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PERIODS OF VARIABLE STARS IN THE GLOBULAR CLUSTER MESSIER 9

BY

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(With Plate XXXIII)

The globular cluster Messier 9, NGC 6333, is one of the brighter globular clusters, but it is situated in a region of considerable obscuration in Ophiuchus. Discovered by Messier in 1764, the cluster has been relatively little studied, doubtless due to its considerable southern declination. Its right ascension is 17h 16m, and declination $-18° 28'$ (1950). At galactic longitude 333° and latitude $+9°$, the cluster, with apparent magnitude 8.92 is one of the brightest of the numerous group situated around the galactic centre. With an absolute magnitude of -7.78[1] this cluster ranks among the more luminous globular clusters, which causes the stars to be crowded together in the central region on a photographic plate.

Messier 9 was among those clusters which Bailey[2] suggested should be searched for variables, at about the same time that Shapley[3] announced one variable in it in 1916. No further work has been done on variables in the cluster since that time, except that contained in a progress report by the writer[4] at the Columbus meeting of the American Astronomical Society in 1947.

The writer began work on this object in 1939 with the 36-inch Steward Observatory telescope, through the kindness of Dr. E. F. Carpenter and the National Academy of Sciences. This is the fifth[5] in a series of papers on southern globular clusters, resulting from that visit. During a six-week interval of that year 14 plates were taken on this cluster. In subsequent seasons, the 74-inch David Dunlap reflector has been used to continue the programme. Unfortunately the southern declination of this object prevents photographing it over an interval greater than 2.7 hours on any one night. Further, our seeing conditions deteriorate noticeably when such a low object is far off the meridian. However, 89 plates have been obtained with the 74-inch, making 103 plates now available for study.

In addition to the variable found by Shapley, twelve new variables have been found by the writer. Thirty pairs of plates were blinked in this investigation. A sequence was set up in the cluster from six sequence plates exposed on both the cluster and a standard sequence. One plate with the 36-inch telescope was exposed for 20 minutes on Kapteyn Area 134, and five with the 74-inch were exposed on Area 133 with exposure times ranging from 6 to 12 minutes. However, because of the great zenith distance involved, with uncertainties in atmospheric absorption, the magnitudes cannot have a high weight.

Table I lists the comparison stars with their positions and magnitudes. The positions were measured with a reseau, with the centre of the cluster corresponding to the one used by Shapley. Table II contains the observations of the variables, the means from two measures, except for No. 11. This variable is located right in the heart of the cluster. A number of plates taken under exceptional seeing conditions show its variability beyond question, but it is futile to attempt to estimate it on most plates.

TABLE I

POSITIONS AND MAGNITUDES OF COMPARISON STARS

Star	x″	y″	Mag.
a	+ 50	− 4	13.3
b	− 89	− 108	13.6
c	− 120	+ 21	14.1
d	− 87	− 27	14.7
e	− 86	+ 4	15.1
f	− 174	+ 49	15.4
g	− 187	+ 2	15.9
h	− 104	− 7	16.2
k	− 119	+ 7	16.6
l	− 125	− 9	16.9
m	− 129	+ 1	17.2
n	− 127	− 4	17.7

Apparently no spectacular bright variables, with periods of weeks or months, exist in this cluster. All the variables found appear to be typical RR Lyrae stars with the exception of No. 8. This star, though of the same mean brightness and range as the cluster type variables, seems to have a very small range for any given year, and a different level of brightness for different years. The writer cannot suggest a period for it or even, as yet, classify the type of variation.

