PUBLICATIONS OF
THE DAVID DUNLAP OBSERVATORY
UNIVERSITY OF TORONTO

VOLUME I NUMBER 18

# PERIODS OF VARIABLE STARS IN THE GLOBULAR CLUSTER NGC 5053

BY

HELEN B. SAWYER

1946
THE UNIVERSITY OF TORONTO PRESS
TORONTO, CANADA

# PERIODS OF VARIABLE STARS IN THE GLOBULAR CLUSTER NGC 5053

By Helen B. Sawyer

THE globular cluster NGC 5053 is a loose globular cluster in high galactic latitude, with very low intrinsic luminosity. With an absolute magnitude of only $-5.3$,[1] this cluster ranks near the bottom of the luminosity scale of globular clusters, the only cluster of lower luminosity being NGC 7492, of absolute magnitude $-4.7$. Its concentration class is XI,[2] its galactic latitude and longitude are $+78°$ and $310°$. At R.A. $13^h\ 39^m.0$, Dec. $+17°\ 57'$ (1950) it is well placed for observation in the northern hemisphere.

## A. Variable Stars.

In 1927 Baade[3] announced the discovery of nine variable stars in this object, and published estimates of their magnitudes on 37 plates, taken mostly with the 1-metre Hamburg reflector. A plate of the cluster identifying the variables and sequence stars is given in his paper. From the behaviour of the variables on these plates, he assumed that they were all cluster type variables, with a mean median magnitude of 16.19, but he determined no periods.

An accumulation of 64 plates taken by the writer with the 74-inch David Dunlap reflector over the past nine years provides material for intensive investigation of the variables in this cluster. For telescopic assistance in taking these plates, I am indebted to Dr. F. S. Hogg, Mr. Gerald Longworth, and Miss Ruth Northcott.

Numerous pairs of plates were searched systematically with the blink microscope, but only one new variable was detected, No. 10, at $x = +94''$, $y = +56''$, on Baade's co-ordinate system.

The magnitude sequence as determined by Baade was used, and the variables estimated twice on each plate. Periods have now been determined for all ten variables, all of which were found to be of the cluster type. For most of the variables, the same period satisfies both the series of observations by Baade (which are not republished in this paper) and those of Sawyer. There is a separation of about ten years between these two series. For two variables, there is real evidence for a period change in this interval. And for one other variable, five isolated, early, scattered observations by Baade are

TABLE I.

