUNG, as revised and described by KWEE and VAN WOERDEN (1956).

The computed epochs have been given in Table 3 (nos. 48, 49, 51 and 52); their respective mean errors turned out to be $\pm {}^d.00084$, $\pm {}^d.00055$, $\pm {}^d.00096$ and $\pm {}^d.00068$.

FIGURE 2



In the same way we re-computed the time of minimum for the observations by HOGG and KRON (no. 50), using their normal points. Its mean error turned out to be $\pm^{d}.00097$.

A weighted least-squares solution from the data of Table 3 gives the following formula for the times of the primary minimum:

$$\text{min. I} = \text{J. D. Hel. } 2434525.25721 + {}^{d}.9120800\, E. \pm .00062 \pm .0000002 \text{ m.e.} \quad (1)$$

TABLE 3

Observed minima

No	epoch of minimum	p	E	$O-C$	references
1	2418132.390	1	− 17973	− .053	LUIZET
2	25114.400	1	− 10318	− .016	KORDYLEWSKI
3	5364.315	1	− 10044	− .011	MCLAUGHLIN
4	5433.637	1	− 9968	− .007	,,
5	5457.347	1	− 9942	− .011	,,
6	5774.750	1	− 9594	− .012	,,
7	5872.336	1	− 9487	− .018	KORDYLEWSKI
8	6144.132	1	− 9189	− .022	MCLAUGHLIN
9	7573.382	1	− 7622	− .001	LAUSE
10	7612.611	1	− 7579	+ .008	,,
11	7624.456	1	− 7566	− .004	,,
12	7625.384	1	− 7565	+ .012	,,
13	7636.322	1	− 7553	+ .005	,,
14	7656.3766	2	− 7531	− .0060	,,
15	7666.406	1	− 7520	− .009	,,
16	7667.321	1	− 7519	− .007	,,
17	7697.411	1	− 7486	− .015	,,
18	7698.325	1	− 7485	− .013	,,
19	8286.626	1	− 6840	− .004	,,
20	8299.384	1	− 6826	− .015	,,
21	8422.527	1	− 6691	− .003	,,
22	8423.430	1	− 6690	− .012	,,
23	8446.2385	2	− 6665	− .0054	,,
24	8455.349	1	− 6655	− .016	,,
25	8457.182	1	− 6653	− .007	,,
26	8466.297	1	− 6643	− .013	,,
27	8477.255	1	− 6631	+ .000	,,
28	8555.705	1	− 6545	+ .012	,,
29	8671.532	1	− 6418	+ .004	,,
30	8683.368	1	− 6405	− .017	,,
31	8693.404	1	− 6394	− .014	,,
32	8694.330	1	− 6393	+ .000	,,

TABLE 3 (*continued*)

No	epoch of minimum	p	E	$O-C$	references
33	2428808.3349	2	− 6268	− .0047	LAUSE
34	8819.278	1	− 6256	− .007	„
35	8820.208	1	− 6255	+ .011	„
36	8829.313	1	− 6245	− .005	„
37	8968.873	2	− 6092	+ .007	BALDWIN
38	8979.826	4	− 6080	+ .015	„
39	9020.867	4	− 6035	+ .013	„
40	9032.722	4	− 6022	+ .011	„
41	9073.765	4	− 5977	+ .010	„
42	9074.676	4	− 5976	+ .009	„
43	9083.797	4	− 5966	+ .009	„
44	9084.720	2	− 5965	+ .020	„
45	9085.623	4	− 5964	+ .011	„
46	31266.410	1	− 3573	+ .015	TSESEVICH
47	1288.297	1	− 3549	+ .012	„
48	3796.50553	95	− 799	+ .00026	present paper
49	3806.53870	222	− 788	+ .00055	„ „
50	4525.25551	73	0	− .00170	HOGG and KRON
51	7352.70166	71	+ 3100	− .00362	present paper
52	7374.59608	145	+ 3124	+ .00088	„ „

5. *The normal points of the light-curve*

In order to combine the 797 observations into a light-curve consisting of a restricted number of normal points we have taken for every normal point about 10 individual observations with a total weight of about 235. In this way we obtained 84 normal points.

Figure 2 gives the unrectified light-curve.

The phase of the individual observations has been computed with the formula:

$$\text{Phase} = (\text{J. D. Hel.} - 2434525.25721) \times 1.09639505. \quad (2)$$

Table 4 gives the individual observations and Table 5 the normal points.