Table II. Measures of Variable Stars in NGC 6333

Plate	Julian Day	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5	Var. 6	Var. 7	Var. 8	Var. 9	Var. 10	Var. 12	Var. 13
4252	29408.951	16.8	15.85	– –	– –	– –	16.2	– –	16.2	16.2	– –	15.8	– –
4267	09.927	– –	15.85	16.8	16.8	– –	16.1	16.9	– –	16.4	– –	16.6	– –
4278	11.946	16.75	15.8	16.7	16.8	– –	16.4	16.8	16.2	16.65	– –	15.9	– –
4298	24.884	16.6	15.6	16.1	16.7	– –	16.35	16.5	16.2	16.55	– –	16.4	– –
4311	25.876	16.8	15.75	16.85	16.05	– –	16.4	16.75	16.2	16.7	– –	16.65	– –
4326	27.886	15.65	15.85	15.8	16.0	– –	16.35	16.55	16.35	16.2	– –	15.75	– –
4367	31.861	16.75	15.55	16.85	16.3	– –	16.45	16.7	16.35	16.4	– –	15.9	– –
4374	32.883	16.75	15.85	16.8	16.8	– –	15.85	16.7	– –	16.65	– –	16.3	– –
4397	34.860	16.7	16.15	16.75	16.8	16.2	16.4	15.95	16.3	16.4	– –	16.3	– –
4411	35.870	16.65	15.75	16.65	– –	16.0	15.6	16.75	16.3	16.7	– –	15.75	– –
4421	36.854	16.2	15.4	16.6	16.8	16.7	16.5	16.5	16.25	16.6	– –	16.65	– –
4436	37.858	15.8	15.8	16.7	16.2	– –	16.25	16.75	16.4	16.5	– –	16.6	– –
5975	843.644	16.85	16.0	16.8	16.85	16.7	15.75	16.75	16.1	16.35	16.3	16.2	[16.9
7860	30519.750	15.95	16.2	16.55	16.8	16.7	16.25	16.5	16.55	16.3	16.6	16.6	16.9
7874	20.749	16.8	16.0	16.55	15.9	16.5	16.0	16.85	16.65	16.45	16.5	16.6	[16.8
7875	.764	16.75	16.1	16.55	16.0	16.3	15.8	16.7	16.6	16.75	16.7	16.6	[16.8
7924	49.674	16.05	16.05	16.0	16.3	16.6	16.55	16.7	16.6	16.05	16.9	15.85	17.8
7939	50.707	15.7	15.95	16.75	16.95	16.3	16.3	16.85	16.55	16.3	16.9	16.45	17.5
7956	53.653	15.6	16.2	16.7	16.1	16.2	16.05	16.5	16.6	16.4	16.4	15.9	17.6
7959	.688	15.7	16.05	16.8	16.1	16.3	16.15	16.7	16.65	16.7	16.6	15.95	17.6
7976	54.694	16.75	16.05	16.75	16.75	16.5	16.45	16.75	16.6	16.75	16.5	16.65	16.8
7993	55.689	16.7	15.65	15.75	16.25	16.7	16.6	16.7	16.6	16.75	16.5	16.65	16.8
7996	.733	16.75	15.8	16.05	16.15	16.5	16.6	16.8	16.55	16.45	16.7	16.75	17.0
8013	56.671	16.0	16.25	16.7	16.85	16.4	16.05	16.1	16.6	16.55	16.8	16.35	16.8
8019	.732	16.2	16.2	16.8	16.85	16.5	16.1	16.35	16.55	16.2	16.8	16.35	17.1
8116	86.584	16.15	15.9	16.0	16.0	– –	16.45	16.8	16.7	16.45	16.6	16.7	[16.9
8118	.616	16.1	15.95	16.2	16.05	16.3	16.6	16.85	16.45	16.45	16.6	16.85	[16.8
8818	880.773	16.75	15.9	16.0	16.8	16.7	16.15	16.85	– –	16.15	16.4	15.95	[17.3
8850	84.759	16.35	15.85	16.6	16.2	16.5	16.2	16.15	– –	16.3	16.6	15.95	– –

