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VARIABLE STARS IN THE GLOBULAR CLUSTER MESSIER 22

BY

HELEN B. SAWYER

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By Helen B. Sawyer

(with Plate XXX)

One of the clusters placed on the observing list at the Steward Observatory in 1939 was the large, bright globular cluster Messier 22, NGC 6656. This is the third of a series of papers[1] presenting results derived from plates on southern globular clusters taken by the writer with the 36-inch reflector.

Messier 22, R.A. 18^h 33^m, Dec. –23° 58′ (1950), is well known among the globular clusters. The cluster was one of the first in which variable stars were noted. Bailey[2] announced the discovery of 16 variables in 1902. Bailey and his assistants did considerable work on the determination of periods in this cluster, but the only paper he published on them was a brief general summary[3] in which he stated that most of the variables had periods of two-thirds of a day. Exceptions to this rule were No. 3 with a period of about one-third of a day, and No. 14, of which the period is 200 days.

In 1927 Shapley[4] published a paper on the distance of Messier 22, with a summary of information about the variables as determined by Miss Swope, who had added a seventeenth variable. Seven periods were given to a considerable accuracy, five were dubious, one was irregular and four unknown. One period was suggested as possibly 7.097 days, thus making the star a possible long-period Cepheid.

The writer's principal interest in the cluster was in searching for additional variable stars and in investigating any long-period Cepheids which the cluster might contain. Considerable spread in the maximum magnitudes of the known variables suggested that the cluster might be a good one in which to test once more the period-luminosity relationship. A series of plates for this purpose was taken at the Steward Observatory, 19 plates (one of them red) on 14 nights. However, when the writer came to work over these plates, it was found that such a compact series afforded an excellent start for period determination of the cluster type variables and, with the help of Harvard material, this determination has now been completed.

I am greatly indebted to Dr. Edwin Carpenter for the use of the Steward telescope and to Dr. Harlow Shapley who placed at my disposal the existing Harvard plates on this cluster and the unpub-

lished measures of several observers, including Bailey, Gould and Miss Swope. With the help of this material I have been able to make a rather thorough investigation of the periods in this cluster, except for the determination of the actual size of the period changes of the c-type variables.

From a survey with a blink microscope of the Steward plates by the writer, eight new variables have been found, bringing to a total of 25 the number within the boundaries of the cluster. All the variables, both old and new, are identified in Plate XXX.

Two sequence plates of ten minutes' exposure time on both the cluster and Selected Area 134 were taken to check the sequence previously published[4]. In general the magnitudes determined from these plates agree with those previously given, but there is a deviation around magnitude 14.0. When the Arizona plates were measured with the new sequence they gave light curves in which the magnitude progression was more regular. For the measures published in this paper the new sequence was used as given in Table I. The letters of the comparison stars are those assigned by Bailey and identified in *H.A.* 38.

TABLE I

MAGNITUDE SEQUENCE IN MESSIER 22

Star	Mag. Sawyer	Sawyer—Swope	Star	Mag. Sawyer	Sawyer—Swope
a	11.1	0.0	f	13.6	+0.4
b	11.2	0.0	g	14.0	+0.2
c	12.2	+0.1	h	14.4	+0.1
d	12.9	+0.1	k	14.5	0.0
e	13.2	+0.3	l	15.0:	+0.4

The period determination for most of the variables has been based on measures from 132 plates as follows: 73 X and 21 A plates from Harvard, 19 early Mount Wilson plates and 19 Steward plates.

Table II gives the data on the variables, arranged according to number. The second column of the table gives the number of the variable when included in Chevalier's catalogue[5]. The x and y co-ordinates, however, are those derived by Bailey and already published several times for the variables first discovered. For the new variables, co-ordinates were measured by the writer on this same system. More accurate co-ordinates may be found in Chevalier's catalogue, which uses a different centre.