6. *Discussion*

The light-curve shows no significant asymmetric terms. There are no noticeable variations from cycle to cycle either.

The analysis of the uneclipsed parts of the light-curve resulted in the following formula:

$$l_v/l_c = 1.2761 + .0335 \cos\theta - .1987 \cos 2\theta \quad (3)$$
$$\pm .0071 \quad \pm .0048 \qquad \pm .0084 \text{ m.e.}$$

In the least-squares solution which led to this formula we have confined ourselves to the normal points of which the phase φ lay in the intervals .1590 − .3410 and .6590 − .8410.

The reflection term appears to have the wrong sign and the ellipticity coefficient has too large a value to be explained by theoretical considerations.

Disregarding the reflection effect and assuming a mean limb-darkening coefficient of .6, the coefficients in formula (3) resulted in a value of the ellipticity coefficient $z = .207$. On the other hand, even if we assume that the inclination angle $i = 90°$ and that both components fill their Roche limits (KOPAL 1959), then using BALDWIN's (1940) mass-ratio of 3.5, we should expect that $z = .139$. Performing the rectification in the usual way with the values of the coefficients in formula (3), we obtained a rectified light-curve in which the secondary minimum vanishes completely and even becomes brighter than the uneclipsed light!

In view of these difficulties any rectification and solution of the orbital elements remain very tentative.

I am much indebted to Mr K. K. KWEE for his continual help and to Prof. P. TH. OOSTERHOFF for his advice and interest, and also to Dr G. WESTERHOUT and Mr W. N. BROUW for their photo-electric observations.

