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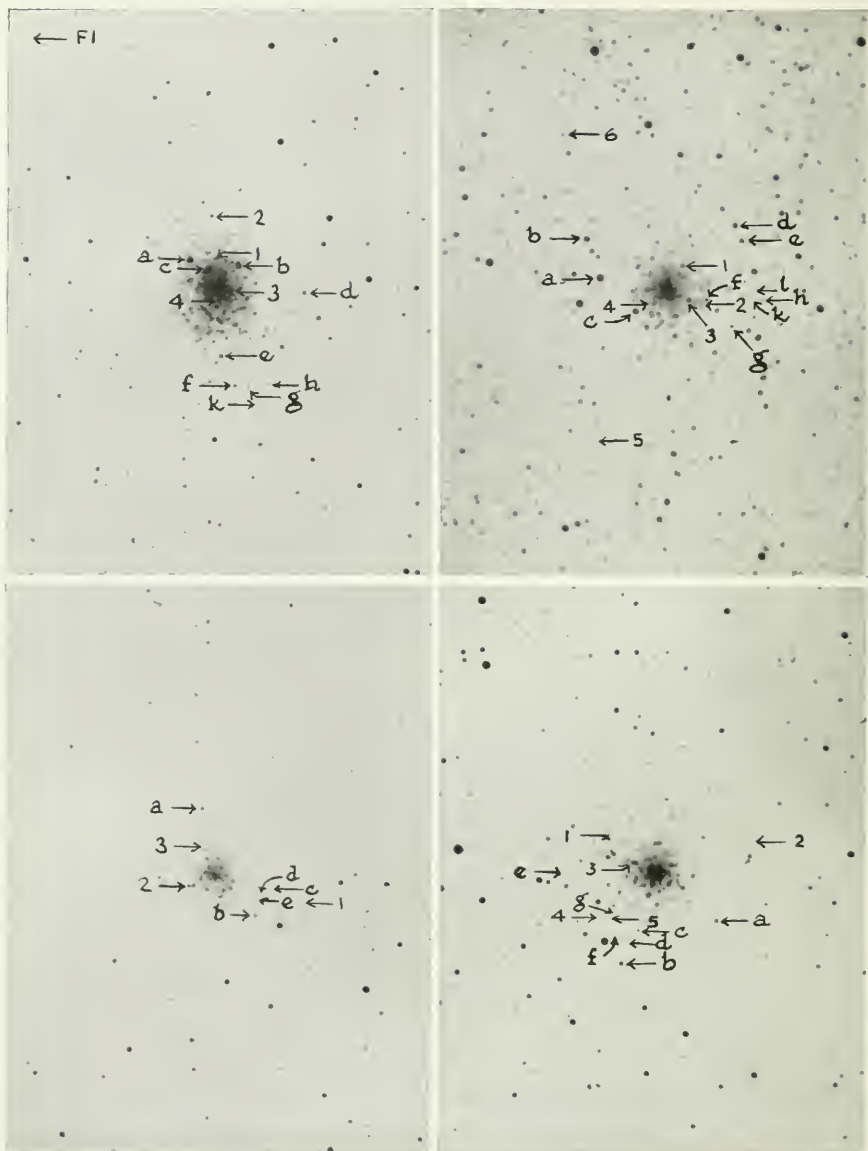
NEW VARIABLE STARS IN FOUR  
GLOBULAR CLUSTERS IN  
OPHIUCHUS

BY  
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Upper left, NGC 6273  
Lower left, NGC 6287

Upper right, NGC 6284  
Lower right, NGC 6293

Scale, 13" per mm. 3.5 × enlargement from Steward Observatory photographs of 20 min. exposure on 6273 and 6293, 30 min. on 6284 and 6287. NGC 6273 is the most elliptical globular cluster; NGC 6287 very heavily obscured.