The fifth and sixth columns give the maximum and minimum magnitudes indicated by all the plates. In the next column is given the mean, which is the mean of maximum and minimum magnitudes. For comparison, the following column gives a median magnitude, taken as the brightness which the star is above half the time. An epoch of maximum is given for most variables from the Steward plates. The last column gives the period. In most cases, a period given only to the fourth decimal place indicates a change of period. Notes on the individual stars accompany the table.

For three stars, Nos. 5, 12, and 17, no period is listed. The possible period of 7 days suggested by Miss Swope for No. 5 does not appear to be confirmed by the series of 16 nights of Arizona plates, which show only a small range for this star. The existing measures suggest a period longer than this, but the star may belong to the bright irregular class. The variability of No. 12, which Bailey himself doubted, is not confirmed by the Arizona plates. The star is one component of a double. Variable No. 17, classified as irregular by Miss Swope, is left in this classification. The observational material is much scantier for it than for the other stars because at maximum it is about the same brightness as the other variables at minimum.

Of the twenty-two periods listed, eighteen are of cluster type variables, one (No. 14) is a long-period variable, one (No. 11) is a typical Cepheid, and two (Nos. 8 and 9) appear to be a semi-regular type with periods of two and three months. Several of these stars require special comment.

Variable No. 11, previously noted as "short-period" would appear to be a long-period Cepheid, but since this star is located at almost the exact centre of the cluster it is an exceedingly difficult object on which to get reliable magnitude estimates. The scatter from any derived period is bound to be large, making it rather difficult to distinguish between true and fictitious periods. Of all the periods tested, the period 1.69050 days best represents all the observations. The star is 0.8 magnitude brighter in the mean than the cluster type variables and thus seems to afford additional evidence for the validity of the period-luminosity relation.

The three variables Nos. 5, 8, and 9 are conspicuous by reason of their brightness, averaging a magnitude and a half brighter than the cluster types. Their range is less than a magnitude and, since they tend to be overexposed, the magnitude estimates are not very reliable. Unfortunately the Arizona series contributes little information on these stars, except to show that the period of variation is long or irregular. For No. 9, an RV Tauri type of curve is suggested when a period of 87.71 days is used to compute the phases. This is represented in Figure 1. This type of variable is not shown to best advantage by combining observations from many different epochs but, in this case, the observations are too scattered to be treated in any other way. For No. 8, a period of 61.1 days represents many of the observations but a period as long as 73 days cannot be ruled out. For No. 5, no period is suggested. All three of these stars would merit further and more accurate observations.

TABLE II

Variable Stars in Messier 22

No.	Chev. No.	x''	y''	Max.	Min.	Mean	Median	Epoch Max.	Period
1	348	— 54.0	— 10.0	13.9	14.9	14.4	14.5	29425.892	0.615543
2	857	+158.6	+ 69.2	13.1	14.3	13.7	13.85	29436.917	0.6418
3	...	+214.7	+420.2	14.6	[15.2	15.0:	15.0	29434.918	0.340
4	465	— 4.0	— 68.0	13.6	14.6	14.1	14.3	29438.96	0.716391
5	158	—178.2	— 33.8	12.0	12.8	12.4		...	...
6	299	— 74.4	—100.0	13.6	14.5	14.05	14.25	29429.938	0.638547
7	82	—342.4	+411.2	13.5	14.5	14.0	14.2	29424.947	0.6495191
8	382	— 39.5	— 64.8	12.0	12.7	12.35		13373.6	61:
9	135	—211.2	— 35.0	12.7	13.3	13.0		16761.5	87.71
10	389	— 39.0	—125.0	13.5	14.6	14.05	14.3	29438.919	0.646020
11	461	— 14.4	+ 14.0	12.9	13.8	13.35	13.35	29436.917	1.69050
12	531	+ 0.8	— 77.8	14.2	14.5	Var?		...	...
13	719	+ 76.4	+158.9	13.5	14.5	14.0	14.25	29439.920	0.6725217
14	...	+250.8	+486.4	13.8	[15.5	...		18160.6	200.2
15	804	+115.3	— 83.2	14.0	14.5	14.25	14.2	29439.844	0.3721
16	877	+185.0	— 17.8	14.0	14.5	14.25	14.25	29429.938	0.3237
17	...	—438.0	+126.0	14.6	[15	...		...	...
18	259	— 86	+433	13.7	14.4	14.0	14.15	29425.892	0.3249
19	381	— 33	+130	13.9	14.5	14.2	14.25	29424.947	0.384010
20	221	—120	—123	13.7	14.5	14.1	14.1	29429.938	0.430061
21	601	+ 36	+ 88	13.8	14.8	14.3	14.1	29425.892	0.3265
22	...	—1089	+213	13.7	14.9	14.3	14.5	29424.947	0.624538
23	505	— 5	— 14	14.1	14.9	14.5	14.5	29432.919	0.3557
24	427	— 26	+ 10	13.8	14.2	14.0	14.1	29425.892	0.415:
25	952	+326	+375	13.9	14.4	14.15	14.25	29425.892	0.4023595