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TABLE 4

Individual observations

J. D. Hel. 24337 +	Δm	Φ
April 17, '51		
54.51467	+ .163	.9617
54.54571	+ .353	.9957
54.54925	+ .345	.9996
54.55133	+ .347	.0019
54.55404	+ .359	.0049
54.55717	+ .337	.0083
54.56265	+ .326	.0143
54.56550	+ .324	.0174
54.56835	+ .303	.0205
54.57092	+ .254	.0234
54.57370	+ .194	.0264
54.57647	+ .207	.0295
54.57918	+ .158	.0324
54.58307	+ .221	.0367
April 22, '51		
59.46644	− .236	.3908
59.46811	− .249	.3927
59.46950	− .286	.3942
59.47110	− .280	.3959
59.47255	− .230	.3975
59.47394	− .196	.3990
59.47540	− .253	.4006
59.47867	− .251	.4042
59.47999	− .244	.4057
59.48130	− .265	.4071
59.48832	− .255	.4148
59.48950	− .245	.4161
59.49075	− .224	.4175
59.49221	− .203	.4191
59.49353	− .208	.4205
59.49478	− .230	.4219
59.49617	− .209	.4234
59.49749	− .255	.4249
59.49887	− .221	.4264
59.50019	− .201	.4278
59.50151	− .201	.4293
59.50311	− .206	.4310
59.50450	− .208	.4326
59.50596	− .261	.4342
59.51096	− .225	.4396
59.51255	− .200	.4414
59.51561	− .162	.4447
59.53880	− .199	.4702
59.54033	− .152	.4718
59.54144	− .183	.4731
59.54478	− .157	.4767
59.54776	− .180	.4800
59.54943	− .150	.4818
59.55262	− .188	.4853
59.55512	− .158	.4881
59.55630	− .183	.4893
59.55755	− .194	.4907
59.55894	− .152	.4922
59.56179	− .160	.4954
59.56318	− .152	.4969
59.56450	− .171	.4983
59.56582	− .170	.4998
59.56721	− .157	.5013
59.60005	− .150	.5373
59.60137	− .170	.5388
59.60276	− .192	.5403
59.60415	− .180	.5418
59.60540	− .197	.5432
59.60693	− .179	.5449
59.60957	− .190	.5478
59.61089	− .207	.5492
59.61644	− .211	.5553
59.61769	− .193	.5567
April 24, '51		
61.55035	− .370	.6756
61.55223	− .337	.6777
61.55362	− .350	.6792
61.55501	− .342	.6807
61.55633	− .369	.6822
61.55952	− .362	.6857
61.56084	− .338	.6871
61.56223	− .359	.6886
61.56341	− .370	.6899
61.57758	− .377	.7055
61.57897	− .398	.7070
61.58022	− .398	.7084
61.58133	− .409	.7096
61.58251	− .403	.7109
61.58390	− .373	.7124
61.58508	− .383	.7137
61.58619	− .408	.7149
61.58744	− .407	.7163
61.58862	− .417	.7176
61.58973	− .385	.7188
61.59258	− .412	.7219
61.59383	− .437	.7233
61.59508	− .414	.7247
61.59647	− .429	.7262
61.59800	− .396	.7279
61.60397	− .431	.7344
61.60522	− .429	.7358
61.60709	− .394	.7378
61.60821	− .404	.7391
61.60939	− .408	.7403
61.61626	− .397	.7479
61.61772	− .399	.7495
61.61904	− .421	.7509
61.62175	− .425	.7539
61.62286	− .413	.7551
61.62418	− .419	.7566
61.62557	− .445	.7581
61.62682	− .429	.7595
April 25, '51		
62.44901	− .314	.6609
62.45061	− .265	.6627
62.45256	− .359	.6648
62.45506	− .371	.6675
62.45651	− .339	.6691
62.45790	− .382	.6706
62.45936	− .371	.6722
62.46082	− .350	.6738
62.46283	− .366	.6761
62.48387	− .392	.6991
62.48554	− .361	.7010
62.48700	− .390	.7026
62.48839	− .315	.7041
62.48984	− .390	.7057
62.49116	− .417	.7071
62.49262	− .413	.7087
62.49387	− .400	.7101
62.49540	− .401	.7118
62.50248	− .396	.7195
62.50380	− .385	.7210
62.50519	− .382	.7225
62.50672	− .412	.7242
62.50804	− .372	.7256
62.51818	− .408	.7367
62.52658	− .395	.7459
62.52804	− .431	.7475
April 30, '51		
67.51658	− .447	.2170
67.51810	− .390	.2186
67.51956	− .415	.2202
67.52109	− .490	.2219
67.52283	− .513	.2238
67.52491	− .445	.2261
67.52637	− .410	.2277
67.53053	− .513	.2323
67.53956	− .422	.2422
67.54053	− .463	.2432
67.54248	− .362	.2454
67.54394	− .439	.2470
67.54526	− .414	.2484
May 2, '51		
69.46596	− .319	.3542
69.46755	− .306	.3560
69.46922	− .316	.3578
69.47089	− .346	.3597
69.47283	− .296	.3618
69.47498	− .346	.3641
69.47672	− .312	.3660
69.47839	− .292	.3679
69.48158	− .318	.3714
69.49290	− .275	.3838
May 10, '51		
77.56273	− .370	.2315
77.56454	− .415	.2335
77.56620	− .464	.2353
77.56822	− .431	.2375
77.56968	− .412	.2391
77.57870	− .415	.2490
77.58065	− .398	.2512
77.58252	− .396	.2532
77.59086	− .426	.2623
77.59211	− .390	.2637
77.59336	− .426	.2651
77.59836	− .414	.2706
77.59961	− .409	.2719
77.60093	− .405	.2734
77.60252	− .410	.2751

TABLE 4 (*continued*)

