

NGC 5466*

JAMES CUFFEY

Goethe Link Observatory, Indiana University

(Received December 5, 1960)

The well-resolved globular cluster NGC 5466 is shown to have a color-magnitude relation resembling those of M3 and other clusters of very different physical structure. The distance modulus 16.56 and the distance 20.5 kpc are derived. Absorption appears to be negligible. In the analysis of the plate residuals the 18 previously known variables are displayed conspicuously. A list of additional high-residual stars for future investigation as possible variables is given in the text. Three of them are definitely variables, and 22, suspects. The space distribution of the globular clusters north of galactic latitude 50° is discussed in order to test the hypothesis that the clusters form a physical group, rather than a random sample of the halo population of the Milky Way system. The evidence suggests this may be the case, but does not conclusively establish it. Improvements in the distances for some of the objects are still needed to obtain the true relationship of these objects to each other and to the Milky Way system.

1. INTRODUCTION

AN unusually interesting high-latitude globular cluster with an extremely open, well-resolved structure, NGC 5466 was described by Shapley (1930) as a "loose globular cluster," like NGC 7492 and NGC 5053; he listed its concentration class as XII. Christie (1940) determined its integrated photographic apparent magnitude to be 10.39. Baade (1926) and Sawyer (1945) found a total of 18 variable stars. The present study, undertaken in 1953, is part of a survey presenting improved information on the globular clusters north of 50° galactic latitude, and examining the relationship of the clusters M3, M53, NGC 5053, NGC 5466, and MGC 4147 to each other and to the Milky Way (Cuffey 1954).

TABLE I. NGC 5466, photoelectric standards.

Star	<i>P</i>	<i>V</i>	<i>P-V</i>	Wt.	
BD 29° 2483	8.20	8.18	+0.02	10	A2
BD 29° 2493	7.98	7.05	+0.93	2	K0
A	14.38	14.02	+0.36	5	
B	14.81	14.19	+0.62	11	
C	16.60	16.87	-0.27	3	
D	18.52	18.02	+0.50	5	
E	16.93	16.31	+0.62	8	
F	14.18	13.94	+0.24	11	
G	15.03	13.91	+1.12	1	
1-4-12	15.80	15.41	+0.39	2	
4-3-1	16.82	16.50	+0.32	1	

Photometric results for NGC 5466 obtained by combining photoelectrically measured standard stars and photographic iris photometer measures are presented here. Photoelectric magnitudes for the standard stars, obtained with a refrigerated 1P21 photometer and the 100-inch Mt. Wilson reflector, are summarized in Table I. They were reduced to the *P, V* system represented in the photoelectric magnitudes determined by W. A. Baum for stars in Selected Areas 57 and 68. I am indebted to Dr. Baum for his permission to use these

* Publications of the Goethe Link Observatory, Indiana University, No. 43.

values in advance of publication. A similar system by Eggen (1955) was used for reduction of zero-point observations made photoelectrically with the 36-inch reflector of the Goethe Link Observatory. The filters used with both telescopes were similar in transmission properties to those used by the *B, V* system of Johnson and Morgan. Thus the magnitudes in Table I may be expected to differ from the *B, V* system mainly by the difference in zero point between the *P* and *B* magnitude systems. It is likely that the photometric system adhered to in the present paper is related to the *B, V* system by the formula suggested by Baum,

$$B - V = 0.92(P - V) + 0.16,$$

although no extensive effort was made to derive the relation independently.

Offset guiding was used in measuring the faintest stars. Four one-minute deflections of star plus sky, along with four similar deflections on sky alone comprise a single observation of unit weight in Table I.

TABLE II. NGC 5466, Plate material 100-inch Mt. Wilson reflector.

	No.	Aperture (inches)	Exposure (minutes)	Date (1953)	Quality
Blue series	H18C	58	45	Apr. 12	exc.
	31	84	40	Apr. 14	exc.
	35	84	40	May 3	good
	38	84	10	May 3	good
	47	84	40	May 4	exc.
	62	58	44	May 6	fair
	64	58	60	May 7	good
	67	58	60	May 7	good
	68	58	60	May 7	fair
Yellow series	H17C	58	60	Apr. 12	exc.
	30	84	40	Apr. 14	exc.
	32	84	35	Apr. 14	exc.
	36	84	40	May 3	good
	37	84	10	May 3	good
	48	84	40	May 4	exc.
	54	84	25	May 4	good
	61	58	60	May 6	exc.
	65	58	60	May 7	exc.
	66	58	60	May 7	exc.
	69	58	38	May 7	poor