REMARKS TO TABLE II

1. Miss Swope's period of 0.615542 is virtually unchanged.
2. One of the brightest regular variables in the cluster, because a companion star contributes some of the light. This is the only variable with period greater than 0.4 day which shows a possible period change. The period 0.641789 satisfies almost all the observations.
3. The scarcity of measures on this very faint star leaves the period uncertain. Probably not a cluster member.
4. This star has the longest cluster type period in the cluster.
5. Miss Swope's suggestion of possible 7-day period is not confirmed. A longer period, or irregularity, is indicated.
6. A close companion makes magnitude estimates inaccurate.
7. Miss Swope's period is unchanged.
8. Existing observations do not permit a rigorous period determination, but a period between 61 and 73 days seems indicated.
9. Semi-regular variable, with RV Tauri characteristics.
10. Another variable which has a close companion.
11. Apparently a long period Cepheid, though, since it is the central star in the cluster, estimates are difficult, with a large error. The related reciprocal period 0.6283 gives a curve with larger scatter.
12. No evidence of variation from Arizona measures.
13. Only slight refinement of Miss Swope's period.
14. Definitely long period variable.
15. Period change. Period 0.372054 satisfies interval of several thousand days.
16. Period change. Period 0.323736 satisfies all but earliest observations.
17. Arizona observations contribute no further information to Miss Swope's 'Probably irregular."
18. Period change. Period 0.324863 satisfies a large number of observations.
19. The shortest period in the cluster which gives no evidence of period change.
20. The longest period of the c-type variables.
21. Period change. Period 0.326579 satisfies many observations.
22. No Arizona maximum, but period well determined.
23. Period change. Large scatter, because the star is in centre of cluster and one of most difficult variables to estimate.
24. Period determination based on Arizona plates only, so that the possibility of a fictitious period is not ruled out. This new variable was first supposed to be identical with Bailey's No. 1. When it was discovered that there really are two variables side by side in the centre of the cluster, it was too late to measure the star on the Harvard plates.
25. Curve shows great regularity despite the short period.

Table III gives the observations of all the variables from the Steward plates since they are a uniform series of measures on many consecutive nights. Figures 2 and 3 give the plot of the Steward measures on the basis of the adopted sequence and period, showing the light curves arranged according to increasing period length. The curve drawn is that obtained from the means of the measures on Harvard and Mount Wilson plates, representing over a hundred points. These points are not individually plotted because of inhomogeneity in the measures due to different series of plates and different observers. For most of the variables, the estimates from the Steward plates satisfactorily represent the course of light variation and the scatter indicates the difficulty of estimating the star in question.