TABLE II—*Continued*

Plate	Julian Day	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5	Var. 6	Var. 7	Var. 8	Var. 9	Var. 10	Var. 12	Var. 13
8896	30899.690	16.7	16.05	16.4	16.85	16.4	16.45	17.0	16.6	16.6	16.2	16.1	17.4
8901	.735	16.85	16.2	16.35	16.8	16.4	16.6	16.7	16.65	16.2	16.4	16.4	16.9
8904	.774	16.65	16.25	16.45	16.9	16.5	16.4	16.15	16.7	16.2	16.8	16.4	16.8
8921	900.692	16.9	15.8	16.85	15.9	16.4	15.85	16.8	16.65	16.4	16.4	15.85	16.9
8927	.772	16.85	15.95	15.85	16.15	16.5	16.15	16.95	16.85	16.25	16.8	15.9	17.2
9004	32.632	15.65	15.65	16.85	16.7	16.5	16.95	16.65	16.55	16.65	16.3	16.45	[17.1
9007	.669 •	15.85	15.9	16.75	16.8	16.5	16.75	16.8	16.55	16.25	16.4	16.2	[17.4
9024	33.615	16.7	15.95	16.5	15.8	16.1	15.95	16.95	16.65	16.55	16.4	16.8	[17.6
9028	.664	16.9	16.15	16.65	16.1	16.4	16.5	16.8	16.9	16.25	16.3	16.7	[17.4
9032	.704	16.75	16.25	16.75	16.45	16.6	16.65	16.05	16.7	16.05	16.6	16.8	17.3
10102	1257.712	15.7	15.9	– –	– –	– –	– –	– –	– –	– –	– –	– –	– –
10103	.728	15.7	15.9	16.7	[16.6	16.2	– –	16.7	– –	16.35	– –	16.7	16.8
10112	58.705	16.8	15.75	16.35	16.55	16.5	15.8	16.3	16.7	16.35	16.7	15.95	16.8
10113	.710	16.85	15.7	16.4	16.55	16.4	15.9	16.4	16.75	16.35	16.7	15.95	16.9
10116	.744	16.65	15.7	16.55	16.7	16.5	15.95	16.55	16.75	16.7	16.8	16.05	16.9
10118	.763	16.85	15.8	16.55	16.6	16.4	16.3	16.6	16.75	16.65	16.5	16.0	[16.9
10133	59.712	16.8	16.0	16.25	16.8	16.3	16.6	17.0	16.7	16.5	16.5	16.1	[16.9
10135	.749	16.85	16.05	15.8	16.8	16.4	16.75	17.0	16.8	16.6	16.5	16.0	[16.9
10138	.788	16.9	15.95	15.95	16.6	16.4	16.25	16.9	– –	16.65	16.3	16.05	[16.9
12046	969.776	16.9	15.65	16.7	16.7	16.1	15.75	16.9	– –	16.6	16.2	– –	16.9
12050	.803	16.8	15.8	16.8	16.8	16.3	15.7	16.8	16.3	16.4	16.4	16.85	16.8
12119	76.741	16.7	15.8	16.45	16.3	16.4	16.65	17.0	16.3	16.35	16.5	16.05	[17.1
12123	.783	16.85	15.85	16.6	15.9	16.5	16.3	16.95	16.5	16.4	16.5	15.9	[16.9
12144	77.756	16.4	16.3	15.9	16.85	16.1	16.05	16.75	16.3	16.65	16.9	16.9	17.5
12262	99.726	16.5	16.0	16.3	16.25	16.1	16.5	[16.6	– –	16.5	– –	15.95	– –
12281	2000.703	16.75	16.1	16.45	16.85	16.5	16.15	16.95	16.5	16.5	16.7	16.5	[17.2
12284	.735	16.7	16.0	15.75	16.85	16.6	15.75	17.0	16.6	16.65	16.9	16.6	[17.2
12327	04.688	16.5	16.3	16.7	16.8	16.2	16.6	16.4	16.3	16.1	16.4	16.75	17.5
12329	.715	16.7	16.15	16.7	16.7	16.3	16.6	16.5	16.25	16.05	16.5	16.65	17.8
12344	05.690	15.7	16.1	15.95	16.05	16.6	16.1	16.95	16.25	16.0	16.5	16.75	17.7
12348	.743	16.0	16.2	16.35	16.35	16.4	16.3	16.85	16.3	16.05	16.6	16.8	17.4
12365	06.682	16.7	16.35	16.75	16.8	16.3	16.8	16.8	16.5	16.1	16.5	16.25	17.7
12368	.728	16.7	15.6	16.75	16.8	16.6	16.7	16.85	16.5	16.2	16.7	16.4	16.7