OBSERVATIONS OF VARIABLE STARS IN NGC 5053

| Plate | Julian Day | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3285 | 29076.610 | 16.1 | 16.35 | 16.2 | 15.9 | 16.35 | 16.35 | 16.1 | 16.45 | 16.1 | 16.2 |
| 3298 | 77.620 | 16.5 | 16.15 | 16.0 | 16.2 | 16.0 | 16.35 | 16.05 | 16.05 | 16.45 | 16.15 |
| 3312 | 78.618 | 16.2 | 16.35 | 16.4 | 15.95 | 16.35 | 16.25 | 16.3 | 16.2 | 16.4 | 16.4 |
| 3327 | 79.631 | .. | 16.45 | 16.3 | 16.3 | 16.1 | 16.35 | 16.5 | 16.45 | 16.35 | 16.4 |
| 5696 | 785.639 | 16.6 | 16.45 | 15.95 | 15.75 | 16.25 | 16.3 | 16.4 | 16.25 | 16.2 | 16.5 |
| 5707 | 86.625 | 16.3 | 16.05 | 16.5 | 16.3 | 16.15 | 16.15 | 16.4 | 16.05 | 16.3 | 16.2 |
| 5710 | .672 | 16.35 | 16.1 | 16.4 | 16.55 | 15.9 | 16.35 | 16.3 | 16.35 | 16.5 | 16.05 |
| 5721 | 87.621 | 16.45 | 16.45 | 16.45 | 15.65 | 16.4 | 16.6 | 16.2 | 16.05 | 16.4 | 16.2 |
| 6833 | 30169.622 | 16.0 | 16.35 | 16.5 | 16.4 | 16.5 | 16.0 | 16.2 | 16.5 | 16.4 | 16.4 |
| 6844 | 70.631 | 16.4 | 16.2 | 16.3 | 15.85 | 15.95 | 16.25 | 16.3 | .. | 16.2 | 16.1 |
| 7854 | 519.640 | 15.9 | 16.35 | 15.8 | 16.45 | 16.2 | 16.3 | 16.25 | 16.4 | 16.4 | 16.2 |
| 7856 | .677 | 15.95 | 16.4 | 16.0 | 16.45 | 16.3 | 16.15 | 16.3 | 16.5 | 16.4 | 16.2 |
| 7869 | 20.642 | 16.35 | 16.0 | 16.5 | 16.3 | 16.5 | 16.35 | 16.1 | 16.1 | 16.0 | 16.2 |
| 7871 | .678 | 16.45 | 16.15 | 16.45 | 15.95 | 16.5 | 16.35 | 16.2 | 16.15 | 16.05 | 16.35 |
| 7988 | 55.617 | 16.5 | 16.3 | 16.5 | 16.1 | 16.45 | 16.0 | 16.35 | 16.45 | 16.15 | 16.2 |
| 7990 | .640 | 16.55 | 16.45 | 16.5 | 16.2 | 16.35 | 16.1 | 16.25 | 16.65 | 16.25 | 16.3 |
| 8007 | 56.611 | 16.05 | 15.95 | 16.45 | 16.45 | 15.95 | 16.55 | 16.2 | 16.2 | 16.45 | 16.35 |
| 8010 | .635 | 16.05 | 15.9 | 16.45 | 16.55 | 15.95 | 16.45 | 16.25 | 16.25 | 16.45 | 16.4 |
| 8803 | 880.610 | 16.5 | 16.05 | 16.4 | 16.5 | 16.15 | 16.3 | 15.9 | 16.05 | 16.3 | 16.2 |
| 8806 | .638 | 16.45 | 15.95 | 16.3 | 16.3 | 16.1 | 16.3 | 16.1 | 16.1 | 16.3 | 16.0 |
| 8809 | .676 | 16.25 | 16.1 | 16.0 | 16.45 | 16.35 | 16.3 | 16.1 | 16.3 | 16.35 | 16.1 |
| 8812 | .706 | 15.8 | 16.25 | 15.95 | 16.3 | 16.4 | 16.45 | 16.3 | 16.5 | 16.35 | 16.2 |
| 8815 | .745 | 15.8 | 16.35 | 16.0 | 16.4 | 16.45 | 16.4 | 16.4 | 16.55 | 16.35 | 16.4 |
| 8829 | 83.612 | 16.35 | 16.05 | 16.15 | 15.8 | 16.3 | 16.4 | 16.25 | 16.4 | 16.35 | 16.1 |
| 8832 | .647 | 16.45 | 15.95 | 15.9 | 15.9 | 16.4 | 16.5 | 16.3 | 16.5 | 16.4 | 16.0 |

