STUDIES BASED ON THE COLORS AND MAGNITUDES IN STELLAR CLUSTERS[1]

EIGHTH PAPER: THE LUMINOSITIES AND DISTANCES OF 139 CEPHEID VARIABLES

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Aside from the error involved in the determination of the zero-point of the luminosity-period curve,[2] most of the error affecting the absolute parallax of an isolated Cepheid variable is due to the uncertainty of apparent magnitude, since the period of light-variation is usually known with an accuracy that for this work is superfluous. Scores of observers, employing numerous methods and systems of magnitudes, have participated in the discovery and observation of these stars; but observations have often been made solely for the determination of periods, little attention being given to light-curves or accurate values of maximum and minimum light. Frequently the magnitudes are referred to the system of the *Bonner Durchmusterung*, and only occasionally, for the brighter or best known stars, to the Potsdam or Harvard photometric scales.

Adding to the uncertainty in the systems of magnitude the occasional difficulty, arising from changes in the form of light-curves, in obtaining accurate mean values of maximum and minimum brightness, we must expect an average probable error in the adopted median magnitude of the order of 0.4 mag. The consequent average probable error computed for the parallaxes of stars that are normal Cepheids is about 20 per cent of the tabulated values; for a number of the brighter stars and for well-observed cluster-type variables the error is only a little more than half that amount, but possibly it attains a maximum of 50 per cent for some of the faintest stars that are scantily observed on uncertain magnitude systems. Accurate determinations of the apparent visual or

[1] *Contributions from the Mount Wilson Solar Observatory*, No. 153.

[2] *Mt. Wilson Contr.*, No. 151, sec. III.

photovisual magnitude should reduce the probable error of the parallax of any Cepheid to less than 15 per cent.

The estimated range of 10 to 50 per cent in the probable error of the parallaxes allows for a variation in the probable error of apparent median brightness from a tenth to a whole magnitude—an amount which is shown by an examination of the underlying observational material to be sufficient. We note, therefore, that for parallaxes obtained with the period-luminosity curve the accuracy appears to surpass that of direct measures on any object for which the parallax is less than 0."01, and is essentially independent of distance. About two-thirds of the Cepheids now known have parallaxes smaller than 0."001.

The greatest chance for serious error in the work lies in the unintentional inclusion of some stars that are not typical Cepheids. For a star showing periodic continuous variation which simulates certain Cepheid characteristics but exhibits peculiarities such as double maxima or minima, we have found from cluster studies that the absolute brightness usually is less than for typical variables having the same period. The mean periods of such peculiar stars are often long; and, conversely, Cepheids of very long period are frequently abnormal. Until the normality of period and light-curve is established, we must, therefore, look with some doubt upon the enormously great absolute luminosity (and distance) obtained for galactic variables with periods in excess of forty days. Accordingly such stars are relegated to a supplementary table, which also contains provisional parallaxes and luminosities of variables that for various other reasons seem uncertain.

The list of variables in Table I is essentially complete for typical stars with definitely determined periods less than forty days. The various Harvard compilations and Hartwig's annual catalogue are the principal sources of observational data.[1] Names and posi-

[1] *Note added to proof, April, 1918.*—Hartwig's catalogue and ephemeris of variable stars for 1915 was the last number of that annual publication available when the tables for this paper were compiled. The issue for 1918, which has now been received, contains not only numerous revisions of the periods of the older variables but also some additions to the list. The corrections demanded by the revised periods have been applied to the values in all the tables, the text has been modified where necessary, and the statistical results in Tables II–VI now include the data for the twelve additional stars in Table I*a*.

tions have been taken, whenever possible, from Table VIII of *Harvard Annals*, **56**. For a majority of the stars the median visual magnitude of the eighth column is the mean of the maximum and minimum magnitudes given in this Harvard list, although for a number of variables improved magnitudes are obtainable from recent literature. All photographic magnitudes have been reduced to the visual system with the aid of a mean color-curve. The periods are mainly from Hartwig's catalogues, but occasionally recent publications afford better values. The parallaxes have been computed from the absolute magnitudes, which were read directly from the luminosity-period curve. A representation of the curve appears in Fig. 1 of *Contribution* No. 151. For the sake of uniformity the first decimal place is retained for all the distances in the last three columns, though for the larger values it is generally meaningless.

The 35 stars in Table II include: (1) all with periods greater than forty days, some of which, RS Puppis, for instance, seem to show typical Cepheid variation, although others, with M-type spectra, may be classed more correctly with the long-period variables; (2) a few with period or type somewhat uncertain; (3) 7 stars that appear to belong to the RV Tauri type of variation,[1] and (4) a number known to be otherwise peculiar or irregular. Further observation is sure to place some of these stars with those of Table I. While it is very probable that the absolute brightness of all of them is high, in many cases the luminosity-period relation may not hold rigorously. Moreover, the high galactic latitude of some variables with periods in excess of forty days suggests, as strongly as the frequent peculiarities of period and amplitude, that these stars differ too greatly from the typical Cepheid to make the estimated distances of much value.

[1] The periods of RV Tauri, R Sagittae, and V Vulpeculae are taken as thirty-nine, thirty-five, and thirty-eight days, respectively; these values, representing approximately the cycle of the principal variations, are more likely to give correct absolute luminosities. Cf. van der Bilt, *Recherches Astronomiques de l'Observatoire d'Utrecht*, VI, 1916. On the authority of Enebo similar treatment is accorded TV Andromedae, RY Lacertae, SW Persei, and RX Ursae Majoris. L_2 Puppis is a bright southern variable that may belong to this interesting type; a critical examination of its spectrum is very desirable. The study of the secondary variations of such typical stars as RR Lyrae (*Astrophysical Journal*, **43**, 217, 1916) shows that the difference between the RV Tauri type and the ordinary Cepheids is not so great as appears superficially.