J. D. Hel. 24337+	Δm	Φ
May 11, '51		
78.40595	− .370	.1560
78.40734	− .325	.1575
78.40873	− .320	.1590
78.41019	− .339	.1606
78.41345	− .369	.1642
78.41484	− .362	.1657
78.41630	− .378	.1673
78.41762	− .368	.1688
78.41901	− .374	.1703
78.42033	− .390	.1717
78.42241	− .377	.1740
78.42373	− .387	.1755
78.42512	− .388	.1770
78.42658	− .423	.1786
78.42790	− .375	.1800
78.43588	− .385	.1888
78.43727	− .414	.1903
78.43859	− .392	.1918
78.44005	− .385	.1934
78.44151	− .354	.1950
78.44276	− .410	.1963
78.44436	− .409	.1980
78.44574	− .389	.1995
78.44713	− .388	.2011
78.44852	− .394	.2026
78.44998	− .416	.2042
78.45137	− .413	.2057
78.45297	− .423	.2075
78.45429	− .424	.2089
78.45568	− .431	.2104
78.45880	− .410	.2138
78.46019	− .431	.2154
78.46158	− .411	.2169
78.46304	− .429	.2185
78.46449	− .415	.2201
78.46713	− .429	.2230
78.46859	− .421	.2246
78.46998	− .376	.2261
78.47130	− .428	.2276
78.47269	− .450	.2291
78.47415	− .421	.2307
78.47540	− .400	.2320
78.49873	− .435	.2576
78.50005	− .437	.2591
78.50137	− .425	.2605
78.50269	− .424	.2620
78.50401	− .407	.2634
78.50533	− .441	.2649
78.50686	− .420	.2665
May 21, '51		
88.40864	− .299	.1229
88.41038	− .322	.1248
88.41177	− .283	.1262
88.41336	− .281	.1280
88.41482	− .308	.1296
88.41614	− .315	.1310
88.41767	− .299	.1327
88.41906	− .320	.1342
88.42052	− .325	.1358
88.42184	− .270	.1373
88.42322	− .313	.1388
88.43100	− .323	.1473
88.43225	− .313	.1487
88.43406	− .314	.1507
88.43538	− .324	.1521
88.43677	− .360	.1536
88.43815	− .339	.1552
88.43961	− .333	.1568
88.44093	− .355	.1582
88.44232	− .340	.1597
88.44579	− .327	.1635
88.44934	− .359	.1674
88.45065	− .361	.1689
88.45204	− .362	.1704
88.45343	− .369	.1719
88.45496	− .372	.1736
88.45656	− .414	.1753
88.45815	− .388	.1771
88.45961	− .370	.1787
88.46107	− .362	.1803
88.46246	− .364	.1818
88.46385	− .363	.1833
88.46531	− .371	.1849
88.46670	− .405	.1865
88.46802	− .404	.1879
88.46940	− .373	.1894
88.47107	− .385	.1913
88.47315	− .379	.1935
88.47427	− .423	.1948
88.47565	− .425	.1963
88.47705	− .415	.1978
88.47843	− .430	.1993
88.47982	− .395	.2008
88.48121	− .374	.2024
88.48260	− .417	.2039
88.48406	− .398	.2055
88.48538	− .411	.2069
88.48677	− .407	.2085
88.48815	− .405	.2100
88.48954	− .431	.2115
88.49093	− .409	.2130
88.49232	− .424	.2146
88.49371	− .415	.2161
88.49517	− .408	.2177
88.49649	− .412	.2191
88.49788	− .421	.2206
88.49927	− .411	.2222
88.51163	− .427	.2357
88.51315	− .398	.2374
88.51454	− .418	.2389
88.51600	− .446	.2405
88.51885	− .408	.2436
88.52045	− .410	.2454
88.52211	− .436	.2472
88.52496	− .408	.2503
88.52635	− .413	.2519
88.52871	− .402	.2544
88.53017	− .427	.2560
88.53149	− .441	.2575
88.53274	− .442	.2589
88.53406	− .421	.2603
88.53545	− .429	.2618
88.53677	− .382	.2633
88.53885	− .405	.2656
88.54024	− .422	.2671
88.54163	− .414	.2686
88.54302	− .385	.2701
88.54440	− .385	.2717
88.54571	− .381	.2731
88.55065	− .400	.2785
88.55225	− .415	.2803
88.56524	− .372	.2945
88.56663	− .400	.2960
88.56802	− .390	.2975
88.56940	− .397	.2991
88.57079	− .366	.3006
88.57218	− .385	.3021
88.57357	− .359	.3036
88.57496	− .390	.3052
88.57635	− .386	.3067
88.57774	− .386	.3082
88.57940	− .363	.3111
88.58086	− .369	.3127
88.58225	− .380	.3142
88.58364	− .366	.3158
88.58510	− .312	.3174
88.58642	− .345	.3188
88.58795	− .347	.3205
May 25, '51		
92.43194	− .196	.5339
92.43431	− .186	.5365
92.43583	− .208	.5382
92.43736	− .158	.5399
92.43882	− .140	.5415
92.44028	− .169	.5431
92.44181	− .185	.5448
92.44694	− .201	.5504
92.44826	− .184	.5518
92.45035	− .174	.5541
92.45174	− .195	.5556
92.45313	− .198	.5572
92.45458	− .214	.5588
92.45660	− .228	.5610
92.45792	− .190	.5624
92.45931	− .200	.5639
92.46118	− .217	.5660
92.46257	− .197	.5675
92.46396	− .232	.5690
92.46521	− .218	.5704
92.46646	− .227	.5718
92.46785	− .254	.5733
92.46931	− .244	.5749
92.47167	− .239	.5775
92.47299	− .221	.5789
92.47451	− .258	.5806
92.47604	− .244	.5823
92.47743	− .263	.5838
92.47875	− .238	.5853
92.48021	− .220	.5869
92.48549	− .236	.5926
92.48674	− .256	.5940
92.48819	− .283	.5956
92.48972	− .272	.5973
92.49111	− .273	.5988
92.49306	− .266	.6009
92.49451	− .258	.6025