TABLE I *Continued*

OBSERVATIONS OF VARIABLE STARS IN NGC 5053

| Plate | Julian Day | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8838 | 30884.637 | 15.8 | 16.5 | 16.45 | 16.55 | 16.25 | 16.15 | 16.3 | 16.25 | 16.55 | 16.2 |
| 8841 | .665 | 15.9 | 16.4 | 16.4 | 16.5 | 16.1 | 16.2 | 16.35 | 16.35 | 16.5 | 16.3 |
| 8844 | .697 | 15.95 | 16.35 | 16.5 | 16.55 | 16.0 | 16.3 | 16.4 | 16.35 | 16.55 | 16.4 |
| 8848 | .738 | 16.05 | 16.05 | 16.5 | 16.5 | 16.05 | 16.45 | 16.35 | 16.5 | 16.4 | 16.4 |
| 8889 | 99.620 | 16.1 | 16.1 | 16.15 | 15.7 | 16.5 | 16.15 | 15.95 | 16.4 | 16.05 | 16.4 |
| 8898 | .705 | 16.2 | 16.3 | 16.0 | 15.9 | 15.95 | 16.45 | 16.25 | 16.45 | 16.1 | 16.3 |
| 8914 | 30900.617 | 16.5 | 16.35 | 16.5 | 16.45 | 16.3 | 16.4 | 16.05 | 16.35 | 16.4 | 16.2 |
| 8924 | .720 | 16.4 | 15.9 | 16.55 | 16.5 | 16.4 | 16.05 | 16.0 | 16.55 | 16.4 | 16.25 |
| 10100 | 1257.665 | 16.45 | 16.0 | 16.55 | 16.45 | 16.5 | 16.5 | 16.3 | 16.35 | 16.35 | 16.2 |
| 10106 | 58.633 | 16.25 | 16.5 | 16.2 | 16.0 | 16.05 | 16.1 | 16.05 | 16.05 | 15.9 | 16.5 |
| 10109 | .667 | 15.7 | 16.5 | 16.35 | 16.15 | 16.15 | 16.05 | 16.2 | 16.1 | 15.95 | 16.45 |
| 10114 | .722 | 15.8 | 16.5 | 16.45 | 16.3 | 16.2 | 16.3 | 16.35 | 16.35 | 16.2 | 16.45 |
| 10122 | 59.608 | 16.35 | 16.15 | 15.85 | 16.45 | 16.4 | 16.25 | 15.95 | 16.5 | 16.25 | 16.35 |
| 10127 | 646 | 16.55 | 16.2 | 15.9 | 16.5 | 16.4 | 16.45 | 15.9 | 16.3 | 16.45 | 16.4 |
| 10131 | .692 | 16.55 | 16.3 | 16.0 | 16.55 | 16.5 | 16.5 | 16.15 | 16.0 | 16.45 | 16.45 |
| 12034 | 969.630 | 16.5 | 16.55 | 16.5 | 15.8 | 16.45 | 16.3 | 16.5 | 16.45 | 16.45 | 16.4 |
| 12035 | .638 | 16.4 | 16.35 | 16.4 | 15.85 | 16.4 | 16.15 | 16.3 | 16.4 | 16.45 | 16.4 |
| 12037 | .680 | 16.5 | 16.1 | 16.5 | 15.8 | 16.4 | 16.25 | 16.25 | 16.5 | 16.45 | 16.3 |
| 12038 | .688 | 16.45 | 15.95 | 16.4 | 15.95 | 16.3 | 16.3 | 16.15 | 16.4 | 16.4 | 16.15 |
| 12040 | .708 | 16.45 | 16.0 | 16.45 | 16.0 | 16.4 | 16.4 | 16.2 | 16.4 | 16.5 | 16.2 |