## NEW VARIABLE STARS IN FOUR GLOBULAR CLUSTERS IN OPHIUCHUS

by HELEN B. SAWYER

THIS is the second<sup>1</sup> in a series of papers from plates taken by the writer at the Steward Observatory with the 36-inch reflector in 1939. This paper deals with four difficult objects which have previously been studied very little. These are the highly elliptical cluster NGC 6273 (Messier 19) and three exceedingly faint objects, NGC 6284, 6287 and 6293. These comprise a group of consecutive clusters in Shapley's catalogue<sup>2</sup> of globular clusters. In spite of their faintness they have been known for many years, since they were noted originally by Sir William Herschel. Only one of these clusters, NGC 6293, has been searched for variables;<sup>3</sup> and in none of them is there a record of the magnitudes of the bright stars.

All four of these clusters are very difficult objects for a scale as small as that of the 36-inch, that is, about 45'' to the millimetre. Furthermore, the high southern declinations of the objects, all of which lie between  $-22^\circ$  and  $-26^\circ$ , make them hard objects to photograph from the United States and render magnitude determination uncertain. Nevertheless the writer felt that a little knowledge might be gleaned where none existed before. At least half a dozen plates, and one sequence plate, were obtained on each cluster. These have been studied carefully in the blink microscope. Twenty-seven new variables have been found, of which fifteen are within the cluster boundaries and twelve in the surrounding field.

The magnitudes of the 25 brightest stars, including the 6th and 30th, have also been determined. It must be emphasized that since the magnitudes depend on only one sequence plate for each cluster, with a second exposure on Selected Area 132, the magnitudes must be considered as preliminary.

1. *NGC 6273 = Messier 19*, R.A.  $16^h 59^m.5$ , Dec.  $-26^\circ 11'$  (1950). This cluster is noteworthy as having the greatest degree of ellipticity (6 on a scale of 10) of any globular cluster so far estimated.<sup>4</sup> Even on small scale photographs it is strikingly elongated. It is much the brightest of this group of four clusters and shows many more stars than the others on photographs of compar-

able exposure time. Twelve plates with average exposure of twenty minutes were available for a survey. There is no previous record of a variable search in this object.

Six variables were found, of which four are fairly close to the cluster centre and two are some distance from it. The positions and magnitudes of the variables and the comparison stars are given in Table I. For this cluster and the subsequent three, the positions

TABLE I

NEW VARIABLE STARS IN NGC 6273							
No.	x''	y''	Max.	Min.	Remarks		
1	+ 4	+ 48	14.1	15.1			
2	+ 14	+ 123	13.4	14.7			
3	- 28	- 6	14.2	15.2			
4	- 2	- 24	15.1	15.7			
F <sub>1</sub>	+ 347	+ 421	15.2	16.0	16 <sup>h</sup> 55 <sup>m</sup> 20 <sup>s</sup> .5	-25° 58'.0*	
F <sub>2</sub>	+ 546	+1119	15.3	[16.0	16 55 35.2	-25 46.4	

COMPARISON STARS							
	x''	y''	m		x''	y''	m
a	+ 50	+ 40	12.6	f	- 38	- 179	14.5
b	- 36	+ 34	13.0	g	- 62	- 181	15.1
c	+ 16	+ 28	13.7	h	- 95	- 173	15.3
d	- 153	- 8	14.1	k	- 83	- 208	15.7
e	- 12	- 127	14.4				

\*R.A., Dec., epoch 1875.

of those variables which are so far from the cluster centre that they are probably field stars have been measured from the nearest C.P.D. star and right ascensions and declinations derived. In Figure 1 will be found sketches of the regions sufficient to identify these field variables. Plate XXIX shows the cluster with the cluster variables marked.

Variables 1 and 2 should prove rather interesting objects since at maximum they are among the four brightest stars in the cluster region and their variations change the entire appearance of the cluster. Naturally the twelve available observations are insufficient to determine the nature of variation but these variables are possibly long-period Cepheids. Since there is a good series of observations which will help in future period work, these are published in Table II, which gives the magnitude estimates of the variables on all

these plates. The sequence plate was of twenty minutes' exposure on the cluster, and twenty minutes on S.A. 132.