TABLE II—*Continued*

Plate	Julian Day	Var. 1	Var. 2	Var. 3	Var. 4	Var. 5	Var. 6	Var. 7	Var. 8	Var. 9	Var. 10	Var. 12	Var. 13
13406	32354.754	15.6	15.9	16.65	16.1	16.6	16.6	16.4	16.25	16.45	16.7	15.9	17.0
13427	55.714	16.7	16.3	16.45	16.85	16.3	15.75	16.85	16.35	16.65	16.7	16.95	17.1
13430	.742	16.75	16.2	16.75	16.9	16.3	15.75	16.9	16.45	16.6	16.8	16.85	17.4
13450	56.719	16.3	15.65	15.7	16.25	16.7	16.85	16.75	16.4	16.4	16.7	16.75	17.2
13452	.735	16.55	15.8	15.75	16.1	16.7	16.75	16.8	16.35	16.15	16.6	16.7	17.4
13466	57.731	15.6	16.15	16.65	16.8	16.3	16.65	16.75	16.35	16.05	16.5	16.05	17.4
13469	.765	15.8	16.15	16.7	16.75	16.5	16.6	16.1	16.1	16.05	16.4	16.1	17.7
13490	60.689	15.8	16.15	16.5	16.8	– –	16.25	16.8	16.1	16.1	16.2	16.65	17.4
13494	.740	16.3	16.0	16.6	16.3	16.2	16.2	16.9	16.3	16.15	16.6	16.8	17.8
14511	733.653	16.75	15.7	16.7	16.7	16.5	16.65	16.2	16.15	16.10	16.6	16.9	[17.4
14513	.685	16.8	15.8	16.8	16.85	16.5	16.45	16.5	16.25	16.15	16.7	16.9	17.4
14518	.725	15.65	16.05	16.7	16.85	16.4	15.7	16.4	16.3	16.05	16.7	16.8	16.8
14522	.764	15.75	15.9	16.65	16.8	16.2	15.9	16.6	16.05	16.1	16.6	16.6	16.8
14535	34.647	16.75	16.4	16.25	16.4	16.7	16.45	16.95	16.1	16.1	16.5	16.45	17.3
14538	.678	16.6	16.35	16.3	16.05	16.6	16.5	16.9	16.15	16.0	16.6	16.4	16.8
14543	.736	16.85	16.5	16.55	16.05	16.6	16.75	16.85	16.05	16.25	16.5	16.8	16.9
14581	40.643	16.8	16.1	16.1	16.9	16.4	16.7	16.65	16.1	16.6	16.7	16.1	17.7
14585	.688	16.85	16.25	16.25	16.55	16.6	16.5	16.75	16.2	16.5	16.8	15.9	17.6
14590	.746	15.8	16.1	16.45	16.05	16.8	16.6	16.7	16.1	16.35	16.7	15.85	17.7
14605	41.642	16.75	16.2	16.6	16 85	16.4	15.75	16.95	16.1	16.45	16.7	16.85	17.8
14611	.731	16.7	15.65	16.15	16.75	16.1	16.0	16.5	16.05	16.35	16.7	16.75	17.5
14625	42.625	16.2	16.05	16.7	16.8	16.8	16.8	16.8	16.1	16.7	16.8	16.7	17.7
14631	.685	16.4	16.25	16.7	16.85	16.6	16.65	16.75	16.1	16.35	16.9	16.75	17.8
14634	.735	16.4	16.25	16.55	16.05	16.3	16.75	16.8	16.05	16.05	16.8	16.5	17.8
14753	70.588	16.8	16.2	16.65	16.8	16.4	16.75	16.8	16.15	16.15	16.7	16.15	17.8
14763	.683	15.8	15.65	16.8	16.85	16.7	16.65	16.0	16.1	16.7	16.4	16.45	16.7
16026	3068.761	15.75	16.1	16.15	16.75	16.7	16.05	16.75	16.4	16.5	16.5	16.75	17.0
16029	.785	15.7	16.1	16.15	16.8	16.7	16.05	16.8	16.15	16.6	16.3	16.75	17.2
16055	69.749	16.8	15.75	16.7	16.25	16.4	16.55	17.2	16.45	16.5	16.5	16.8	17.2
16060	.790	16.8	15.7	16.8	16.35	16.4	16.7	16.55	16.5	16.6	16.6	16.7	17.3
16179	95.685	16.0	15.9	16.85	– –	16.6	16.35	16.1	16.25	16.5	16.3	16.7	17.2
16183	.749	15.8	15.95	16.85	16.7	– –	16.5	16.65	16.05	16.3	– –	16.2	– –