TABLE I *Continued*

OBSERVATIONS OF VARIABLE STARS IN NGC 5053

| Plate | Julian Day | No. 1 | No. 2 | No. 3 | No. 4 | No. 5 | No. 6 | No. 7 | No. 8 | No. 9 | No. 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12041 | 31969.715 | 16.4 | 15.9 | 16.45 | 16.1 | 16.5 | 16.3 | 16.15 | 16.3 | 16.5 | 16.15 |
| 12056 | 70.610 | 15.75 | 16.3 | 15.9 | 16.45 | 15.8 | 16.55 | 16.15 | 16.15 | 16.6 | 16.1 |
| 12057 | .619 | 15.75 | 16.3 | 16.0 | 16.5 | 15.9 | 16.6 | 16.3 | 16.15 | 16.45 | 16.2 |
| 12060 | .660 | 15.8 | 16.45 | 16.0 | 16.35 | 15.9 | 16.35 | 16.3 | 16.25 | 16.35 | 16.0 |
| 12061 | .669 | 15.8 | 16.3 | 16.15 | 16.35 | 15.95 | 16.4 | 16.3 | 16.25 | 16.3 | 16.15 |
| 12064 | .710 | 16.0 | 16.45 | 16.3 | 16.2 | 15.95 | 16.05 | 16.5 | 16.55 | 16.15 | 16.2 |
| 12066 | .725 | 16.0 | . | 16.15 | . | . . | 16.05 | . | . . | . . | 16.2 |
| 12105 | 76.607 | 16.2 | 16.15 | 16.1 | 16.3 | 16.35 | 16.1 | 16.2 | 16.3 | 16.2 | 16.3 |
| 12108 | .629 | 16.25 | 16.2 | 16.2 | 16.35 | 16.4 | 16.2 | 16.3 | 16.3 | 16.15 | 16.2 |
| 12112 | .667 | 16.4 | 16.25 | 16.3 | 16.4 | 16.35 | 16.35 | 16.4 | 16.05 | 16.0 | 16.2 |
| 12114 | .695 | 16.35 | 16.3 | 16.4 | 16.45 | 16.4 | 16.4 | 16.4 | 16.1 | 16.15 | 16.25 |
| 12131 | 77.603 | 16.55 | 16.3 | 16.4 | 15.7 | 16.4 | 16.5 | 16.2 | 16.5 | 16.3 | 16.15 |
| 12134 | .643 | 16.4 | 16.05 | 16.0 | 15.9 | 16.4 | 16.4 | 16.3 | 16.4 | 16.4 | 16.1 |
| 12139 | .692 | 16.3 | 16.05 | 15.85 | 16.1 | 16.05 | 16.3 | 16.25 | 16.45 | 16.45 | 16.2 |
| 12322 | 2001.642 | 16.4 | 16.1 | 16.45 | 16.4 | 16.4 | 16.05 | 16.0 | 15.95 | 16.45 | 16.1 |
| 12324 | .656 | 16.4 | 16.05 | 16.5 | 16.5 | 16.4 | 16.1 | 16.0 | 16.0 | 16.5 | 16.1 |
| 12341 | 05.657 | 15.95 | 16.2 | 16.1 | 15.85 | 15.85 | 16.4 | 15.95 | 16.25 | 16.2 | 16.3 |
| 12342 | .665 | 16.05 | 16.2 | 16.1 | 15.95 | 15.95 | 16.45 | 15.95 | 16.2 | 16.3 | 16.3 |
| 12360 | 06.624 | 16.4 | 16.4 | 16.5 | 16.45 | 16.3 | 16.35 | 16.35 | 16.5 | 16.5 | 16.3 |
| 12363 | .656 | 16.5 | 16.35 | 16.4 | 16.5 | 16.3 | 16.0 | 16.1 | 16.5 | 16.55 | 16.4 |

not well represented by a period which suits all the other observations.

Table I contains the observations of the variables on the David Dunlap plates. Table II gives the elements of the variables as derived from these observations in conjunction with those of Baade. The light curves are represented by the individual observations in figures 1 and 2. Baade's observations have been represented in separate curves.

For this cluster, the longest cluster type period is 0.74 day, and the shortest is 0.29 day. The average range of these ten variables

TABLE II

ELEMENTS OF VARIABLE STARS IN NGC 5053

| Var. | Magnitude Max. | Min. | Mean | Epoch of Maximum | Period d |
|---|---|---|---|---|---|
| 1 | 15.8 | 16.6 | 16.2 | 30519.640 | 0.647178 |
| 2 | 15.9 | 16.5 | 16.2 | 30556.611 | 0.378953 |
| 3 | 15.8 | 16.6 | 16.2 | 30519.640 | 0.592946 |
| 4 | 15.7 | 16.6 | 16.15 | 29787.621 | 0.400585 |
| 5 | 15.8 | 16.6 | 16.2 | 29786.672 | 0.416868 |
| 6 | 16.0 | 16.6 | 16.3 | 30555.617 | 0.292198 |
| 7 | 15.9 | 16.5 | 16.2 | 30880.610 | 0.351581 |
| 8 | 15.8 | 16.6 | 16.2 | 30520.642 | 0.362842 |
| 9 | 15.9 | 16.6 | 16.25 | 30520.642 | 0.74173 |
| 10 | 16.0 | 16.5 | 16.25 | 29077.620 | 0.30354 |

REMARKS TO TABLE II

Var. 4. A double star; Baade did not publish his observations and the period depends solely on those of Sawyer.

Var. 5. The early isolated observations by Baade are omitted from the light curve as they do not harmonize with the rest.

Var. 6. The shortest period derived in this cluster.

Var. 7. The one Mt. Wilson observation is omitted from the light curve.

Var. 8. Definitely a changing period. Baade's observations are plotted with the same epoch, but with a period of 0.362852. $\beta$ for this star is $-12 \times 10^{10}$. The early observations by Baade are omitted from the curve.

Var. 9. The longest period in the cluster, and apparently increasing in length. Baade's observations are represented by the elements Maximum = 24976.456 + 0.74169 E. The value of $\beta$ here is $48 \times 10^{10}$. Martin found large positive values of $\beta$ around this length of period. The five early observations of Baade are omitted. A great deal of work was done in an attempt to find a shorter, related period for this star, but the value around 0.74 best represents the observations.