TABLE I

PARALLAXES AND DISTRIBUTION IN SPACE OF 127 CEPHEID VARIABLES*

No.	Name	Position in 1900		Galactic		Period in Days	Med. Mag. Visual	Abs. Mag.	Parallax	Distance (Unit Is 100 Parsecs)		
		R.A.	Decl.	Long.	Lat.					Radial	Projected	From Plane
1...	SY Cassiopeiae	0^h $9^m.8$	+57°52′	85°	− 4°	4.071	9.6	−1.8	0″.00052	19.2	19.2	− 1.3
2...	SW Andromedae	0 18.4	+28 51	85	−33	0.442	9.3	−0.3	0.0012	8.3	7.0	− 4.5
3...	TU Cassiopeiae	0 20.9	+50 44	88	−11	2.137	7.9	−1.2	0.0015	6.6	6.5	− 1.3
4...	α Ursae Minoris	1 25.4	+88 46	91	+26	3.968	2.12	−1.81	0.016	0.6	0.5	+ 0.3
5...	RR Ceti	1 27.0	+ 0 50	114	−59	0.553	8.6	−0.4	0.0016	6.3	3.2	− 5.4
6...	RW Cassiopeiae	1 30.7	+57 15	97	− 4	14.80	9.5	−3.8	0.00022	45.4	45.3	− 3.2
7...	U Trianguli	1 49.7	+33 17	106	−27	0.447	11.6	−0.3	0.00042	23.8	21.2	−10.8
8...	UX Persei	2 6.1	+57 37	102	− 4	4.6	10.6	−2.0	0.00030	33.3	33.2	− 2.3
9...	UY Persei	2 27.1	+58 26	104	− 2	5.5	9.6	−2.2	0.00044	22.7	22.7	− 0.8
10...	SU Cassiopeiae	2 43.0	+68 28	101	+ 9	1.950	5.9	−1.2	0.0038	2.6	2.6	+ 0.4
11...	TU Persei	3 1.8	+52 48	111	− 5	0.607	11.7	−0.4	0.00038	26.3	26.2	− 2.3
12...	RW Camelopardalis	3 46.2	+58 22	112	+ 5	16.402	8.8	−3.9	0.00029	34.5	34.4	+ 3.0
13...	SX Persei	4 10.2	+41 29	126	− 5	4.290	10.8	−1.9	0.00029	34.5	34.4	− 3.0
14...	SZ Tauri	4 31.4	+18 20	147	−17	3.149	7.1	−1.6	0.0018	5.5	5.2	− 1.6
15...	SV Persei	4 42.8	+42 7	130	0	11.128	8.9	−3.3	0.00036	27.8	27.8	0
16...	RX Eridani	4 45.2	−15 54	182	−33	0.587	9.2	−0.4	0.0012	8.2	6.9	− 4.5
17...	SU Aurigae	4 49.6	+30 24	140	− 7	0.470	8.7	−0.3	0.0016	6.3	6.2	− 0.8
18...	U Leporis	4 52.0	−21 23	188	−33	0.581	9.5	−0.4	0.0010	9.5	8.0	− 5.2
19...	RX Aurigae	4 54.5	+39 49	134	0	11.626	7.6	−3.4	0.00063	15.9	15.9	0
20...	SY Aurigae	5 5.5	+42 43	133	+ 4	10.138	9.2	−3.2	0.00033	30.3	30.2	+ 2.1
21...	Y Aurigae	5 21.5	+42 21	134	+ 6	3.859	9.6	−1.8	0.00052	19.2	19.1	+ 2.0
22...	RZ Geminorum	5 56.6	+22 15	155	+ 1	5.529	9.4	−2.2	0.00048	20.8	20.8	+ 0.4
23...	RS Orionis	6 16.5	+14 44	164	+ 2	7.566	8.6	−2.7	0.00055	18.2	18.2	+ 0.6
24...	T Monocerotis	6 19.8	+ 7 8	171	− 1	27.012	6.2	−4.7	0.00066	15.2	15.2	− 0.3
25...	RT Aurigae	6 22.1	+30 34	151	+11	3.728	5.3	−1.8	0.0038	2.6	2.6	+ 0.5
26...	RZ Camelopardalis	6 23.7	+67 6	115	+23	0.480	12.0	−0.3	0.00035	28.6	26.3	+11.2
27...	W Geminorum	6 29.2	+15 24	165	+ 5	7.916	7.1	−2.8	0.0010	9.5	9.5	+ 0.8
28...	ζ Geminorum	6 58.2	+20 43	164	+13	10.154	4.0	−3.2	0.0036	2.8	2.7	+ 0.6
29...	TZ Aurigae	7 4.6	+40 56	143	+23	0.392	11.8	−0.3	0.00038	26.3	24.2	+10.3
30...	RR Geminorum	7 15.1	+31 4	155	+21	0.397	10.2	−0.3	0.00079	12.7	11.9	+ 4.5