Because of the limited hour angle of the plates, considerable difficulty was experienced in determining the periods. The method worked out by R. W. Tanner[6] for detecting spurious periods in spectroscopic binaries has proved of great value in the investigation of periods in this cluster. From the known fact that the phase residuals, $\Delta\varphi$, of a spurious period will be related to the deviation, α, of the time of the observation from the meridian or ideal time, Tanner shows that by making use of the statistical relation between $\Delta\varphi$ and α one could weed out the spurious periods and confirm true periods. When the period obtained is the true one, a plot of $\Delta\varphi$ against α shows points scattered along the x-axis (α-axis), but if the period is a false one then a definite slope of the points is obtained, accentuated by the observations at the larger hour angles. From the amount of slope the true period may be determined. Once a preliminary period was obtained for a variable in Messier 9, according to Tanner's method phase residuals from a mean light curve were plotted against the hour angle of the observations. In the case of four variables this method showed that an alternative period was the correct one.

The elements of all the variables, with the exception of Nos. 8 and 11, are contained in Table III. The ranges given for the variables are from the 74-inch plates where nearby stars are better separated from the variables. The periods determined range in length from 0.24 day to 0.67 day. Of the eleven periods, seven are over half a day, and four are definitely less than a half day. This is the type of cluster with a double maximum in period frequency, with periods around two-thirds of a day and one-third of a day, and no periods around one-half day. Judged from its magnitude and position, No. 13 is almost certainly a field variable, and is not regarded as a cluster member. This happens to be the faintest variable for which the writer has ever determined a period.

The light curves of the variables are represented in figures 1 and 2. In three cases where the Arizona plates give systematically brighter magnitudes, these have been indicated by open circles.

Several of the variables are among the brightest stars at maximum, reaching magnitude 15.6. The mean magnitude of the 25 brightest stars is 15.50, with the 6th brightest at 14.9 and the 30th at 15.8. These values have been determined with the same sequence as used for the variables, but they agree remarkably well with the determination made by Shapley[7] years earlier, when a different sequence was used and an independent selection of bright stars made. Then the values obtained were 15.61, 15.08, and 15.88 respectively. There appears to be only a tenth of a magnitude difference between the two sets of values, a rather remarkable result when the brightest stars and the sequence were selected and measured quite independently each time.