Var. 10. No observations by Baade, so the period is determined solely from Sawyer's observations.

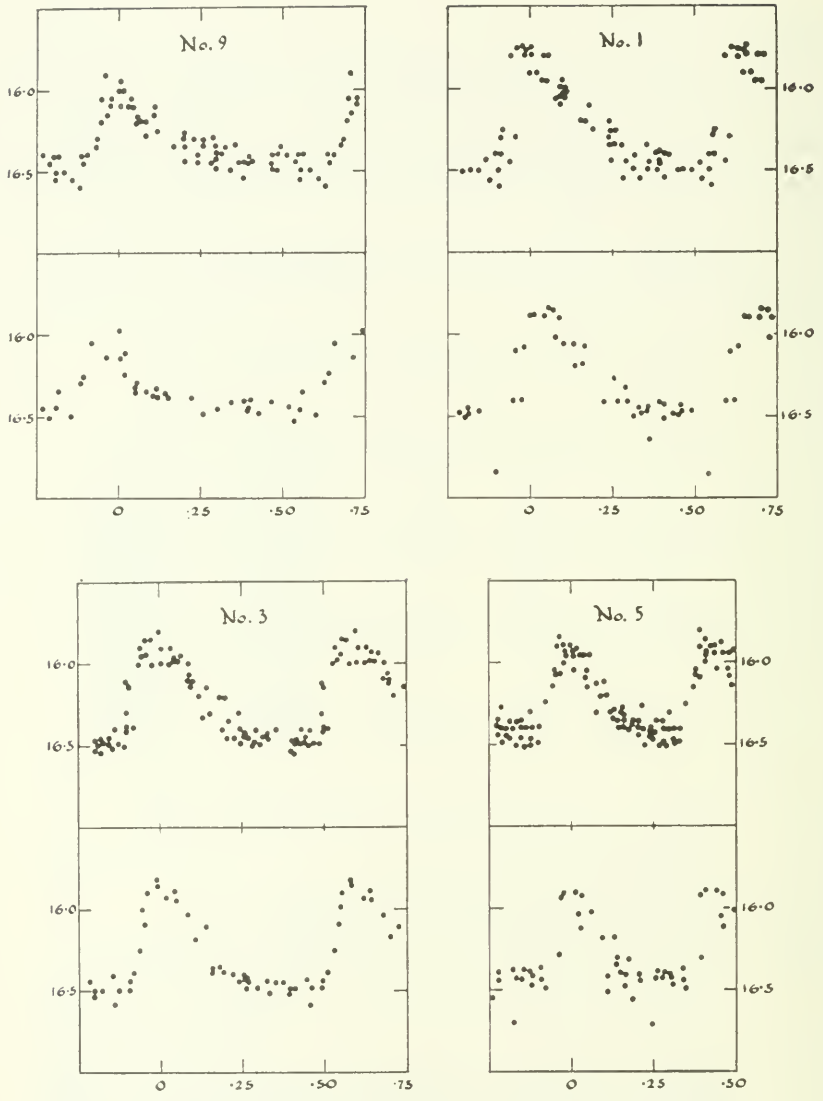


Fig. 1. Light curves of the longer period cluster type variables in NGC 5053, with periods from 0.74 day to 0.41 day. The upper curve for each variable represents observations by Sawyer, the lower, a series made a dozen years earlier by Baade.