31...	X Puppis	7 28.4	−20 42	204	0	25.953	8.5	−4.6	0.00024	41.7	41.7	0
32...	V Carinae	8 26.7	−59 47	242	−12	6.695	7.8	−2.5	0.00087	11.5	11.2	− 2.4
33...	T Velorum	8 34.4	−47 1	233	− 3	4.639	8.0	−2.0	0.0010	10.0	10.0	− 0.5
34...	V Velorum	9 19.2	−55 32	244	− 4	4.371	7.8	−1.9	0.0012	8.7	8.7	− 0.6
35...	*l* Carinae	9 42.5	−62 3	251	− 7	35.523	4.3	−5.1	0.0013	7.6	7.5	− 0.9
36...	RR Leonis	10 2.1	+24 29	176	+54	0.452	9.6	−0.3	0.0010	9.5	5.6	+ 7.7
37...	UW Carinae	10 23.3	−59 10	254	− 1	5.346	9.0	−2.2	0.00058	17.2	17.2	− 0.3
38...	YZ Carinae	10 24.6	−58 51	253	− 1	18.158	8.6	−4.1	0.00029	34.5	34.5	− 0.6
39...	UX Carinae	10 25.4	−57 6	252	+ 1	3.682	8.2	−1.7	0.0010	9.5	9.5	+ 0.2
40...	UY Carinae	10 28.5	−61 16	255	− 3	5.544	8.8	−2.2	0.00063	15.9	15.9	− 0.8
41...	Y Carinae	10 29.4	−57 59	253	0	3.640	8.4	−1.7	0.00096	10.4	10.4	0
42...	UZ Carinae	10 32.6	−60 30	255	− 2	5.205	9.3	−2.1	0.00052	19.2	19.2	− 0.7
43...	SV Velorum	10 40.9	−55 46	253	+ 3	14.097	8.7	−3.7	0.00033	30.3	30.3	+ 1.6
44...	VY Carinae	10 40.9	−57 2	254	+ 2	18.984	7.3	−4.1	0.00052	19.2	19.2	+ 0.7
45...	WW Carinae	10 47.6	−58 51	256	0	4.676	9.6	−2.0	0.00048	20.8	20.8	0
46...	WZ Carinae	10 51.4	−60 24	257	0	23.00	7.8	−4.4	0.00036	27.8	27.8	0
47...	XX Carinae	10 53.4	−64 36	258	− 4	15.725	8.2	−3.8	0.00040	25.0	25.0	− 1.8
48...	U Carinae	10 53.7	−59 12	256	0	38.740	7.4	−5.3	0.00029	34.5	34.5	0
49...	XY Carinae	10 58.3	−63 43	258	− 3	12.434	8.9	−3.5	0.00033	30.3	30.3	− 1.6
50...	XZ Carinae	11 0.1	−60 26	258	0	16.644	8.4	−3.9	0.00035	28.6	28.6	0
51...	ST Centauri	11 5.5	−51 57	256	+ 8	3.151	10.0	−1.6	0.00048	20.8	20.6	+ 2.9
52...	SU Draconis	11 32.2	+67 53	100	+49	0.660	9.2	−0.4	0.0012	8.3	5.4	+ 6.3
53...	UZ Centauri	11 36.3	−62 8	262	0	3.334	9.2	−1.6	0.00069	14.5	14.5	0
54...	S Muscae	12 7.4	−69 36	266	− 7	9.657	6.8	−3.1	0.0010	9.5	9.4	− 1.2
55...	SW Draconis	12 12.8	+70 4	94	+48	0.570	10.0	−0.4	0.00083	12.0	8.0	+ 8.9
56...	SX Centauri	12 15.9	−48 39	266	+14	16.50	8.2	−3.9	0.00038	26.3	25.5	+ 6.4
57...	T Crucis	12 15.9	−61 44	267	+ 1	6.732	7.2	−2.5	0.0012	8.7	8.7	+ 0.2
58...	R Crucis	12 18.1	−61 4	267	+ 1	5.825	7.3	−2.3	0.0012	8.3	8.3	+ 0.1
59...	R Muscae	12 36.0	−68 52	270	− 7	0.882	7.0	−0.6	0.0030	3.3	3.3	− 0.4
60...	Z Canum Venat.	12 45.0	+44 19	88	+73	1.890	10.2	−1.1	0.00055	18.2	5.3	+17.4
61...	SS Hydrae	13 25.0	−23 8	284	+38	8.20	7.8	−2.8	0.00076	13.2	10.4	+ 8.1
62...	VW Centauri	13 27.1	−63 33	275	− 2	15.037	8.9	−3.8	0.00029	34.5	34.5	− 1.2
63...	RV Ursae Majoris	13 29.4	+54 31	74	+62	0.468	9.8	−0.3	0.00096	10.4	4.9	+ 9.2
64...	ST Virginis	14 22.4	− 0 26	315	+53	0.411	10.8	−0.3	0.00060	16.7	10.0	+13.3
65...	V Centauri	14 25.4	−56 27	284	+ 3	5.494	7.1	−2.2	0.0014	7.2	7.2	+ 0.4
66...	RS Boötis	14 29.2	+32 11	18	+66	0.377	10.3	−0.3	0.00076	13.2	5.3	+12.0

* Table I*a*, which is appended to this table, contains twelve additional Cepheids. Cf. n. 1, p. 2.