The mean median magnitude of 9 RR Lyrae stars which are cluster members is 16.39, which value we may take as the modulus of the cluster. Excluded from this mean are variables No. 2, an obvious double star; No. 8, of unknown type; No. 11 in centre of cluster; and No. 13 undoubtedly a field star. The modulus of 16.61

TABLE III

ELEMENTS OF THE VARIABLE STARS IN NGC 6333

Var. No.	x″	y″	Magnitudes Max.	Min.	Mean	Epoch Julian Day	Period in Days
1	+ 91	− 76	15.6	16.9	16.25	29427.886	0.585727
2	+ 40	− 31	15.6	16.4	16.0	29436.854	0.628191
3	+ 207	− 210	15.7	16.85	16.27	32000.735	0.605397
4	+ 23	− 35	15.8	16.95	16.37	30520.749	0.670076
5	+ 34	− 7	16.0	16.8	16.4	29435.870	0.274708
6	− 70	− 14	15.7	16.95	16.32	29435.870	0.607795
7	− 111	− 80	15.95	17.2	16.57	29434.860	0.628456
8	− 73	− 99	16.05	16.9	16.47	– –	– –
9	+ 334	− 191	16.0	16.75	16.37	30933.704	0.322990
10	+ 37	+ 26	16.2	16.9	16.55	30553.653	0.242322
11	− 4	− 7	15.7	16.8	16.25	– –	– –
12	− 275	− 136	15.85	16.95	16.40	29408.951	0.571784
13	+ 259	+ 11	16.7	17.8	17.25	30554.694	0.47985

REMARKS TO TABLE III AND FIGURES 1 AND 2

1. The variable announced by Shapley in 1916.
2. A double star, south and west component varies; the invariable component is about magnitude 16.3.
5. Very difficult to estimate; in a chain of stars which merge under poor seeing. Where really clear cut estimates are made on good plates, scatter on curve is less than with all observations grouped together.
8. Type of variation unknown.
9. This variable is farthest from sequence, which increases scatter in the light curve.
10. Arizona measures are on too small a scale to be used; this is the most difficult variable in the cluster for period determination.
11. Too close to centre for period determination.
12. A faint nearby star may be responsible for the systematically brighter Arizona magnitudes.
13. Probably not a member of the cluster.