Because of the importance of the ellipticity of the cluster, the stars in the cluster region were counted on the best plate. Shapley,<sup>5</sup> in 1919, published a diagram of the ellipticity, but without the

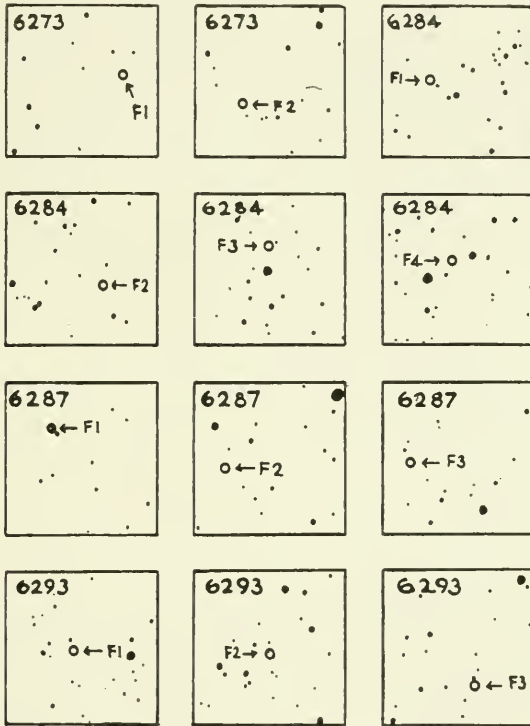


FIGURE 1

Charts to aid in identification of new field variables.  
Positions are given in tables.

numbers of stars. The writer has counted a total of 910 stars within a rectangular reseau placed centrally on the cluster, in squares of 20".156 to the side. These stars were then recounted according to sector by a circular protractor, a method followed in other clusters by Pease and Shapley.<sup>6</sup> A total of 805 stars fell within the circle of radius 200". The plate was counted twice,

reversed by  $180^\circ$  between the two counts. The means of the two counts are given in Table III; and Figure 2 shows the frequency of stars per  $30^\circ$  sector in the squares counted ( $20''.156$  to a side). The position angle of the major axis is  $15^\circ$ , which is the value previously determined by Shapley.

2. *NGC 6284*, R.A.  $17^h 01^m.5$ , Dec.  $-24^\circ 41'$  (1950). This is an inconspicuous cluster in a heavy background of stars. Only about a hundred cluster stars show on plates of half-hour exposure. Eight such plates were available.

In a search of these plates ten new variable stars have been found, of which five are so far from the cluster centre that they are probably not members of it. All of these variables are faint. Table IV gives the position of the variables and their maximum

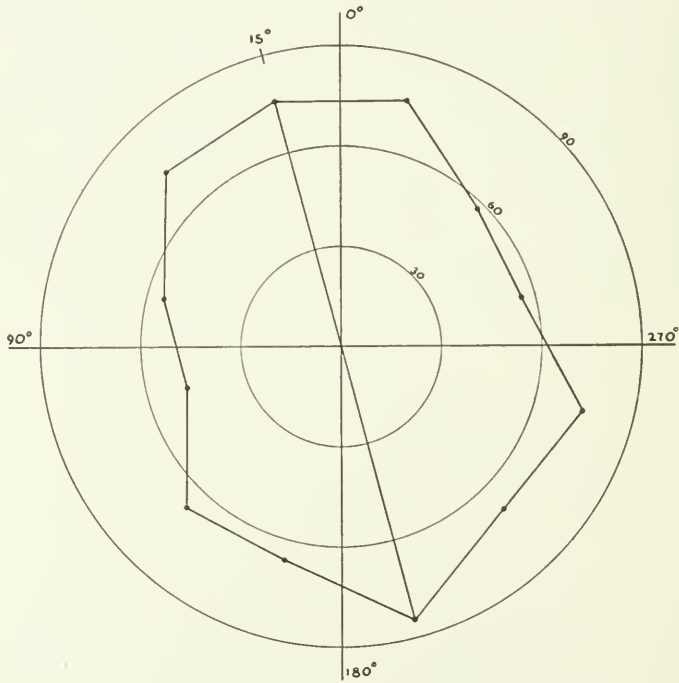


FIGURE 2

Diagrams of number of stars counted in thirty degree sectors in *NGC 6273*, the most elliptical of globular clusters. Numbers on the circles indicate numbers of stars. The position angle of the major axis is  $15^\circ$ .