TABLE I—*Continued*

No.	Name	Position in 1900		Galactic		Period in Days	Med. Mag. Visual	Abs. Mag.	Parallax	Distance (Unit Is 100 Parsecs)		
		R.A.	Decl.	Long.	Lat.					Radial	Projected	From Plane
67...	RU Boötis	14h 41m.5	+23° 44′	358°	+63°	0.493	13.5	−0.3	0″.00017	58.8	26.7	+52.4
68...	RY Boötis	14 45.2	+23 27	356	+62	9.0	7.2	−3.0	0.00091	11.0	5.2	+ 9.7
69...	R Trianguli Aust.	15 10.8	−66 8	285	− 9	3.389	7.0	−1.7	0.0018	5.5	5.4	− 0.9
70...	U Normae	15 34.6	−54 59	293	− 1	12.641	8.9	−3.5	0.00033	30.3	30.3	− 0.5
71...	S Trianguli Aust.	15 52.2	−63 30	290	− 9	6.323	6.9	−2.4	0.0014	7.2	7.1	− 1.1
72...	U Trianguli Aust.	15 58.4	−62 38	291	− 9	2.568	8.1	−1.4	0.0013	7.9	7.8	− 1.2
73...	RW Draconis	16 33.8	+58 1	54	+40	0.443	10.4	−0.3	0.00072	13.9	10.6	+ 8.9
74...	RV Scorpii	16 51.8	−33 27	319	+ 4	6.062	7.1	−2.4	0.0013	7.9	7.9	+ 0.6
75...	SW Herculis	16 54.2	+21 42	9	+33	0.493	13.5	−0.3	0.00017	58.8	49.3	+32.0
76...	ST Ophiuchi	17 28.8	− 1 0	350	+15	0.450	11.6	−0.3	0.00042	23.8	23.0	+ 6.2
77...	X Sagittarii	17 41.3	−27 48	329	− 1	7.012	4.7	−2.6	0.0035	2.9	2.9	− 0.0
78...	RY Scorpii	17 44.3	−33 40	324	− 4	20.32	8.2	−4.2	0.00033	30.3	30.2	− 2.1
79...	Y Ophiuchi	17 47.3	− 6 7	347	+ 8	17.121	6.3	−4.0	0.00087	11.5	11.4	+ 1.6
80...	S Arae	17 51.4	−49 25	311	−13	0.452	9.3	−0.3	0.0012	8.3	8.1	− 1.9
81...	W Sagittarii	17 58.6	−29 35	330	− 5	7.595	4.7	−2.7	0.0033	3.0	3.0	− 0.3
82...	W Serpentis	18 4.1	−15 34	342	+ 2	14.153	9.0	−3.7	0.00029	34.5	34.5	+ 1.2
83...	WZ Sagittarii	18 11.1	−19 6	340	− 2	21.7	8.4	−4.4	0.00028	35.7	35.7	− 1.2
84...	Y Sagittarii	18 15.5	−18 54	340	− 4	5.773	5.8	−2.3	0.0024	4.2	4.2	− 0.3
85...	XX Sagittarii	18 19.0	−16 51	343	− 4	6.43	9.0	−2.7	0.00046	21.7	21.7	− 1.5
86...	U Sagittarii	18 26.0	−19 12	341	− 6	6.745	6.9	−2.5	0.0013	7.6	7.6	− 0.8
87...	Y Scuti	18 32.6	− 8 27	351	− 3	10.347	9.0	−3.2	0.00036	27.8	27.8	− 1.4
88...	Y Lyrae	18 34.2	+43 52	40	+20	0.503	11.8	−0.3	0.00038	26.3	24.7	+ 9.0
89...	RU Scuti	18 36.7	− 4 13	356	− 1	19.7	8.9	−4.2	0.00024	41.7	41.7	− 0.7
90...	RZ Lyrae	18 39.9	+32 41	29	+15	0.511	10.4	−0.3	0.00072	13.9	13.4	+ 3.6
91...	YZ Sagittarii	18 43.7	−16 50	346	− 8	9.553	7.4	−3.1	0.00079	12.7	12.6	− 1.8
92...	RT Scuti	18 44.0	−10 30	351	− 5	0.496	9.4	−0.3	0.0012	8.7	8.7	− 0.8
93...	SZ Aquilae	18 59.6	+ 1 9	3	− 3	17.136	8.7	−4.0	0.00029	34.5	34.5	− 1.8
94...	TT Aquilae	19 3.2	+ 1 9	4	− 5	13.753	7.6	−3.6	0.00058	17.2	17.1	− 1.5
95...	RR Lyrae	19 22.3	+42 36	43	+12	0.567	7.25	−0.35	0.0030	3.3	3.2	+ 0.7
96...	U Aquilae	19 24.0	− 7 15	359	−13	7.024	6.6	−2.6	0.0014	6.9	6.7	− 1.6
97...	XZ Cygni	19 30.4	+56 10	56	+16	0.467	9.7	−0.3	0.0010	10.0	9.6	+ 2.8