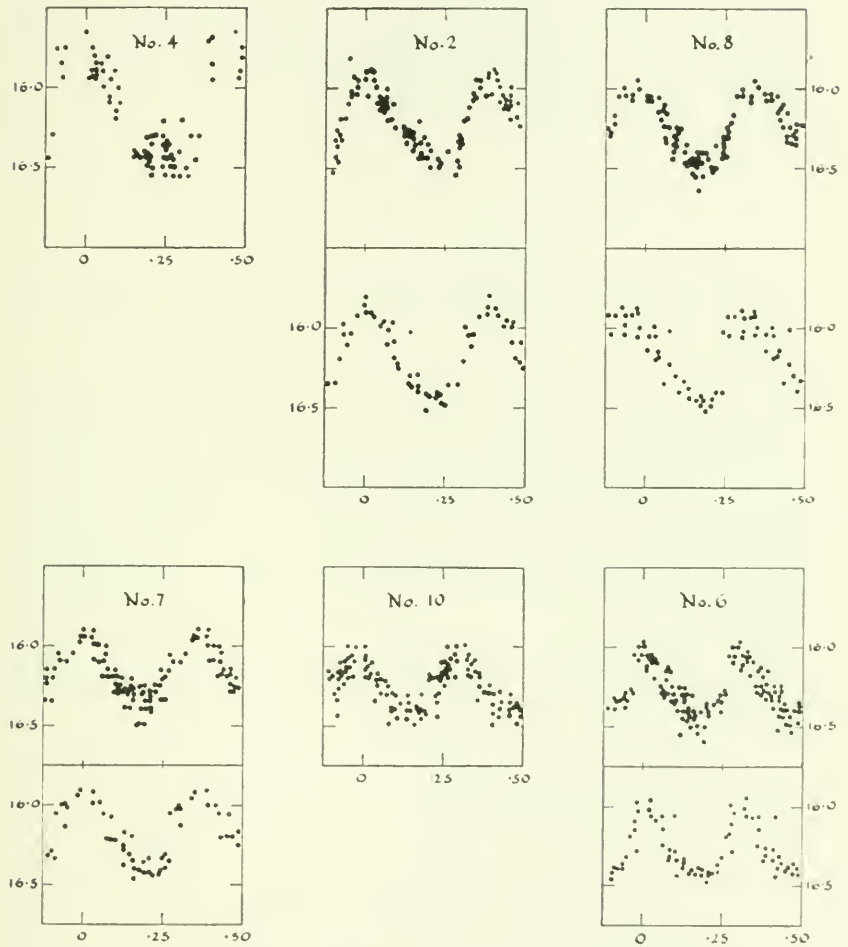


Fig. 2. Light curves of the shorter period variables in NGC 5053, with periods from 0.40 day to 0.29 day. For variables Nos. 4 and 10, no observations by Baade were available.

is rather small, being only 0.7 magnitude. In regard to period frequency, this cluster is another of the double maximum type discussed by the writer,[4] with an avoidance of periods close to half a day. In this case, however, as shown in figure 3, the majority of periods lie in the one-third of a day region.

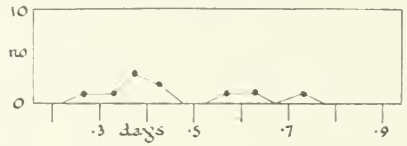


Fig. 3. The frequency distribution of periods in NGC 5053, intervals of 0.05 day.

B. Variable Stars in Relation to Colour-Magnitude Diagram

This cluster is important as a testing-ground for the relation between variable and non-variable stars, since Cuffey[5] has determined the colour-magnitude diagram for it. Schwarzschild,[6] Cuffey, and Baade,[7] have pointed out that the cluster type variables in globular clusters lie in a definite region of the colour-magnitude diagram, and that most of the stars in this region tend to be variable.

With the 36-inch Link reflector, Cuffey made a photometric survey of this cluster, and obtained magnitudes and red colour indices for 155 stars in it. The colour-magnitude diagram was found to be characteristic for a globular cluster, although unusual in that one of the fainter branches extends toward red stars, though he points out that this trend might be changed by observational evidence a magnitude or two fainter.

Cuffey found the nine variable stars to be closely grouped together at the beginning of the faint blue branch, near apparent red photographic magnitude 15.6, and red colour-index 0.7. In and around this same colour magnitude region were fourteen stars not known to be variable. Cuffey lacked sufficient plates to confirm or deny the variability of these.

The writer has estimated these stars on all of her plates, from an identification chart kindly provided by Dr. Cuffey. The stars lying in this critical region of the colour-magnitude diagram are, according to numbers in Cuffey's unpublished catalogue: 68, 15, 81, 90, 101, 118, 148, 156, and 158. No. 68 proved to be the same as

Variable No. 10 which had been independently found by the writer with the blink microscope. Other stars close to the region, which Cuffey suggested as possible variables are: 21, 25, 33, 131, and 146.