TABLE II  
MAGNITUDES OF NEW VARIABLES IN NGC 6273

Plate	Julian Day	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
4193	9403.882	14.2	14.3	14.3	....	15.9	15.5
4194	.899	14.2	14.2	14.3	....	16.0	15.4
4208	05.888	14.1	14.5	....	....	15.7	15.5
4224	06.876	14.2	14.5	14.2	....	15.8	15.5
4236	07.886	14.5	14.7	14.5	....	16.0	[16.0
4249	08.876	14.5	14.6	14.5	15.2	15.5	15.4
4264	09.865	14.5	14.1	15.2	15.4	15.7	15.9
4275	11.868	15.0	13.4	14.5	15.1	15.2	15.3
4287	22.827	14.4	14.6	14.5	15.7	15.9	15.4
4324	27.821	15.1	13.5	15.1	15.6	15.2	15.5
4420	36.833	14.1	14.6	14.5	15.6	15.6	15.5
4456	39.739	14.2	13.7	14.5	15.7	15.4	15.5

TABLE III  
TABLE OF STAR COUNTS IN NGC 6273

Pos. Ang.	No. Stars	Stars/Sq.	Pos. Ang.	No. Stars	Stars/Sq.
15°	76	3.20	195°	85	3.32
45	74	2.93	225	69	2.95
75	55	2.20	255	75	3.00
105	48	1.98	285	56	2.26
135	67	2.58	315	58	2.50
165	66	2.68	345	76	2.81

and minimum magnitudes. The variables are marked on Plate XXIX for identification. The plates are too few in number to give any indication as to the nature of variability.

3. *NGC 6287*, R.A. 17<sup>h</sup> 02<sup>m</sup>.1, Dec. -22° 38' (1950). This is one of the most heavily obscured of all visible globular clusters. It lies on the edge of a region in Ophiuchus where the total photographic absorption as determined by Baker and Kiefer<sup>7</sup> is at least three magnitudes. The cloud which hangs over this region is apparently one end of the streamers from the Rho Ophiuchi region. Seven plates were available, of thirty minutes' exposure time, but fewer than fifty cluster stars show on any plate, even though stars to magnitude 17.5 are visible. A very large telescope is certainly needed to penetrate the obscuration in front of this cluster.

Six variable stars have been found, of which three are so far from the centre of the cluster that they are doubtless field stars.

TABLE IV

## POSITIONS OF VARIABLE STARS IN NGC 6284

No.	x''	y''	Max.	Min.	Remarks		
1	- 24	+ 36	15.6	16.1			
2	- 47	- 17	16.1	17.0			
3	- 28	- 13	15.3	15.7			
4	+ 22	- 18	15.4	16.3	Following comp. of double		
5	+ 109	- 205	16.4	17.0			
6	+ 139	+ 221	15.9	16.4			
F <sub>1</sub>	+ 553	+ 151	15.7	16.5	16 <sup>h</sup> 57 <sup>m</sup> 30 <sup>s</sup> .8	-24° 32'.5*	
F <sub>2</sub>	- 149	- 560	16.1	16.6	16 56 39 .9	-24 44 .6	
F <sub>3</sub>	+ 300	+ 926	15.4	16.4	16 57 11 .5	-24 19 .6	
F <sub>4</sub>	+ 356	+ 723	16.0	16.4	16 57 15 .8	-24 23 .0	

## COMPARISON STARS

	x''	y''	m		x''	y''	m
a	+ 93	+ 21	13.5	f	- 54	- 14	15.7
b	+ 111	+ 76	14.4	g	- 89	- 52	16.2
c	+ 46	- 26	14.6	h	- 131	- 15	16.4
d	- 96	+ 90	15.2	k	- 117	- 13	16.9
e	- 104	+ 66	15.5	l	- 112	- 4	17.2

\*R.A., Dec., epoch 1875

TABLE V

## NEW VARIABLE STARS IN NGC 6287

No.	x''	y''	Max.	Min.	Remarks		
1	- 152	- 40	16.2	17.1			
2	+ 46	- 26	15.7	15.9	Although small, variation appears genuine.		
3	+ 26	+ 44	16.1	16.8	Bright on only one plate.		
S	+ 32	+ 4	16.2	17.1			
F <sub>1</sub>	+ 38	+ 641	15.7	16.1	16 <sup>h</sup> 57 <sup>m</sup> 41 <sup>s</sup> .2	-22° 21'.1*	
F <sub>2</sub>	-1027	- 10	15.1	15.8	16 56 24 .3	-22 31 .8	
F <sub>3</sub>	+ 446	- 573	16.1	17.1	16 58 10 .0	-22 41 .5	

## COMPARISON STARS

	x''	y''	m
a	+ 30	+ 113	15.4
b	- 73	- 72	15.7
c	- 99	- 20	15.9
d	- 71	- 40	16.4
e	- 62	- 48	17.1

\*R.A., Dec., epoch 1875.

