PUBLICATIONS OF
THE DAVID DUNLAP OBSERVATORY
UNIVERSITY OF TORONTO

VOLUME I NUMBER 2

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BY

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1938
THE UNIVERSITY OF TORONTO PRESS
TORONTO, CANADA

Publications of the David Dunlap Observatory, Volume I, Number 2.

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Introduction. The two clusters NGC 6218 and NGC 6254, known also as Messier 12 and Messier 10 respectively, form a rather unusual pair in the sky. They are quite similar in appearance, with an arrangement of the brighter stars which is relatively loose for a globular cluster. Situated in the constellation of Ophiuchus near the celestial equator, they are only about three degrees apart in the sky. These clusters belong to a group which has a relative scarcity of bright stars. The luminosity curve of NGC 6218, as plotted from the data of Küstner's catalogue, is shown in Figure 1. There are fewer than two hundred stars of absolute magnitude brighter than zero.

The writer began photographing these clusters with the 72-inch reflector during her first season at the Dominion Astrophysical Observatory in 1931. The clusters were observed at that observatory each season through 1934, and since then observation has been continued with the 74-inch telescope of the David Dunlap Observatory. A number of Mount Wilson plates are available taken by F. G. Pease, H. Shapley and P. Th. Oosterhoff, to whom the writer is much indebted. Something of an astronomical record has been attained in that plates from the three largest existing telescopes have been available to study these clusters.

The writer has hunted both clusters intensively for variables as reported in a paper "One Hundred and Thirty-Two New Variable Stars in Globular Clusters", now in press.[1] The clusters are exceedingly poor in variable stars as in Messier 12 only one variable was found, and in Messier 10, only two. Plates giving the identification of the variables and comparison stars appear in the paper just mentioned. The variables, though scarce, are interesting objects however, as in each cluster the outstanding variable is practically the brightest star in the cluster. It is curious that the variability of these bright objects should have escaped detection for so long, but it may be recalled that a similar thing happened in the case of the brightest variable, which is also the

brightest star, in the globular cluster Messier 2.[2] There Prof. Bailey found eleven fainter variables from an inspection of photographs, but failed to notice the variability of the brightest star in the cluster.

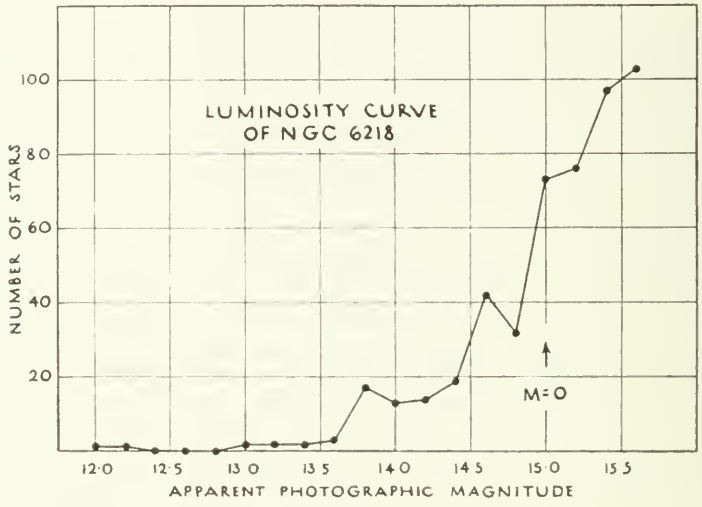

Figure 1

The luminosity curve of NGC 6218 as plotted from Küstner's Catalogue, Bonn Veröff. 26, 1933. The stars are grouped in intervals of 0.2 magnitude. There are 482 stars represented in the diagram; a few brighter stars (doubtless field stars) are omitted. The variable is the brightest star definitely attributable to the cluster, as at maximum it reaches 12.0. To give an idea of the absolute magnitudes, the line for absolute magnitude zero, based on the distance determined in this paper, is indicated.

1. NGC 6218 = Messier 12

This cluster is at R.A. $16^h\ 42^m.0$, Dec. $-1°\ 46'$ (1900), galactic longitude 344°, latitude +25°. The writer has photographed it for six seasons, and obtained observations on 33 nights. In addition, 14 Mount Wilson plates taken by Dr. Pease and Dr. Shapley in the years 1912-1919, and 7 by Dr. Oosterhoff in 1935 bring the total number of nights up to 50 and of observations to 59.