TABLE 4 (*continued*)

J. D. Hel. 24337+	Δm	Φ
May 25, '51		
92.49653	− .261	.6047
92.49785	− .265	.6062
92.49917	− .272	.6076
92.50063	− .288	.6092
92.50201	− .283	.6108
92.50340	− .260	.6123
92.50500	− .281	.6140
92.50639	− .293	.6156
92.50799	− .319	.6173
92.50931	− .307	.6188
92.51069	− .302	.6203
92.51229	− .298	.6220
92.51368	− .319	.6236
92.51507	− .321	.6251
92.51653	− .312	.6267
92.51792	− .301	.6282
92.51958	− .306	.6300
92.52104	− .305	.6316
92.52243	− .302	.6331
92.52458	− .307	.6355
92.52590	− .296	.6369
92.53069	− .346	.6422
92.53222	− .341	.6439
92.53368	− .339	.6455
92.53500	− .289	.6469
92.54063	− .399	.6531
92.54194	− .340	.6545
92.54333	− .328	.6560
92.54451	− .329	.6574
92.54583	− .329	.6588
92.57958	− .386	.6958
92.58069	− .407	.6970
92.58194	− .396	.6984
92.58389	− .407	.7005
May 29, '51		
96.47467	+ .219	.9664
96.47599	+ .224	.9678
96.47724	+ .215	.9692
96.47856	+ .215	.9706
96.47981	+ .242	.9720
96.48113	+ .240	.9734
96.48245	+ .264	.9749
96.48446	+ .262	.9771
96.48585	+ .302	.9786
96.48731	+ .255	.9802
96.48905	+ .350	.9821
96.49037	+ .326	.9836
96.49062	+ .301	.9849
96.49412	+ .295	.9877
96.49634	+ .315	.9901
96.50314	+ .350	.9976
96.50446	+ .308	.9991
96.50571	+ .336	.0004
96.50703	+ .346	.0018
96.50835	+ .339	.0033
96.50974	+ .314	.0048
96.51120	+ .328	.0064
96.51259	+ .358	.0079
96.51391	+ .332	.0094
96.51523	+ .321	.0108
96.51648	+ .336	.0122
96.51794	+ .310	.0138
96.51946	+ .344	.0155
96.52085	+ .297	.0170
96.52231	+ .285	.0186
96.52356	+ .291	.0200
96.52509	+ .264	.0216
96.52662	+ .264	.0233
96.53002	+ .244	.0270
96.53141	+ .239	.0286
96.53280	+ .214	.0301
96.53398	+ .219	.0314
96.54176	+ .142	.0399
96.54308	+ .123	.0414
96.54446	+ .114	.0429
96.54585	+ .133	.0444
96.54717	+ .081	.0458
96.54870	+ .058	.0475
96.56002	+ .006	.0599
96.56183	− .019	.0619
96.56328	− .024	.0635
96.56460	− .029	.0650
96.56592	− .073	.0664
96.56731	− .037	.0679
96.56856	− .039	.0693
96.56995	− .079	.0708
96.57127	− .077	.0723
96.57273	− .067	.0739
96.57426	− .060	.0756
May 30, '51		
97.42558	+ .360	.0090
97.42717	+ .325	.0107
97.42870	+ .336	.0124
97.43016	+ .348	.0140
97.43155	+ .346	.0155
97.43294	+ .321	.0171
97.43440	+ .286	.0187
97.43655	+ .280	.0210
97.43794	+ .273	.0226
97.44002	+ .263	.0248
97.44148	+ .270	.0264
97.44287	+ .251	.0280
97.44426	+ .220	.0295
97.45204	+ .191	.0380
97.45342	+ .135	.0395
97.45488	+ .146	.0411
97.45627	+ .147	.0426
97.45780	+ .110	.0443
97.46079	+ .087	.0475
97.46238	+ .062	.0493
97.46377	+ .057	.0508
97.47051	+ .029	.0582
97.47197	+ .004	.0598
97.47329	− .023	.0612
97.47460	− .018	.0627
97.47599	− .038	.0642
97.47738	− .032	.0657
97.47877	− .057	.0673
97.48016	− .127	.0688
97.48157	− .055	.0703
97.48544	− .032	.0746
97.48683	− .111	.0761
June 7, '51		
05.47721	− .339	.8367
05.47874	− .359	.8384
05.48020	− .341	.8400
05.48179	− .352	.8417
05.48346	− .341	.8436
05.48485	− .329	.8451
05.48645	− .334	.8468
05.48797	− .337	.8485
05.49145	− .342	.8523
05.49277	− .321	.8538
05.49582	− .331	.8571
05.49902	− .310	.8606
05.50040	− .326	.8621
05.50179	− .313	.8637
05.50325	− .318	.8653
05.50457	− .306	.8667
05.51242	− .276	.8753
05.51381	− .282	.8768
05.51520	− .262	.8784
05.51658	− .260	.8799
05.51783	− .283	.8812
05.51929	− .251	.8828
05.52117	− .272	.8849
05.52263	− .266	.8865
05.52408	− .258	.8881
05.52547	− .244	.8896
05.52686	− .241	.8911
05.52825	− .218	.8927
05.52978	− .197	.8943
05.53138	− .227	.8961
05.53290	− .201	.8978
05.53450	− .203	.8995
05.53624	− .193	.9014
05.53825	− .195	.9036
05.54054	− .187	.9050
05.54179	− .183	.9064
05.54311	− .164	.9079
05.54790	− .156	.9131
05.54929	− .149	.9146
05.55075	− .123	.9162
05.55249	− .120	.9181
05.55395	− .116	.9197
05.55533	− .097	.9213
05.55742	− .083	.9235
05.55895	− .082	.9252
05.56033	− .097	.9267
05.56256	− .067	.9303
05.56388	− .040	.9317
05.56533	− .016	.9333
05.56679	− .052	.9349
05.56818	+ .010	.9364
05.56957	+ .003	.9380
05.57089	+ .045	.9394
June 8, '51		
06.41838	− .269	.8686
06.41998	− .283	.8704
06.42151	− .300	.8720
06.42303	− .282	.8737
06.42449	− .280	.8753
06.42595	− .286	.8769