A seventh possible variable is indicated, a star which has been found to be bright on only one plate, and is put down as a suspected variable. The magnitudes and positions of the variables and comparison stars are given in Table V, and the variables are marked on Plate XXIX. No clue as to the type of variation can be obtained from the few available plates.

4. *NGC 6293*, R.A.  $17^h 07^m.1$ , Dec.  $-26^\circ 30'$  (1950). This cluster is similar in brightness and appearance to *NGC 6284*. About two hundred stars are visible in it on the best Arizona photographs of twenty-five minutes' exposure. A careful search of the eight available photographs has shown only five more variables, in addition to the three previously announced by Shapley. Three of these new variables are so far from the cluster centre that they are doubtless field stars and are numbered as such. The positions of the variables, measured to conform as nearly as possible to the published positions of Shapley's three, are given in Table VI,

TABLE VI  
VARIABLE STARS IN *NGC 6293*

No.	x''	y''	Max.	Min.	Remarks		
1	+ 81.0	+ 49.5	15.9	16.6	Found by Shapley		
2	- 135.6	+ 64.5	15.8	16.7	" " "		
3	+ 48.6	+ 18.6	15.5	15.8	" " "		
4	+ 92	- 81	16.1	17.1			
5	+ 78	- 83	15.7	16.5			
F <sub>1</sub>	- 390	- 349	16.2	16.9	17 <sup>h</sup> 2 <sup>m</sup> 57 <sup>s</sup> .4	-26° 31'.1*	
F <sub>2</sub>	- 395	+ 463	15.8	16.9	17 2 55.5	-26 17.6	
F <sub>3</sub>	-1142	- 413	15.5	16.2	17 0 59.0	-26 32.1	

COMPARISON STARS

	x''	y''	m		x''	y''	m
a	- 110	- 96	15.0	e	+ 162	- 15	16.2
b	+ 52	- 161	15.1	f	+ 70	- 108	16.6
c	+ 24	- 101	15.5	g	+ 68	- 72	17.1
d	+ 47	- 124	15.7				

\*R.A., Dec., epoch 1875.

together with the observed maximum and minimum magnitudes. The magnitudes are determined from one sequence plate, exposed for twenty minutes on the cluster, and twenty minutes on S.A. 132. The variables are identified in Plate XXIX. No conspicuous variation was found in Shapley's Variable No. 3, but the object blurs

with a nearby star. The number of plates is insufficient to tell the nature of the variability of these stars but the similarity of magnitudes and small ranges suggest cluster type.

5. The Moduli of the Four Clusters. The distance moduli of these four clusters have previously depended entirely on measures of the integrated magnitudes and diameters<sup>8</sup> as no indication has been given of the brightness of the cluster stars themselves. It was hoped that the discovery of variable stars in these clusters would be of use in determining a modulus; but the variables are too few to be of help until their periods are determined. Measures of the bright stars have been made for all four clusters and these have been reduced by the method previously adopted<sup>8</sup> to give a distance modulus. Table VII gives the observed magnitudes for the mean

TABLE VII  
MODULI OF THE FOUR CLUSTERS

NGC	Gal.	No.	Obs. Mag.		25 Br.	6th	30th	Modu- lus	D kpc*
	Lat.	Vars.	Max.	Min.					
6273	9°	4	13.4	15.7	14.80	14.4	15.1	15.93	15.3
6284	9	6	15.3	17.0	16.06	15.7	16.4	17.17	27.2
6287	10	3	15.7	17.1	16.08	15.9	16.4	17.33	29.2
6293	9	5	15.5	17.1	15.39	15.1	15.6	16.67	21.6

\*Uncorrected for absorption.

of the 25 brightest stars, and the 6th and the 30th. The magnitudes of the variables in the cluster are given merely for comparison purposes. In each case, the maximum is that observed for the brightest variable; and the minimum is the faintest minimum observed for any variable.