A sequence has been determined from two plates of ten and fifteen minutes exposure respectively on Kapteyn Area 108. As the variable is the brightest star in the region of the cluster a

satisfactory sequence cannot be selected on reflector plates. But the sequence has been sufficient to estimate the variable and determine the period. Dr. Oosterhoff has communicated to the writer that he finds star *e* of the sequence to be variable. This star is a double star, and is resolved on his plates, though not on the writer's. The blending of the images apparently masks the variation on the writer's plates. The magnitudes used for the sequence stars are: *a*, 11.6; *b*, 11.9; *c*, 12.2; *d*, 13.2; *e*, 13.7.

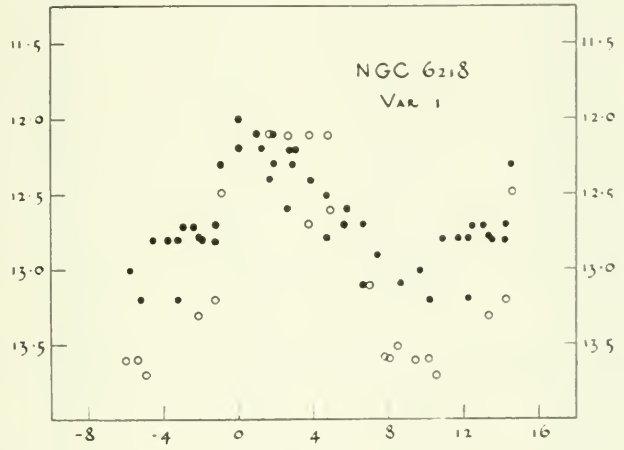

Figure 2

The Light Curve of Variable No. 1 in NGC 6218. Abscissae are days; ordinates, apparent photographic magnitudes. The open circles represent Mount Wilson plates, on which the two components of the variable are usually better resolved.

Variable No. 1 is a double star. Apparently the brighter component of the double varies, while the fainter is constant in light at approximately magnitude 14.0. This makes the estimation of magnitude exceedingly difficult. On the Canadian plates the variables are never separated at maximum, and only rarely toward minimum; while on the Mount Wilson plates they are usually separated toward minimum, and are occasionally resolved near maximum. The variable appears to be a long period Cepheid. The adopted elements are

$$\text{Maximum} = \text{J.D. } 2427306.708 + 15^{d}.508E$$

A period of 15.475 days represents slightly better the observations from some years, but throws others badly out of phase. It is

TABLE I

OBSERVATIONS OF VARIABLE NO. 1 IN N.G.C. 6218

Julian Day 2,400,000.+	Mag.	Phase	Plate No.	Obs.
19535.872	12.5	14.68	100	W
20952.878	12.1	4.86	2981	W
952.946	12.0	4.93	2985	W
953.006	12.1	4.99	2989	W
980.924	12.7	1.89	3058	W
980.989	12.1	1.95	3062	W
981.829	12.1	2.79	3068	W
981.899	12.1	2.86	3071	W
981.982	12.1	2.95	3075	W
982.955	12.1	3.92	3077	W
21435.781	13.1	6.98	3850	W
454.774	13.7	10.47	3872	W
22105.883	13.6	10.20	4945	W
134.704	13.6	8.00	4958	W
26607.689	12.8	14.39	19969	V
607.732	12.8	14.44	19971	V
915.756	12.9	12.28	20541	V
915.775	12.7	12.30	20542	V
921.725	12.4	2.74	20555	V
921.804	12.1	2.82	20558	V
923.758	12.5	4.77	20570	V
924.771	12.6	5.79	20585	V
925.733	12.7	6.75	20595	V
944.715	13.2	10.22	20642	V
944.723	13.2	10.23	20643	V
946.693	13.2	12.20	20671	V
946.701	13.3	12.21	20672	V
27273.761	12.8	13.58	21385	V
274.739	12.3	14.56	21397	V
275.740	12.2	0.05	21410	V
306.708	12.0	0.00	21510	V
307.722	12.1	1.01	21533	V
308.701	12.1	1.99	21551	V
309.718	12.2	3.01	21570	V
639.765	12.9	7.39	23177	V
658.790	12.8	10.88	23239	V
659.714	12.8	11.80	23250	V
664.705	12.2	1.29	23303	V
872.98	13.6	7.95	.....	W
888.95	13.5	8.41	.....	W
889.90	13.6	9.36	.....	W
930.96	12.7	3.89	.....	W