TABLE 4 (*continued*)

J. D. Hel. 24338+	Δm	Φ
June 8, '51		
06.42748	− .272	.8786
06.42901	− .296	.8803
06.43074	− .286	.8821
06.43234	− .230	.8839
06.43623	− .242	.8882
06.43769	− .243	.8898
06.44095	− .212	.8933
06.44234	− .258	.8949
06.46470	− .105	.9194
06.46637	− .107	.9212
06.46776	− .083	.9227
06.46914	− .147	.9242
06.47046	− .070	.9257
06.47192	− .087	.9273
06.47331	− .073	.9288
06.47470	− .078	.9303
06.47602	− .029	.9318
06.47748	− .067	.9334
06.47880	− .011	.9348
06.48019	+ .017	.9364
06.48317	+ .030	.9396
06.48609	− .002	.9428
06.48741	+ .018	.9443
06.48866	+ .063	.9457
06.49005	+ .063	.9472
06.49137	+ .078	.9486
06.49269	+ .098	.9501
06.49394	+ .106	.9514
06.49519	+ .097	.9528
06.49713	+ .127	.9549
06.49914	+ .093	.9571
06.50039	+ .123	.9585
06.50171	+ .163	.9600
06.50289	+ .201	.9613
06.50414	+ .206	.9626
06.50546	+ .220	.9641
06.50678	+ .191	.9655
06.50830	+ .245	.9672
06.50942	+ .230	.9684
06.51074	+ .233	.9699
06.51206	+ .236	.9713
06.51338	+ .265	.9728
06.51657	+ .265	.9763
06.51970	+ .298	.9797
06.52109	+ .317	.9812
06.52248	+ .320	.9827
06.52387	+ .323	.9843
06.52526	+ .316	.9858
06.52664	+ .348	.9873
06.52866	+ .343	.9895
06.53130	+ .350	.9924
06.53269	+ .335	.9939
06.53407	+ .326	.9954
06.53560	+ .362	.9971
06.53699	+ .376	.9986
06.53901	+ .383	.0009
06.54039	+ .375	.0024
06.54178	+ .375	.0039
06.54314	+ .373	.0054
06.54456	+ .306	.0069
06.54595	+ .334	.0085
06.54727	+ .356	.0099
06.54866	+ .363	.0114
06.55005	+ .349	.0130
06.55171	+ .315	.0148
06.55338	+ .344	.0166
06.55498	+ .342	.0184
06.55651	+ .299	.0200
06.55887	+ .295	.0226
06.56046	+ .247	.0244
06.56192	+ .254	.0260
06.56401	+ .169	.0283
July 7, '51		
35.48688	− .446	.7392
35.48876	− .444	7412
35.49049	− .408	.7431
35.49223	− .417	.7450
35.49411	− .403	.7471
35.49584	− .409	.7490
35.49751	− .404	.7508
35.49911	− .419	.7526
35.50070	− .399	.7543
35.50501	− .428	.7590
35.50674	− .411	.7609
35.50827	− .397	.7626
35.50980	− .455	.7643
35.51147	− .436	.7661
35.51299	− .424	.7678
35.52084	− .384	.7764
35.52286	− .424	.7786
35.52431	− .422	.7802
35.52605	− .451	.7821