98...	U Vulpeculae	19 32.3	+20 7	24	− 2	7.990	7.0	−2.8	0.0011	9.1	9.1	− 0.3
99...	SU Cygni	19 40.8	+29 1	32	+ 2	3.846	6.6	−1.8	0.0021	4.8	4.8	+ 0.2
100...	η Aquilae	19 47.4	+ 0 45	8	−14	7.176	4.05	−2.62	0.0046	2.2	2.1	− 0.5
101...	S Sagittae	19 51.5	+16 22	23	− 7	8.382	5.8	−2.9	0.0018	5.5	5.5	− 0.7
102...	X Vulpeculae	19 53.3	+26 17	32	− 3	6.319	8.8	−2.4	0.00058	17.2	17.2	− 0.9
103...	XX Cygni	20 1.3	+58 40	60	+13	0.135	11.8	−0.4	0.00036	27.8	27.0	+ 6.2
104...	RW Aquilae	20 7.3	+15 46	24	−11	7.87	8.8	−2.8	0.00048	20.8	20.4	− 4.0
105...	SZ Cygni	20 29.6	+46 16	52	+ 3	15.113	9.2	−3.8	0.00025	40.0	40.0	+ 2.1
106...	X Cygni	20 39.5	+35 14	44	− 5	16.385	6.5	−3.9	0.00083	12.0	12.0	− 1.0
107...	T Vulpeculae	20 47.2	+27 52	40	−11	4.436	5.8	−2.0	0.0028	3.6	3.5	− 0.7
108...	UY Cygni	20 52.3	+30 3	43	−10	0.561	10.0	−0.4	0.00083	12.0	11.8	− 2.1
109...	VX Cygni	20 53.6	+39 48	50	− 5	20.125	9.7	−4.2	0.00017	58.8	58.6	− 5.1
110...	RV Capricorni	20 55.9	−15 37	1	−37	0.468	10.0	−0.3	0.00087	11.5	9.2	− 6.9
111...	TX Cygni	20 56.4	+42 12	52	− 3	14.726	9.1	−3.7	0.00028	35.7	35.7	− 1.9
112...	VY Cygni	21 0.4	+39 34	51	− 5	7.859	9.1	−2.8	0.00042	23.8	23.7	− 2.1
113...	SW Aquarii	21 10.2	− 0 20	20	−33	0.459	10.4	−0.3	0.00072	13.9	11.7	− 7.6
114*..	β Cephei	21 27.4	+70 7	75	+14	0.190	3.3	−0.4	0.018	0.6	0.5	+ 0.1
115...	VZ Cygni	21 47.7	+42 40	59	− 9	4.864	8.8	−2.0	0.00069	14.5	14.3	− 2.3
116...	Y Lacertae	22 5.2	+50 33	66	− 5	4.325	9.0	−1.9	0.00066	15.2	15.1	− 1.3
117...	δ Cephei	22 25.4	+57 54	73	+ 1	5.366	4.14	−2.19	0.0054	1.8	1.8	0
118...	Z Lacertae	22 36.9	+56 19	73	− 1	10.89	8.9	−3.3	0.00036	27.8	27.8	− 0.5
119...	RR Lacertae	22 37.4	+55 55	73	− 2	6.412	9.0	−2.4	0.00052	19.2	19.2	− 0.7
120...	V Lacertae	22 44.6	+55 48	74	− 3	4.983	9.0	−2.1	0.00060	16.7	16.7	− 0.9
121...	SW Cassiopeiae	23 2.9	+58 1	77	− 1	5.44	9.4	−2.2	0.00048	20.8	20.8	− 0.4
122...	RS Cassiopeiae	23 32.6	+61 53	82	+ 1	6.295	9.6	−2.4	0.00040	25.0	25.0	+ 0.4
123...	UU Cassiopeiae	23 45.8	+60 21	83	− 2	4.314	9.6	−1.9	0.00050	20.0	20.0	− 0.7
124...	RY Cassiopeiae	23 47.1	+58 12	83	− 2	12.328	9.8	−3.5	0.00022	45.4	45.4	− 1.6
125...	VW Andromedae	23 59.6	+34 12	80	−28	0.517	10.3	−0.3	0.00076	13.2	11.7	− 6.2
126†..	—Hydrae	12 25.2	−25 30	266	+37	0.479	10.9	−0.3	0.00057	17.5	14.0	+10.5
127†..	—Herculis	16 26.2	+18 36	3	+37	0.365	10.4	−0.3	0.00072	13.9	11.1	+ 8.4

* The possible uncertainty in the length of period suspected by Guthnick (*Astronomiche Nachrichten*, **196**, 357, 1913; **205**, 97, 1917) does not affect the adopted absolute magnitude appreciably.

† These stars were added to the tables after receiving (February 1, 1918) the list of new variables in *Harvard Circular* No. 201.

TABLE I*a*

ADDITIONS TO TABLE I

No.	Name	Galactic		Period in Days	Med. Mag. Visual	Parallax	Distance (Unit Is 100 Parsecs)		
		Long.	Lat.				Radial	Projected	From Plane
128	169. 1907 Leonis	149°	+55°	0.685	12.0	0″00033	30.3	17.4	+24.8
129	RR Canum Venaticorum	110	+82	0.558	11.0	0.00052	19.2	2.7	+19.0
130	S Comae	181	+88	0.587	10.9	0.00055	18.2	0.6	+18.2
131	SX Ursae Majoris	77	+60	0.307	10.8	0.00060	16.7	8.4	+14.5
132	RU Canum Venaticorum	20	+73	0.364	11.1	0.00052	19.2	5.6	+18.4
133	W Canum Venaticorum	37	+70	0.552	10.3	0.00072	13.9	4.8	+13.1
134	172. 1907 Boötis	28	+66	0.622	10.8	0.00058	17.2	7.0	+15.7
135	X Scuti	346	− 3	4.187	9.8	0.00046	21.7	21.7	− 1.1
136	Z Scuti	355	− 2	12.9	9.2	0.00029	34.5	34.5	− 1.2
137	SX Aquarii	26	−35	0.536	11.8	0.00036	27.8	22.8	−15.9
138	VV Pegasi	46	−32	0.488	11.2	0.00050	20.0	17.0	−10.6
139	RZ Cephei	77	+ 6	0.309	9.4	0.0012	8.7	8.6	+ 0.9

The period of any star in Table II may be found, if desired, by reading its logarithm from the luminosity-period curve for the corresponding tabulated absolute magnitude; and the adopted median apparent magnitude can be readily computed from the parallax and absolute magnitude. The last five stars of the table were added from Hartwig's 1918 catalogue; see note 1, p. 280. The variables of Table II are not used in the diagrams or in the following discussion.