Julian Day 2,400,000.+	Mag.	Phase	Plate No.	Obs.
931.93	12.6	4.86	.....	W
955.88	13.3	13.30	.....	W
956.90	13.2	14.32	.....	W
28688.653	12.4	1.64	1977	T
689.653	12.6	2.64	1991	T
692.642	12.7	5.63	2006	T
693.706	13.1	6.70	2010	T
695.726	13.1	8.72	2019	T
696.644	13.0	9.64	2031	T
715.642	12.5	13.12	2109	T
29071.668	12.7	12.44	3247	T
072.643	12.8	13.42	3257	T
073.612	12.7	14.39	3270	T
076.632	12.3	1.90	3287	T
077.641	12.3	2.91	3300	T
078.640	12.4	3.91	3314	T
079.449	12.8	4.71	3328	T

Note to Table I. On plate 3058, the components of the variable were resolved, but they were not on the subsequent plate.

possible that in the future a period may be obtained to represent better all the observations, or it may be that the star is slightly irregular around a mean period.

Table I gives the observations on this star, indicating in successive columns the Julian Day, magnitude, phase, plate number, and the initial of the observatory where the plate was taken, W standing for Mount Wilson, V for the Dominion Astrophysical, and T for the David Dunlap Observatory. Figure 2 shows the light curve as obtained from the adopted elements. The open circles represent the Mount Wilson observations which fall systematically below those of Victoria and Toronto, due to the better resolution of the double star.

2. NGC 6254 = Messier 10

This cluster is at R.A. $16^h\ 51^m.9$, Dec. $-3°\ 57'$ (1900), galactic longitude 343°, latitude +22°. It has been observed for eight consecutive seasons, first at the Dominion Astrophysical and later at the David Dunlap Observatory, on a total of 42 nights. In addition, 14 Mount Wilson plates from the collection of Dr. Pease and Dr. Shapley have given observations on 9 additional nights between the years 1912 and 1919.

Two variables were found in this cluster by the writer. In a paper by E. C. Pickering[3] in 1897 there is one previous reference to a variable in this cluster, when he mentions that Professor Bailey has found a variable in it. However, the cluster and variable were not included in Bailey's comprehensive work on variables in globular clusters published in 1902.[4] An attempt has been made to see whether any unpublished records at the Harvard Observatory would identify the variable announced in 1897 and

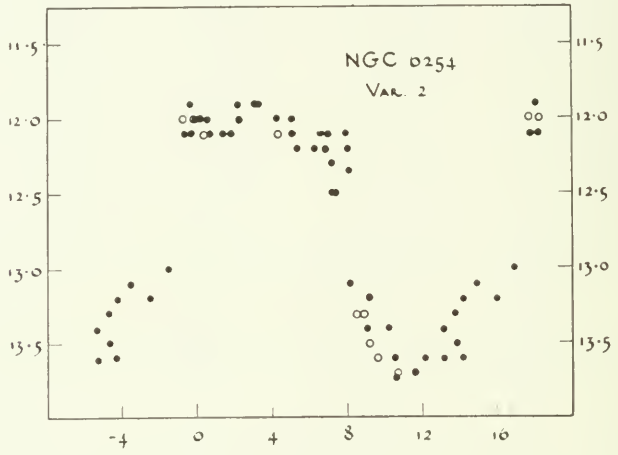

Figure 3

The Light Curve of Variable No. 2 in NGC 6254. Abscissae are days; ordinates, apparent photographic magnitudes. The open circles represent observations from Mount Wilson plates, which for this star show no systematic difference from the Canadian plates.

indicate if it were dropped from the lists because it was not a genuine variable. Miss Walker has located Prof. Bailey's records of a variable star search in this cluster, in which four suspected variables are identified. This search, however, judging from internal evidence, was made about 1917, and there is no mention in these papers of the variable announced earlier. On the plates available to the writer, none of Bailey's suspected variables appears to be a genuine variable.