35.52813	− .428	.7844
35.52994	− .400	.7864
35.53181	− .406	.7884
35.53362	− .394	.7904
35.53536	− .385	.7923
35.53695	− .426	.7941
35.53855	− .415	.7958
35.54022	− .387	.7976
35.54181	− .374	.7994
35.54341	− .415	.8011
35.54508	− .382	.8030
35.54626	− .391	.8043
July 15, '51		
43.43642	− .198	.4550
43.43816	− .155	.4569
43.43996	− .125	.4589
43.44191	− .152	.4610
43.44371	− .184	.4630
43.44538	− .197	.4648
43.47204	− .124	.4940
43.47385	− .120	.4960
43.47545	− .153	.4978
43.47711	− .140	.4996
43.47878	− .136	.5014
43.48052	− .173	.5033
43.48211	− .172	.5051
43.48385	− .157	.5070
43.48559	− .135	.5089
43.48725	− .160	.5107
43.48906	− .140	.5127
43.49066	− .140	.5145
43.49218	− .161	.5161
43.49663	− .149	.5210
43.49823	− .171	.5228
43.49996	− .169	.5247
43.50163	− .146	.5265
43.50336	− .166	.5284
43.50510	− .167	.5303
43.51975	− .192	.5464
43.52177	− .178	.5486
43.52316	− .185	.5501
43.52496	− .216	.5521
43.52663	− .202	.5539
43.52780	− .166	.5552
43.53010	− .196	.5577
43.53170	− .240	.5595
43.53336	− .206	.5613
43.53496	− .204	.5630
43.53670	− .170	.5649
July 21, '51		
49.42145	+ .336	.0170
49.42326	+ .267	.0189
49.42472	+ .319	.0205
49.42645	+ .287	.0224
49.42798	+ .299	.0241
49.42965	+ .277	.0259
49.43166	+ .258	.0281
49.43333	+ .225	.0300
49.43485	+ .202	.0316
49.43631	+ .236	.0332
49.43791	+ .177	.0350
49.43958	+ .196	.0368
49.44110	+ .174	.0385
49.44256	+ .135	.0401
49.44416	+ .136	.0419
49.44604	+ .123	.0439
49.44770	+ .124	.0457
49.44944	+ .127	.0476
49.45110	+ .120	.0495
49.45284	+ .063	.0514
49.45437	+ .061	.0530
49.45597	+ .069	.0548
49.45777	+ .043	.0568
49.45944	+ .035	.0586
49.46097	+ .048	.0603
49.46256	− .015	.0620
49.46430	− .053	.0639
49.46597	− .027	.0658
49.46784	− .014	.0678
49.46944	− .070	.0696
49.47110	− .080	.0714
49.47263	− .050	.0731
49.47416	− .062	.0747
49.47604	− .050	.0768
49.47777	− .094	.0787
49.47937	− .128	.0805
49.48097	− .132	.0822
49.48263	− .128	.0840
49.48430	− .147	.0859
49.48597	− .123	.0877
49.48756	− .172	.0894
49.48923	− .178	.0913
49.49110	− .188	.0933

TABLE 4 (*continued*)