TABLE II

SUPPLEMENTARY LIST OF VARIABLES

No.	Name	Absolute Magnitude	Parallax
1.....	RX Andromedae	−5.5	0″00010
2.....	SZ Cassiopeiae	−5.6	0.00008
3.....	SW Persei	−6.5	0.00008
4.....	SW Aurigae	−4.7	0.00004
5.....	RV Tauri	−5.3	0.00009
6.....	SS Geminorum	−5.5	0.00018
7.....	V Lyncis	−6.2	0.00009
8.....	RU Camelopardalis	−4.4	0.00019
9.....	RS Puppis	−5.3	0.00029
10.....	Z Cancri	−6.2	0.00010
11.....	RX Ursae Majoris	−6.0	0.00003
12.....	S Antliae	−0.3	0.0042
13.....	Z Leonis	−5.8	0.00012
14.....	S Crucis	−2.0	0.0016
15.....	W Virginis	−4.0	0.00014
16.....	V Ursae Minoris	−6.2	0.00015
17.....	UV Draconis	−6.3	0.00010
18.....	TX Scorpii	−0.6	0.0021
19.....	κ Pavonis	−3.0	0.0032
20.....	S Vulpeculae	−6.1	0.00009
21.....	TX Aquilae	−5.1	0.00010
22.....	R Sagittae	−5.1	0.00013
23.....	V Vulpeculae	−5.2	0.00017
24.....	TW Pegasi	−6.3	0.00018
25.....	RY Pegasi	−4.6	0.00010
26.....	RY Lacertae	−6.0	0.00003
27.....	W Cephei	−2.4	0.00091
28.....	X Lacertae	−2.2	0.00076
29.....	TV Andromedae	−6.0	0.00007
30.....	RU Aquarii	−6.1	0.00009
31.....	TZ Persei	−4.0	0.00004
32.....	U Monocerotis	−5.5	0.00044
33.....	UU Herculis	−6.0	0.00010
34.....	TX Ophiuchi	−6.2	0.00005
35.....	AP Sagittarii	−3.3	0.00083

There can be no doubt of the intimate relationship of cluster-type variables to the longer-period Cepheids, but in a few characteristics there appear wide differences—discontinuities in the usual progressive connections. One conspicuous discontinuity appears in the frequency of periods, which is illustrated in Table III for the 139 variables of Tables I and I*a*. Attention has been previously called to this matter by Hertzsprung and others. The reason for the two maxima in the frequency-curve must be sought in the dynamics of the stars themselves.

TABLE III

FREQUENCY OF THE PERIODS OF 139 CEPHEID VARIABLES

Period in Days	Number of Stars	Period in Days	Number of Stars	Period in Days	Number of Stars
0.0–0.2	2	5.0– 5.5	5	13.0–14.0	1
0.2–0.4	7	5.5– 6.0	5	14.0–15.0	4
0.4–0.6	31	6.0– 6.5	6	15.0–16.0	3
0.6–0.8	4	6.5– 7.0	3	16.0–17.0	4
0.8–1.0	1	7.0– 7.5	3	17.0–18.0	2
1.0–1.5	0	7.5– 8.0	6	18.0–19.0	2
1.5–2.0	2	8.0– 8.5	2	19.0–20.0	4
2.0–2.5	1	8.5– 9.0	0	20.0–25.0	1
2.5–3.0	1	9.0– 9.5	1	25.0–30.0	2
3.0–3.5	4	9.5–10.0	2	30.0–35.0	0
3.5–4.0	6	10.0–11.0	4	35.0–40.0	2
4.0–4.5	7	11.0–12.0	2		
4.5–5.0	5	12.0–13.0	4		

Two other notable differences between the two groups are the space distribution and the space velocities. Hertzsprung has maintained in several notes that the cluster-type stars must be of low luminosity because of the large proper motion of their brightest representative, RR Lyrae ($\mu = 0''.25$), and because of the position of many such stars in high galactic latitude. The closely comparable luminosity of the two groups, however, is established by the luminosity-period curve. Moreover, RR Lyrae has a much larger radial velocity than the ordinary Cepheids, $V_0 = 50$ km/sec., and its proper motion may be an indication of great peculiar velocity rather than of large parallax.

This supposition is strongly supported through spectroscopic observations by Adams of four other cluster-type variables. The smallest radial velocity is -52 km/sec. for RS Boötis; the greatest is -196 km/sec. for XZ Cygni, which has an annual proper motion of $0''.1$, according to a determination kindly made at the writer's request by Professor Tucker. If we adopt the parallaxes in Table I, the space velocities of RR Lyrae and XZ Cygni, 400 km/sec., are among the greatest known. The average radial velocity for the longer-period Cepheids is less than 10 km/sec. It is possible, therefore, that the marked contrast between the wide dispersion of isolated cluster-type stars and the galactic concentration of normal Cepheids arises solely from the fact that the velocities of the former are enormous while those of the latter are moderate, in keeping with the motions of most other red and yellow giant stars.

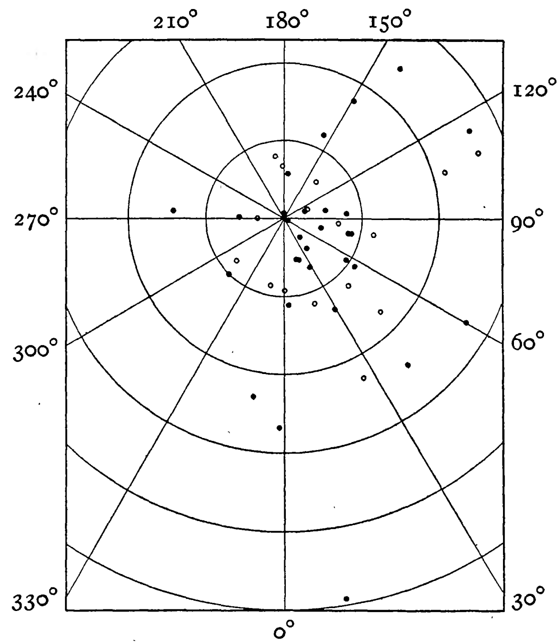

FIG. 1.—Projection on galactic plane of the position of Cepheid variables with periods shorter than one day. The circles are heliocentric, with radii of 1000 parsecs, 2000 parsecs, etc.; galactic longitudes are indicated in the margin. Many of these variables are so far above or below the plane that the diagram does not well represent the distribution in space.