A magnitude sequence has been obtained from three plates, one of fifteen minutes exposure and two of ten, on Kapteyn Area 108. The magnitude sequence is very unsatisfactory as there is a gap

of 1.15 magnitudes between sequence stars in the very interval in which the variable is most frequently found. The magnitudes of the sequence stars are: *a*, 12.35; *b*, 13.5; *c*, 13.85; *d*, 14.1; *e*, 14.3; *f*, 14.65; *g*, 15.3; *h*, 15.6.

The writer has not yet made a serious attempt to find a period for Variable No. 1 in this cluster. It is a bright object in a congested region, with a range of only half a magnitude.

A satisfactory period has been obtained for Variable No. 2, however. It is found that this star, which is the brightest object in the cluster, strongly resembles in period the bright variable in NGC 6218 and also the brightest variable in NGC 6402.[5] The adopted elements are

$$\text{Maximum} = \text{J. D. } 2426607.712 + 18^{d}.754E$$

Table II contains the observations of this variable in the same form used in Table I. Figure 3 gives the light curve of the star from the adopted elements. The gaps in the light curve are probably accounted for by the magnitude sequence, which is poor because of the scarcity of bright stars in the vicinity of the cluster. The magnitude estimates appear sufficient however to define the period well. The Mount Wilson observations are indicated by open circles.

3. The Distances of NGC 6218 and NGC 6254

Since no variables were known in either of these clusters when their distances were last determined, it is interesting to make a new determination of their distances from the period-luminosity relation, although for each cluster it depends on only one star. For NGC 6218, the median apparent magnitude of the variable is 12.8 (subtracting the brightness of the companion star); the absolute magnitude from the period luminosity curve is −2.2, giving a modulus of 15.0, and a distance of 10.0 kiloparsecs. For NGC 6254, the median apparent magnitude of the variable is 12.7, the absolute magnitude −2.3, giving the same modulus as for NGC 6218. We find that the determination of distance from the new data is essentially the same as that found earlier. Table III gives a summary of the recent distance determinations. The adopted, uncorrected, distance is taken as the mean of the distance determined from the Cepheid variable and van de Kamp's distance.

Table IIIb shows that the true distance of the cluster is affected

TABLE II

OBSERVATIONS OF VARIABLES IN NGC 6254

Julian Day 2,400,000.+	Var. No. 1 Mag.	Var. No. 2 Mag.	Var. No. 2 Phase	Plate No.	Obs.
19564.753	13.8	13.3	8.55	113	W
564.861	13.7	13.4	8.66	114	W
565.772	13.5	13.6	9.56	117	W
565.869	13.4	13.6	9.66	119	W
566.819	13.6	13.7	10.61	123	W
566.835	13.5	13.7	10.63	124	W
20952.891	13.6	13.3	8.89	2982	W
980.936	13.7	12.0	18.18	3059	W
981.839	13.6	12.0	0.33	3069	W
981.908	13.8	12.1	0.40	3072	W
981.992	13.6	12.1	0.48	3076	W
21454.747	13.4	12.1	4.38	3869	W
22105.874	13.3	12.0	17.88	4944	W
22134.714	13.6	13.5	9.21	4960	W
26607.712	13.7	12.0	0.00	19970	V
915.796	13.7	12.1	8.02	20543	V
921.742	13.5	13.5	13.97	20556	V
921.758	13.6	13.6	13.98	20557	V
923.804	13.6	13.2	16.03	20572	V
924.739	13.4	13.0	16.97	20583	V
925.746	13.5	12.1	17.97	20596	V
944.735	13.5	12.1	18.20	20644	V
944.744	13.5	12.1	18.21	20645	V
946.713	13.6	12.1	1.43	20673	V
946.722	13.7	12.0	1.44	20674	V
27274.752	13.4	13.7	10.65	21398	V
275.751	13.5	13.7	11.65	21411	V
306.756	13.3	12.0	5.15	21514	V
307.754	13.3	12.1	6.64	21536	V
308.712	13.4	12.1	7.10	21552	V
309.695	13.4	12.2	8.08	21569	V
309.746	13.4	12.3	8.14	21571	V
639.738	13.5	12.0	0.56	23176	V
658.724	13.5	12.1	0.69	23236	V
659.776	13.5	12.1	1.84	23253	V
664.783	13.5	12.2	6.85	23307	V
28016.589	13.7	12.0	2.33	99	T
038.508	13.8	12.2	5.49	184	T
043.555	13.7	13.6	10.54	216	T
308.796	13.6	13.6	13.22	822	T
309.741	13.4	13.6	14.17	835	T