Bailey's early statement in regard to the variables that "the majority of these have a period of about two-thirds of a day" holds true for the variables known at that time. The variables found later

TABLE III

OBSERVATIONS OF THE VARIABLE STARS IN MESSIER 22

Plate	Julian Day	1	2	3	4	5	6	7	8	9	10	11	12
4301	9424.947	14.8	13.8	[15.0	14.5	12.7	14.0	13.7	13.1	13.3	14.1	13.0	14.1
4312	25.892	14.0	13.9	[15.5	14.4	12.6	14.5	14.4	13.1	13.3	14.4	13.6	14.1
4315	.949	14.2	14.0	15.1	14.5	12.5	14.4	14.3	13.1	13.2	14.1	13.6	14.1
4329	27.949	14.5	13.2	[15.0	14.5	12.5	14.5	14.4	13.2	13.4	13.6	13.5	14.2
4345	29.938	14.7	13.1	14.9	14.3	12.4	13.7	14.5	12.9	13.2	13.8	13.2	14.1
4355	30.881	14.2	13.9	14.9	14.4	12.5	14.3	14.0	13.2	13.2	14.2	13.4	14.1
4358	.934	14.4	14.0	[14.8	14.6	12.6	14.4	14.0	13.0	13.3	14.5	13.4	14.1
4369	31.914	14.7	13.8	14.9	14.2	12.5	13.9	14.4	13.0	13.2	14.1	13.1	14.1
4375	32.919	14.6	14.2	14.9	14.4	12.4	14.5	14.1	13.0	13.4	14.6	13.7	14.1
4386	33.919	14.1	13.7	14.9	14.1	12.6	14.3	14.2	13.0	13.3	14.1	13.2	14.0
4394	34.806	14.6	14.1	[15.3	14.2	12.6	14.5	13.9	13.1	13.2	14.4	13.8	14.1
4400	.918	14.8	14.1	14.5	14.4	12.6	14.4	14.3	12.9	13.2	14.7	13.4	14.1
4410	35.853	14.4	14.0	[15.4	14.5	12.3	14.2	14.4	13.0	13.2	14.2	13.4	14.1
4424	36.917	14.4	13.0	[15.2	14.2	12.5	14.4	14.3	12.9	13.2	14.5	12.9	14.1
4438	37.917	14.8	14.0	15.2	14.5	12.5	14.3	13.8	12.9	13.3	14.3	13.8	14.1
4451	38.919	14.4	13.4	[15.2	14.1	12.5	13.9	14.4	13.0	13.4	13.6	13.2	14.2
4461	39.844	14.9	14.1	[15.0	14.2	12.6	14.4	14.3	12.9	13.3	14.4	13.7	14.1
4464	.920	14.9	14.0	[15.2	14.4	12.6	14.3	13.8	12.9	13.3	14.5	13.6	14.1

TABLE III—(*Continued*)

Observations of the Variable Stars in Messier 22

Plate	Julian Day	13	14	15	16	17	18	19	20	21	22	23	24	25
4301	9424.947	14.4	14.4	14.2	14.4	14.4	13.9	13.9	14.0	14.2	13.7	14.5	14.3	14.3
4312	25.892	13.8	14.5	14.4	14.4	14.5	13.8	14.4	14.1	13.9	14.8	14.5	13.8	14.0
4315	.949	14.1	14.5	14.2	14.4	14.4	14.0	14.4	14.1	14.2	14.6	14.5	14.1	14.0
4529	27.949	14.1	14.5	14.2	14.2	14.5	14.2	14.2	14.1	14.2	15.0	14.2	14.2	14.0
4345	29.938	13.8	14.6	14.4	14.1	14.6	14.4	13.9	13.8	14.1	14.1	14.4	14.2	14.0
4355	30.881	14.4	14.7	14.2	14.2	14.6	14.4	14.5	13.9	14.2	14.6	14.5	14.0	14.3
4358	.934	14.5	14.8	14.2	14.2	14.6	14.3	14.4	13.9	14.2	14.6	[14.6	13.9	14.4
4369	31.914	13.6	14.6	14.3	14.2	14.6	14.3	14.1	14.2	14.2	14.1	14.5	14.2	14.1
4575	32.919	14.4	14.7	14.4	14.3	14.6	14.3	14.2	13.9	14.2	14.9	14.2	13.9	14.3
4386	33.919	13.6	14.7	14.2	14.2	14.7	14.3	14.4	13.9	14.4	14.3	[14.5	14.1	14.2
4394	34.806	14.3	14.8	14.3	14.1	14.6	14.2	14.5	14.0	14.1	14.8	[14.8	14.2	14.1
4400	.918	14.5	14.8	14.2	14.3	14.6	14.1	14.0	14.1	14.2	14.4	14.8	14.2	14.2
4410	35.853	14.1	14.8	14.3	14.3	14.6	14.3	14.4	14.2	14.2	14.5	14.7	13.8	14.4
4424	36.917	14.3	14.7	14.2	14.4	14.8	14.0	14.2	13.8	14.0	14.2	14.9	14.2	14.2
4438	37.917	13.5	14.7	14.2	14.4	14.7	13.7	14.2	14.1	14.0	14.7	14.2	13.8	14.3
4451	38.919	14.4	14.7	14.4	14.4	14.6	14.0	14.4	14.1	14.1	14.3	[14.7	14.2	14.3
4461	39.844	14.4	14.8	14.1	14.5	14.7	14.0	14.1	13.8	14.1	15.0	[14.8	14.1	14.5
4464	.920	13.5	14.8	14.2	14.5	14.7	14.1	14.1	14.0	14.0	14.2	14.8	14.1	14.2