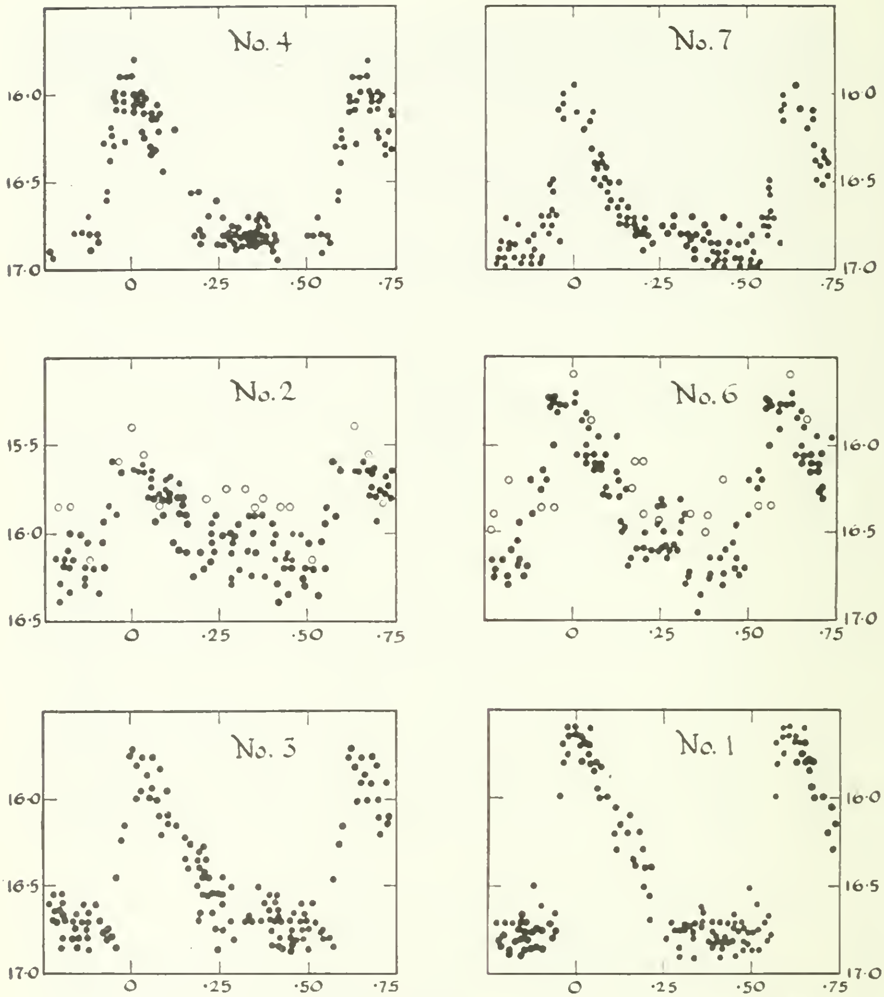

FIG. 1.—Light curves of the longer period cluster type variables in NGC 6333, with periods from 0.67 to 0.58 day. Open circles indicate systematically brighter observations from Arizona plates.

previously determined by Shapley and Sawyer[8] is therefore slightly reduced because the magnitude difference of 0.89 between the 25 brightest stars and the variables is less than was assumed when the variables were unknown.

The cluster is located on the edge of a heavy obscuring cloud, which on the 74-inch plates cuts off most of the stars beyond the

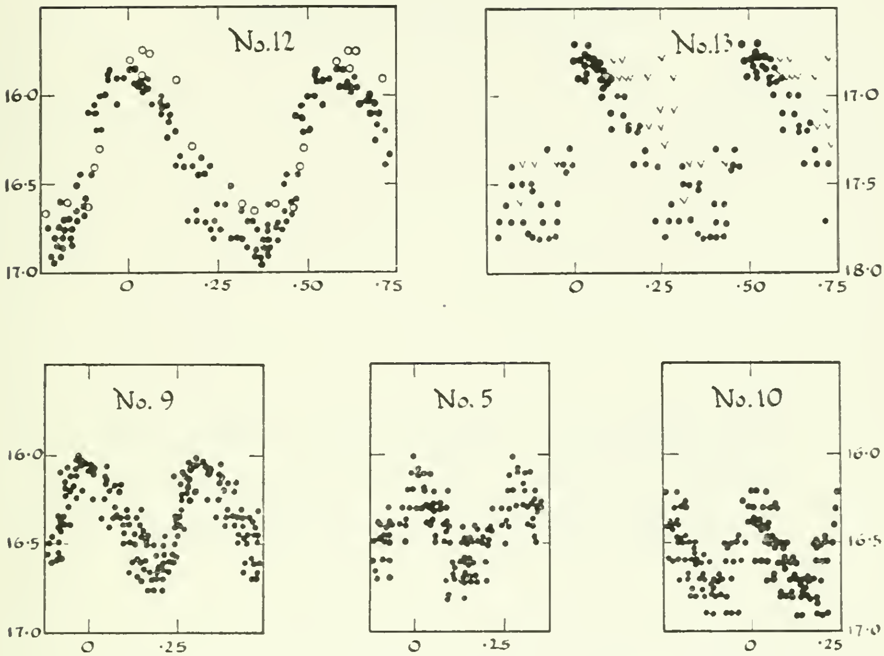

FIG. 2.—Light curves of variables in NGC 6333 with periods from 0.57 to 0.24 day. The faint variable No. 13 is probably not a cluster member.

cluster limits to the south-west, as shown in Plate XXXIII. Because of this and the high colour excess of the cluster,[9] + 0.24, the writer will not attempt to convert this modulus into linear distance. Probably the true correction, when applied, will make this one of the nearer globular clusters.

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Richmond Hill, Ontario
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