Table IV contains a summary of the distribution of the variables with periods less than one day. The number of such stars is not large; the data are without doubt incomplete and there may be a preference for certain parts of the sky; hence no very definite quantitative conclusions should be based upon the material. The projection of these stars on the galactic plane is illustrated in Fig. 1; the distance from the plane is shown in Fig. 3. The great distances of RU Boötis and SW Herculis, and in particular the significance of the former's position so far from the galactic plane, have been remarked upon previously[1] and will be referred

[1] *Publications of the Astronomical Society of the Pacific*, **29**, 183, 1917.

to again in a subsequent paper. Six cluster-type variables, with $R \sin \beta$ greater than 1750 parsecs, are beyond the bounds adopted as defining the equatorial segment of the Galaxy (Fig. 3). The mean distance from the galactic plane is 960 parsecs for these 45 variables of Table IV; for Cepheids with periods greater than a day it is 150 parsecs—less than one-sixth as much. The parallaxes

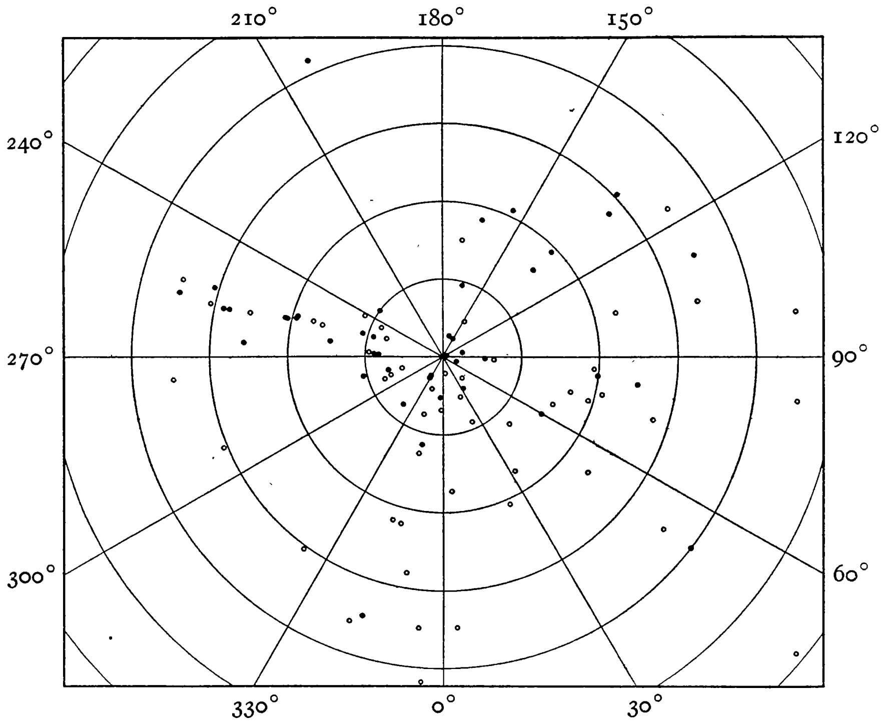

FIG. 2.—Projection on the galactic plane of the positions of Cepheid variables with periods greater than one day. The restriction to the Galaxy is so marked for these stars (see Fig. 3) that the diagram closely represents the distribution in space. The concentration of stars near longitude 255° reflects the systematic study at Harvard of the periods of all Cepheids in a restricted region (*Harvard Circular*, No. 170); it suggests the incompleteness of our data in other longitudes.

of RS Boötis, RU Boötis, XX Cygni, XZ Cygni, and RR Lyrae are the most accurate.

The distribution in the galactic plane of the 94 variables with periods longer than a day is shown in Fig. 2. The space co-ordinates are treated in some detail in Table V, showing the close restriction of ordinary Cepheids to the galactic plane. As a graphical test of

TABLE IV

DISTANCE FROM GALACTIC PLANE OF 45 CEPHEIDS WITH PERIODS LESS THAN A DAY*

Variables North of Galactic Plane		Variables South of Galactic Plane	
Limits of Distance	Number	Limits of Distance	Number
>+1500 parsecs....	7	<−1000 parsecs..	3
+1500 to+1000...	7	−1000 to −500.	5
+1000 to+ 500...	9	− 500 to 0.	8
+ 500 to 0...	6		
Total..........	29	Total.........	16

* Allowance for the position of the sun north of the Milky Way plane would alter these values slightly but would not change the actual dispersion.