by the writer, however, are mostly c-type variables with periods of a third of a day. A selection effect operates here as the variables with smaller ranges were missed by the early observers.

Two important facts stand out from a study of these eighteen cluster type variables. The first is the remarkable distribution of their periods. Ten variables have periods which fall between 0.37 day and 0.43 day and eight periods lie between 0.61 and 0.71 day. But *no* periods were found between 0.43 and 0.61 day. This cluster is comparable with Messier 15, investigated by Bailey,[6] in which he found the same phenomenon. It should be pointed out that this interval in which there are no periods in Messier 22 is the

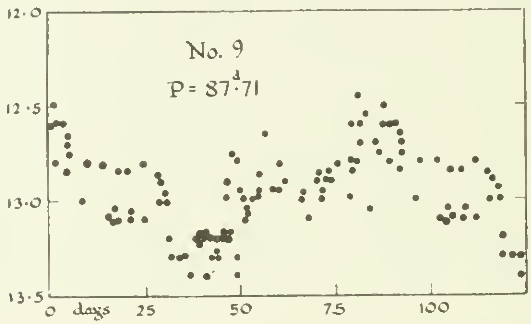

Fig. 1.—Light curve of a semi-regular variable in Messier 22.

easiest one in which to determine periods from plates taken on consecutive nights, so that any selection effect does not operate in the right direction to explain this gap. The subject of the frequency of cluster type periods in globular clusters will be summarized in a separate paper[7] appearing shortly.

The second important fact is that the cluster type variables with long periods show no evidence of period change while those with the shortest periods all give such evidence. All the variables whose periods lie between 0.32 day and 0.38 day inclusive are apparently shifting their periods. The periods are derived from so many sporadic observations rather than well-determined series, however, that the writer has not attempted to determine the amount of the period change. The earliest observations were in 1893 (J.D. 2412656) and the latest in 1939. A change of around one ten-thousandth of a day may be indicated in these intervening 46 years.