J. D. Hel. 24338+	Δm	Φ	J. D. Hel. 24338+	Δm	Φ	J. D. Hel. 24338+	Δm	Φ
July 21, '51			49.55492	− .337	.1633	August 7, '51		
49.49270	− .134	.0951	49.55694	− .355	.1655	66.43846	− .388	.6743
49.49430	− .170	.0968	July 26, '51			66.43985	− .354	.6758
49.49597	− .235	.0987				66.44145	− .328	.6776
49.49770	− .239	.1006	54.44000	− .184	.5193	66.44298	− .369	.6793
49.49951	− .172	.1025	54.44257	− .102	.5221	66.44450	− .356	.6809
49.50104	− .267	.1042	54.44437	− .158	.5241	66.44596	− .373	.6825
49.50270	− .276	.1060	54.44659	− .109	.5265	66.44749	− .384	.6842
49.50458	− .235	.1081	54.44861	+ .061	.5287	66.44909	− .366	.6860
49.50617	− .273	.1098	July 27, '51			66.45068	− .339	.6877
49.50798	− .227	.1118				66.45235	− .328	.6895
49.50944	− .268	.1134	55.43484	− .247	.6100	66.45388	− .359	.6912
49.51097	− .301	.1151	55.43658	− .294	.6119	66.45541	− .374	.6929
49.51277	− .223	.1171	55.43845	− .284	.6140	66.45707	− .405	.6947
49.51444	− .244	.1189	55.44040	− .248	.6161	66.45860	− .378	.6964
49.51638	− .282	.1210	55.44234	− .238	.6182	66.46013	− .382	.6981
49.51812	− .271	.1229	55.44442	− .247	.6205	66.46166	− .339	.6998
49.51985	− .331	.1248	55.44616	− .286	.6224	66.46332	− .429	.7016
49.52180	− .264	.1270	55.44804	− .307	.6245	66.46485	− .410	.7033
49.52680	− .258	.1325	55.44991	− .283	.6265	66.46645	− .404	.7050
49.52854	− .272	.1344	55.45172	− .259	.6285	66.46805	− .402	.7068
49.53027	− .294	.1363	55.45359	− .315	.6306	66.46971	− .458	.7086
49.53215	− .310	.1383	55.45533	− .268	.6325	66.47145	− .381	.7105
49.53395	− .330	.1403	55.45720	− .314	.6345	66.47325	− .483	.7125
49.53569	− .321	.1422	55.45894	− .341	.6364	66.47506	− .424	.7144
49.53749	− .296	.1442	55.46067	− .275	.6383	66.47728	− .377	.7169
49.53895	− .305	.1458	55.46262	− .301	.6405	66.47964	− .390	.7195
49.54069	− .292	.1477	55.46470	− .271	.6427			
49.54235	− .348	.1495	55.46956	− .275	.6481			
49.54416	− .361	.1515	55.47137	− .354	.6501			
49.54590	− .360	.1534	55.47304	− .369	.6519			
49.54798	− .385	.1557	55.47463	− .364	.6536			
49.55138	− .372	.1594	55.47651	− .347	.6557			

TABLE 5

Normal points

mean Δm	mean phase	mean Δm	mean phase	mean Δm	mean phase	mean Δm	mean phase	mean Δm	mean phase
+ .351	.0011	− .304	.1364	− .362	.3139	− .284	.6150	− .346	.8401
+ .343	.0071	− .319	.1476	− .313	.3643	− .303	.6214	− .333	.8493
+ .334	.0127	− .350	.1553	− .244	.4039	− .306	.6277	− .320	.8618
+ .323	.0172	− .349	.1627	− .214	.4305	− .302	.6345	− .286	.8729
+ .290	.0214	− .374	.1707	− .171	.4686	− .322	.6445	− .266	.8808
+ .252	.0253	− .378	.1793	− .156	.4954	− .349	.6557	− .250	.8882
+ .221	.0295	− .390	.1891	− .154	.5121	− .350	.6726	− .209	.8958
+ .187	.0360	− .406	.1969	− .165	.5414	− .354	.6853	− .184	.9049
+ .132	.0426	− .402	.2040	− .191	.5477	− .390	.6968	− .131	.9166
+ .079	.0499	− .419	.2117	− .189	.5539	− .393	.7043	− .093	.9240
+ .010	.0603	− .418	.2193	− .212	.5590	− .404	.7123	− .048	.9315
− .047	.0661	− .420	.2311	− .199	.5648	− .406	.7219	+ .005	.9373
− .060	.0723	− .424	.2440	− .235	.5719	− .418	.7369	+ .094	.9519
− .121	.0824	− .423	.2564	− .245	.5806	− .408	.7478	+ .210	.9661
− .207	.0987	− .415	.2635	− .247	.5909	− .421	.7567	+ .288	.9782
− .262	.1154	− .402	.2728	− .266	.6008	− .422	.7749	+ .335	.9920
− .293	.1274	− .382	.2998	− .276	.6087	− .398	.7966		