Julian Day 2,400,000.+	Var. No. 1 Mag.	Var. No. 2 Mag.	Var. No. 2 Phase	Plate No.	Obs.
365.617	13.5	13.3	13.78	1108	T
366.671	13.4	13.1	14.84	1125	T
391.569	13.3	11.9	2.23	1225	T
392.635	13.3	11.9	3.29	1242	T
398.622	13.4	13.2	9.28	1269	T
399.606	13.2	13.4	10.26	1286	T
688.672	13.8	11.9	18.02	1978	T
689.689	13.8	12.0	0.28	1993	T
692.654	13.3	11.9	3.25	2007	T
693.715	13.4	12.0	4.31	2011	T
695.736	13.3	12.2	6.33	2020	T
696.655	13.3	12.3	7.25	2032	T
715.652	13.7	12.5	7.49	2110	T
29071.687	13.8	12.5	7.20	3248	T
072.670	13.5	13.1	8.18	3258	T
073.621	13.5	13.4	9.14	3271	T
076.695	13.3	13.6	12.21	3288	T
077.648	13.6	13.4	13.16	3301	T
078.647	13.4	13.2	14.16	3315	T

far more by the value of the absorption coefficient one adopts than by the different ways of determining an uncorrected distance of the cluster. If the mean of the three corrected distances is taken, it is very close to the distances given by van de Kamp for these clusters in 1933, 6.9 kiloparsecs for NGC 6218, and 6.7 for NGC 6254. It should be noted that Stebbins and Whitford[11] find the field of NGC 6254 (measured colour excess $E+0.19$) considerably more reddened than that of NGC 6218 ($E+0.13$); this is further confirmed by the counts of nebulae in these fields by Baade.[11] The number of nebulae is normal in the field of NGC 6218, but there are no nebulae in the field of NGC 6254 and the star field is partially obscured. At the mean corrected distance the linear separation of the two clusters is about 500 parsecs.

Now that these two clusters are known to possess such bright variables, photographs may be obtained with smaller, larger-field telescopes which would permit of more sequence stars and lead to better magnitude estimates and a well-defined light curve. There is no reason for assuming that these variables are not physically connected with the cluster in which they appear, and because of the high galactic latitude, we may assume that the variables are

TABLE III

DISTANCES OF NGC 6218 AND NGC 6254

(a) UNCORRECTED FOR ABSORPTION

Source	*NGC 6218*	*NGC 6254*	*Basis*
Shapley and Sawyer,[7] 1929	11.0 kpc	11.2 kpc	Int. mag., diam., bright stars
van de Kamp,[8] 1932	10.6	10.9	Int. mag., bright stars
Sawyer, 1938	10.0	10.0	One long period Cepheid
Uncorrected Mean	*10.3*	*10.4*	Mean of 1932 and 1938

(b) MEAN DISTANCES CORRECTED FOR ABSORPTION

Absorption coefficient of	*NGC 6218*	*NGC 6254*	
van de Kamp[9]	6.7 kpc	6.5 kpc	$\log f = -0.08 \lvert\text{cosec } b\rvert$
Hubble[10]	7.8	7.6	$\log f = -0.05 \lvert\text{cosec } b\rvert$
Stebbins and Whitford[11]	5.7	4.3	$\log f = -2.0\, E$
Mean	*6.7*	*6.1*	

actual members. Because of their apparent brightness, which is greater than that of the variable in Messier 3 already studied spectroscopically by Joy,[12] these variables are especially commended to observers with fast spectrographs.

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Richmond Hill, Ontario,
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