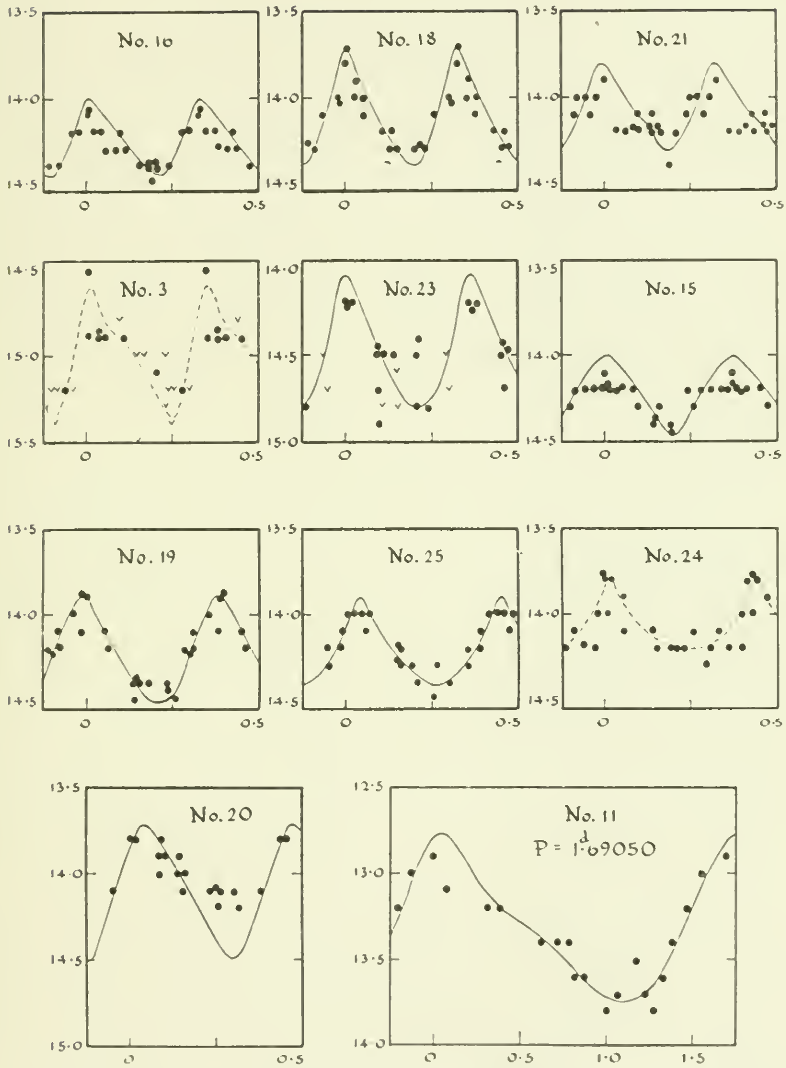

Fig. 2.—Light curves of cluster type Cepheids with periods less than half a day; and one long-period Cepheid.