It will be noted that the variables are much more comparable in brightness with the bright stars than is usual for most clusters. In most clusters, the median magnitude of the variables, which are preponderantly cluster type, is at least a magnitude fainter than the mean of the 25 brightest stars. The explanation may be that only the brightest variables, possibly long-period Cepheids or field stars, have been found in these objects; and that the cluster type variables still lie beyond the reach of these plates. One would expect that NGC 6273 is bright enough so that the cluster type variables would have been found; but it may not have many.

The moduli of the clusters are large, especially for NGC 6284 and 6287. They are all remarkably similar to the moduli previously determined from the integrated magnitudes and diameters. The distances corresponding to these moduli are given in the last column of the table, but these are almost certainly far from the true distances as these clusters are all in a region of absorption.<sup>7</sup> That the clusters are all in an obscured region is shown by the colour excesses of Stebbins and Whitford<sup>9</sup>, which range from +0.12 for NGC 6293 to +0.34 for NGC 6287. The absorption varies rapidly from spot to spot in this region and may amount to as much as three magnitudes. Indeed, NGC 6287, the cluster farthest from the galactic plane of this group of four, is certainly the one with the greatest obscuration.

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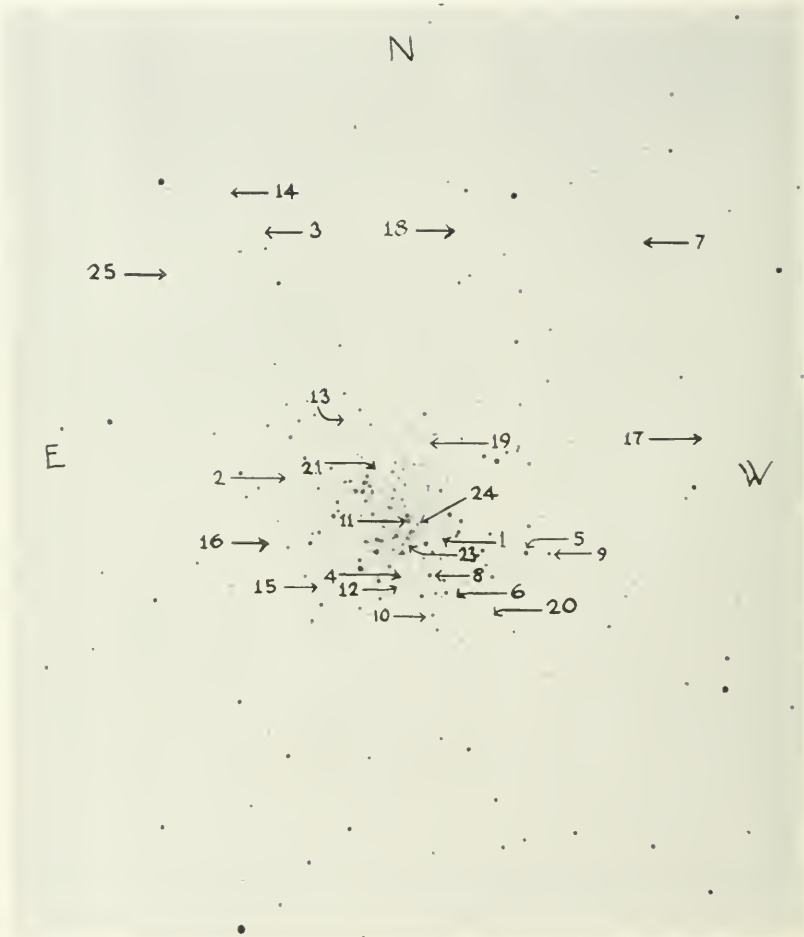
Richmond Hill, Ontario

May 7, 1943.





PLATE XXX



The globular cluster Messier 22, with variable stars identified. Enlargement 4X from Steward Observatory plate 4410, June 20, 1939, exp. 10 min. Scale, 1 mm = 10".8.