Accordingly the magnitudes of these 14 stars were estimated once by the writer on each of 62 plates; the extreme points for the stars were then estimated a second time. The result was somewhat surprising. Not a single one of these stars (apart from the known Var. No. 10) proved to be variable in the sense of having a range large enough to conclude variability. For eleven of these stars, the estimates on 62 plates have a maximum spread of only 0.2 magnitude per star. For one of them, there is one point which gives a spread of 0.3 magnitude. And for the remaining one, No. 158, the estimates have a spread of 0.4 magnitude, with three points over the 0.2 magnitude interval. A star of comparable magnitude, presumed non-variable, was estimated along with the possible variables. The estimates on this star gave a spread of 0.3 magnitude, just one point being over the 0.2 magnitude interval. On the other hand, the estimates of the variable of smallest range, No. 10, have a spread of 0.5 magnitude, with 16 points outside a 0.2 magnitude interval. The distribution of the estimates for these stars is given in Table III.

TABLE III

FREQUENCY OF RECORDED MAGNITUDES FOR CUFFEY'S POSSIBLE VARIABLES ON 62 PLATES

| Star | 16.1 | 16.2 | 16.3 | 16.4 | 16.5 | Star | 16.0 | 16.1 | 16.2 | 16.3 | 16.4 | 16.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 1 | 27 | 34 | | | 21 | | 13 | 34 | 15 | | |
| 81 | | 13 | 38 | 11 | | 25 | | 6 | 44 | 12 | | |
| 90 | | | 14 | 37 | 11 | 33 | | | 3 | 39 | 20 | |
| 101 | | | 22 | 38 | 2 | 131 | | | 16 | 36 | 10 | |
| 118 | | 1 | 37 | 24 | | 146 | | | 6 | 28 | 28 | |
| 148 | | 8 | 24 | 30 | | 68 | 4 | 6 | 19 | 12 | 14 | 7 |
| 156 | 1 | 12 | 38 | 11 | | non- | | | 4 | 11 | 40 | 7 |
| 158 | 2 | 15 | 33 | 10 | 2 | var. | | | | | | |

It would appear then that a star in a globular cluster can have the same colour and magnitude as the cluster type variables and not vary its light by an appreciable amount. This is contrary to the

findings of Schwarzschild in Messier 3 where he concluded "In the color-magnitude diagram of Messier 3 the region occupied by the variables does not seem to contain non-variables, which indicates that stars which can pulsate do pulsate."

Of course a variation whose total range is not more than 0.2 magnitude cannot be ruled out for these stars from the existing observations.

C. Distance of Cluster.

Since Baade's magnitude sequence was employed, the modulus of the cluster as determined from the median magnitudes of the variables should be expected to agree closely with Baade's value. Such proves to be the case. The median magnitude of the ten cluster type variables as determined by the writer is 16.23, with an average deviation of only 0.04 magnitude. The median magnitude of seven variables as determined by Baade was 16.19. Shapley[1] used a modulus of 16.2 in his most recent determination of the distances of high latitude clusters. This gives a distance of the cluster of about 17 kiloparsecs, in excellent agreement with Cuffey's distance of $16 \pm 2$ kiloparsecs as determined from the colour magnitude diagram. Any absorption correction may be neglected for this cluster, since there is an absence of colour excess as well as an excess in the numbers of extragalactic nebulae in nearby fields.

This cluster is noteworthy for its very large distance of about 55,000 light years above the galactic plane, as well as for its very low luminosity. Its luminosity and appearance are in marked contrast to the adjacent cluster NGC 5024, which is a close neighbour in space, but of much higher intrinsic luminosity.

References

1. Shapley, P.N.A.S., v. 30, pp. 61-68, 1944.
2. Shapley and Sawyer, H.B., no. 869, 1929.
3. Baade, Ham. Mitt., v. 6, p. 92, 1927.
4. Sawyer, J.R.A.S.C., v. 37, pp. 295-302 (Comm. D.D.O. no. 11), 1944.
5. Cuffey, Ap. J., v. 98, pp. 49-53, 1943.
6. Schwarzschild, H.C., no. 437, 1940.
7. Baade, Ap. J., v. 100, p. 144, 1944.

Richmond Hill, Ontario
October 31, 1946.