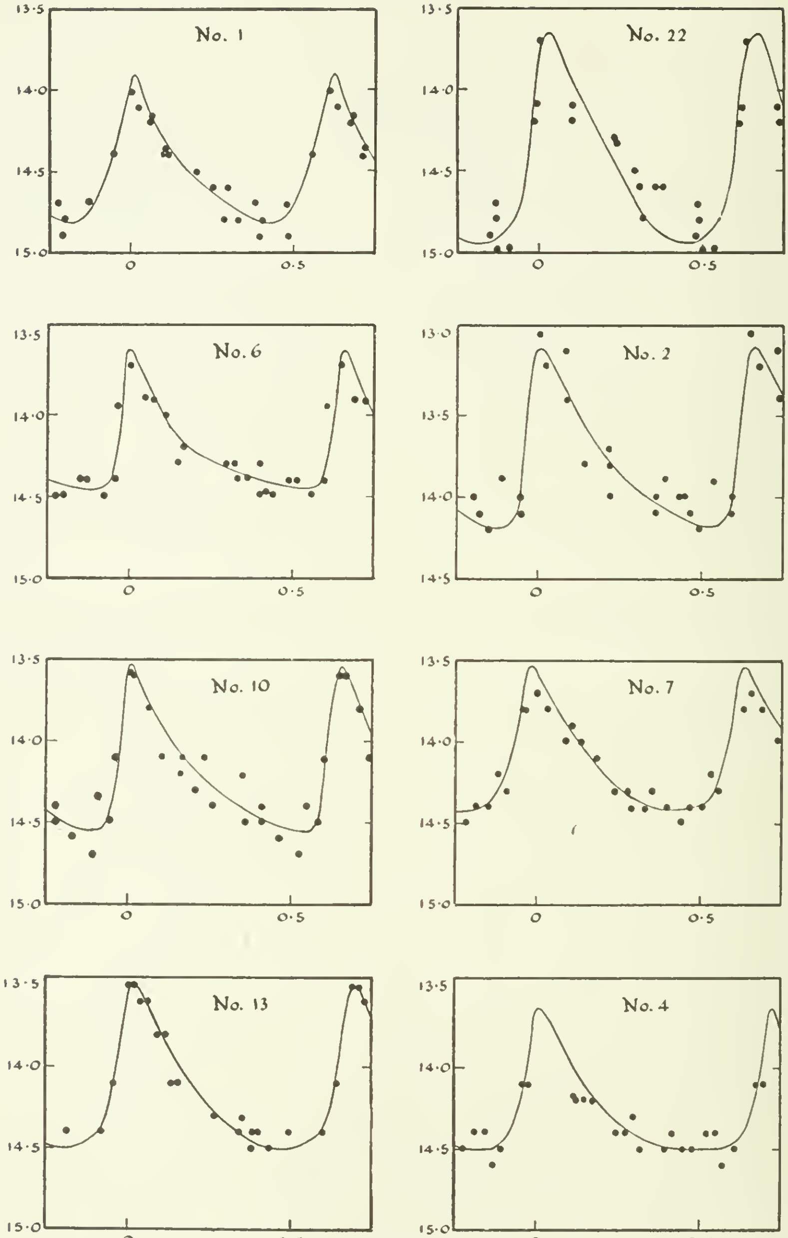

Fig. 3.—Light curves of cluster type Cepheids with periods greater than 0.6 day.

Only one variable not of the c-type shows a period change, namely No. 2, with period 0.6418 day, whose magnitudes are somewhat brighter than those of the other variables because a second component contributes light to the system. This period change is not so well confirmed as those of the c-type variables because a fixed period of 0.641789 days fits almost all the observations.

The value of the modulus of the cluster, uncorrected for absorption, as determined from the average mean magnitude of the cluster type variables (excluding Nos. 2 and 3) is 14.17. This agrees excellently with the modulus of 14.1 determined by Shapley 17 years ago. In computing the distance, however, there will be an absorption correction for this cluster as it is on the edge of a region of obscuration. The colour excess of Stebbins and Whitford[8] is 0.19; there are no nebulae in the field but the star count is normal.

Summary

1. From a study of plates taken at the Steward Observatory, eight new variables have been found in Messier 22.

2. Periods have been checked and determined for 22 variables. One is a long-period Cepheid which falls on the period luminosity relationship. One is a long-period variable, two are semi-regular variables and eighteen are cluster type.

3. The cluster type Cepheids show a remarkable frequency distribution of periods. No periods fall between 0.43 and 0.61 day.

4. The short-period cluster type Cepheids, whose periods lie between 0.32 and 0.38 day, all give evidence of period change, while, with one exception, the variables whose periods are longer than this show no such change.

5. The modulus of the cluster, 14.17, derived from the mean magnitude of the cluster type variables, confirms Shapley's modulus, giving a distance of 6800 parsecs, uncorrected for absorption.

References

(1) Sawyer, *Pub. D.D.O.*, v. 1, no. 12, 1942.
(2) Bailey, *H.A.*, v. 38, 1902.
(3) Bailey, *Pop. Astr.*, v. 28, p. 518, 1920.
(4) Shapley, *H.B.*, no. 848, 1927.
(5) Chevalier, *Ann. Zô-Sè Obs.*, 10 C, 1918.
(6) Bailey, *H.A.*, v. 78, pt. 3, 1919.
(7) Sawyer, *J.R.A.S.C.*, v. 37, pp. 295-302, (Comm. D.D.O. no. 11), 1944.
(8) Stebbins and Whitford, *Ap. J.*, v. 84, p. 141, 1936.

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