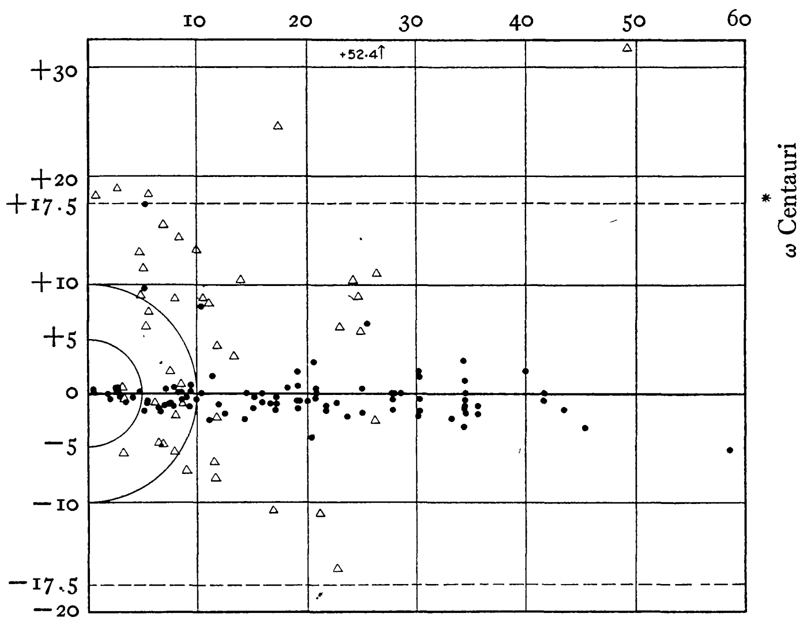

FIG. 3.—Distribution of Cepheid variables. The unit of distance is 100 parsecs. Ordinates are distances from the galactic plane; abscissae are projected distances in the plane; cf. Fig. 5 of the seventh paper. Open triangles and black dots designate respectively cluster-type variables and Cepheids with periods in excess of a day. The nearest globular cluster, ω Centauri, is just outside the boundary of the diagram on the right; RU Boötis, indicated by an arrow, is too far above the plane to fall within the figure. The semicircles with radii of 500 and 1000 parsecs ($\pi=0\overset{''}{.}002$ and $0\overset{''}{.}001$) indicate how very distant most of these variables are as compared with the average star of the tenth magnitude or brighter ($\pi>0\overset{''}{.}004$, Kapteyn). Between the broken horizontal lines, ±1750 parsecs, lies the equatorial galactic region devoid of globular clusters.

the relation of galactic concentration to distance from the sun, the values of $R \sin \beta$ are plotted in Fig. 3, against $R \cos \beta$, triangles for cluster-type variables, and dots for those with periods in excess of a day. It is important to note that for the latter the greatest distance from the plane is attained by the star of shortest period, Z Canum Venaticorum, with $R \sin \beta = +17.4$ and period $= 1.890$ days. Its space velocity may be high.

Table V and Fig. 3 reveal no conspicuous divergence from the galactic plane with increasing distance. The indications of a contrary result, obtained in the earlier study,[1] was due partly to the inclusion of a few stars of the RV Tauri type; these stars are probably of lower luminosity than typical Cepheids of like period, and in consequence the computed distances, both radial and from the plane, were much exaggerated.

TABLE V

SPACE DISTRIBUTION OF 94 CEPHEIDS WITH PERIODS GREATER THAN A DAY*

		Limits of $R \cos \beta$ (in Parsecs)			
		0 to 1000	1000 to 2000	2000 to 4000	>4000
North of Galaxy	No. of stars.......	14	6	11	2
	Mean $R \sin \beta$	+ 220	+220	+160	+100
	Max. $R \sin \beta$	+1740	+810	+640	+210
	Av. dev. from mean	± 320	±200	±140	±100
South of Galaxy	No. of stars.......	17	17	23	4
	Mean $R \sin \beta$	− 80	−100	−140	−260
	Max. $R \sin \beta$	− 160	−240	−400	−510
	Av. dev. from mean	± 40	± 60	± 80	±150
Total No. of Stars.................		31	23	34	6
Mean $R \sin \beta$	Without regard to sign............	150	130	150	210
	With regard to sign	+ 60	− 20	− 40	−140

* Distances are given only to the nearest ten parsecs.

The distribution in longitude (Table VI) of variables with periods greater than one day shows some peculiarities which may be due to incompleteness of the data. There are, for instance, at least 50 stars thought to be Cepheid variables for which periods

[1] *Astrophysical Journal*, **40**, 432, 1914.

have not been determined, and probably a great number for which types are not yet known also belong to this class.

The greater number of Cepheids south of the galactic plane is easily accounted for by assuming the sun to be slightly to the north. In fact the Cepheids should afford a good determination of the distance of the sun from the galactic plane when a more complete list becomes available.

TABLE VI

DISTRIBUTION IN GALACTIC LONGITUDE—NUMBER OF STARS

	0° to 30°	30° to 60°	60° to 90°	90° to 120°	120° to 150°	150° to 180°	180° to 210°	210° to 240°	240° to 270°	270° to 300°	300° to 330°	330° to 360°	Total
North....	0	2	3	3	3	5	1	0	10	2	1	3	33
South....	6	7	9	3	3	1	0	1	13	5	2	11	61
Total....	6	9	12	6	6	6	1	1	23	7	3	14	94

SUMMARY

1. Through the use of the luminosity-period curve the absolute magnitudes and parallaxes have been determined for 174 variables, 139 of which are believed to be perfectly typical members of the Cepheid class (Tables I and I*a*). The average probable error is estimated at 20 per cent.

2. Forty-five variables belong to the cluster type, with absolute luminosities a little more than one hundred times the brightness of the sun. Ninety-four are ordinary Cepheids with periods longer than a day and with luminosities ranging from two hundred to ten thousand times that of the sun. For 35 stars either the type of variation, or the period, or the magnitude is not certain or regular enough to yield final parallaxes (Table II).

3. The distances of Cepheid variables are considerably greater than have been obtained heretofore for individual stars. Less than one-third of them have parallaxes greater than a thousandth of a second. The most distant Cepheids now known are nearly 20,000 light-years from the sun. The nearest globular cluster is at a distance of about 21,000 light-years. (Cf. ω Centauri in Fig. 3.)

4. The numerical evaluation of the distribution in space confirms both the well-known concentration toward the galactic plane of Cepheids with periods greater than a day and the indifference of cluster-type variables to that plane. A plausible explanation of the wide dispersion of the latter is to be found in their relatively very high velocities in space.

Mount Wilson Solar Observatory
December 1917