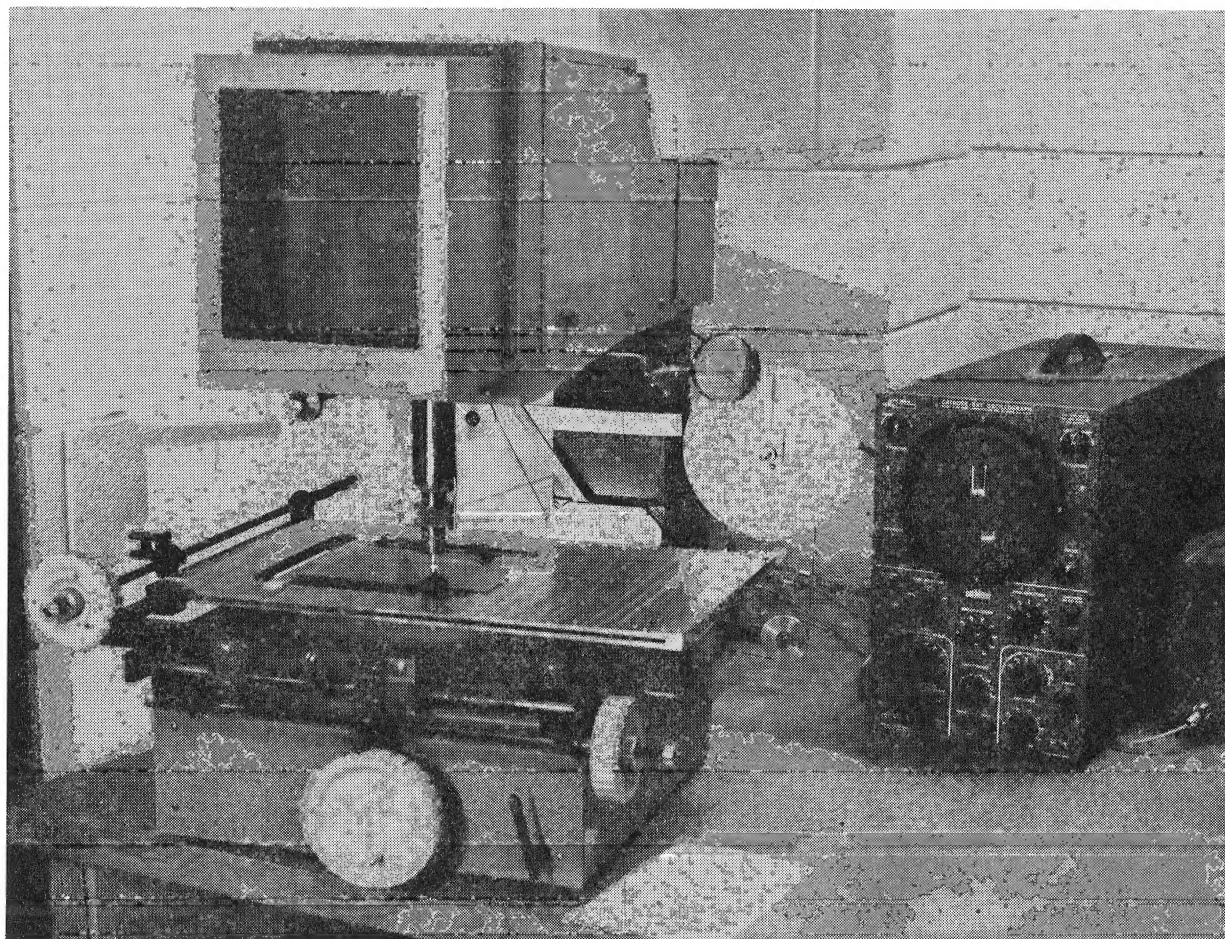


FIG. 1. Iris photometer, Indiana University.

The photographic observations, summarized in Table II, consist of a series of plates taken with the 100-inch reflector at the Mt. Wilson Observatory by the author as guest investigator in 1953. Diaphragms of 84 and 58 inches aperture were used in order to minimize field errors and improve the image quality for better resolution. The yellow plates were Eastman Spectroscopic 103aD, exposed through a GG 14 filter cutting off wavelengths shorter than 5000 Å. The blue plates were Eastman Spectroscopic IIaO exposed with a WG 2 filter to eliminate ultraviolet light beyond 3600 Å. A GG 13 filter, which cuts off the ultraviolet beyond 3800 Å was used in the photoelectric work, and in some additional photographic calibrations with the 36-inch telescope at the Goethe Link Observatory.

Figure 1 shows the iris photometer used for measuring the photographic plates. Designed by the author and built in the Astronomy Department machine shop at Indiana University by Marion Todd, it resembles an instrument described previously (Cuffey 1956). Improvements included a larger viewing screen, and specially built iris which gave a closer approach to linearity in the reduction curves for the fainter stars

than did the commercial iris used in the original model.

The form of the calibration curves for the iris photometer was established by measurements of 100-inch reflector plates of SA57 and 68, and plotting iris reading against the photoelectric magnitudes. The 16 plates listed by Cuffey (1958) were used. In general, the reduction curves are very smooth and resemble those of Fig. 2 in the above reference, but with improved linearity for the fainter stars. Since the general nature of the iris reading-magnitude relation was obtained from this study, adequate numbers of stars for the photographic reduction curves were easily obtained by interpolation between the photoelectric standards. Results summarizing the complete data adopted for the photographic standard stars are given in Table III. Magnitudes and colors of stars in NGC 5466 are listed in Table IV. The star charts, Figs. 2 and 3, show the method used for star designation. A pattern of four sectors and five concentric rings is superimposed upon the cluster. To illustrate, the designation 2-3-17 refers to the star 17 in sector 2 of ring 3 in Fig. 2. Figure 3 shows the central region, ring 1, only. Probable errors of the catalogued values are in Table V and are based

upon analysis of plate residuals to be discussed later in Sec. 3, Table VIIIA.

2. THE COLOR-MAGNITUDE RELATION

The color-magnitude relation for NGC 5466, shown in Figs. 4 and 5, closely resembles the corresponding relations in M3 (Sandage and Johnson 1956) and M53

(Cuffey 1958), a fact which is extremely interesting in view of the unusually open, sparsely populated structure of NGC 5466 compared with the highly concentrated very richly populated structures of M3 and M53. The 18 known variable stars, indicated by the circled points, all occur on the horizontal branch. The red-giant branch, and the branch containing the blue stars are

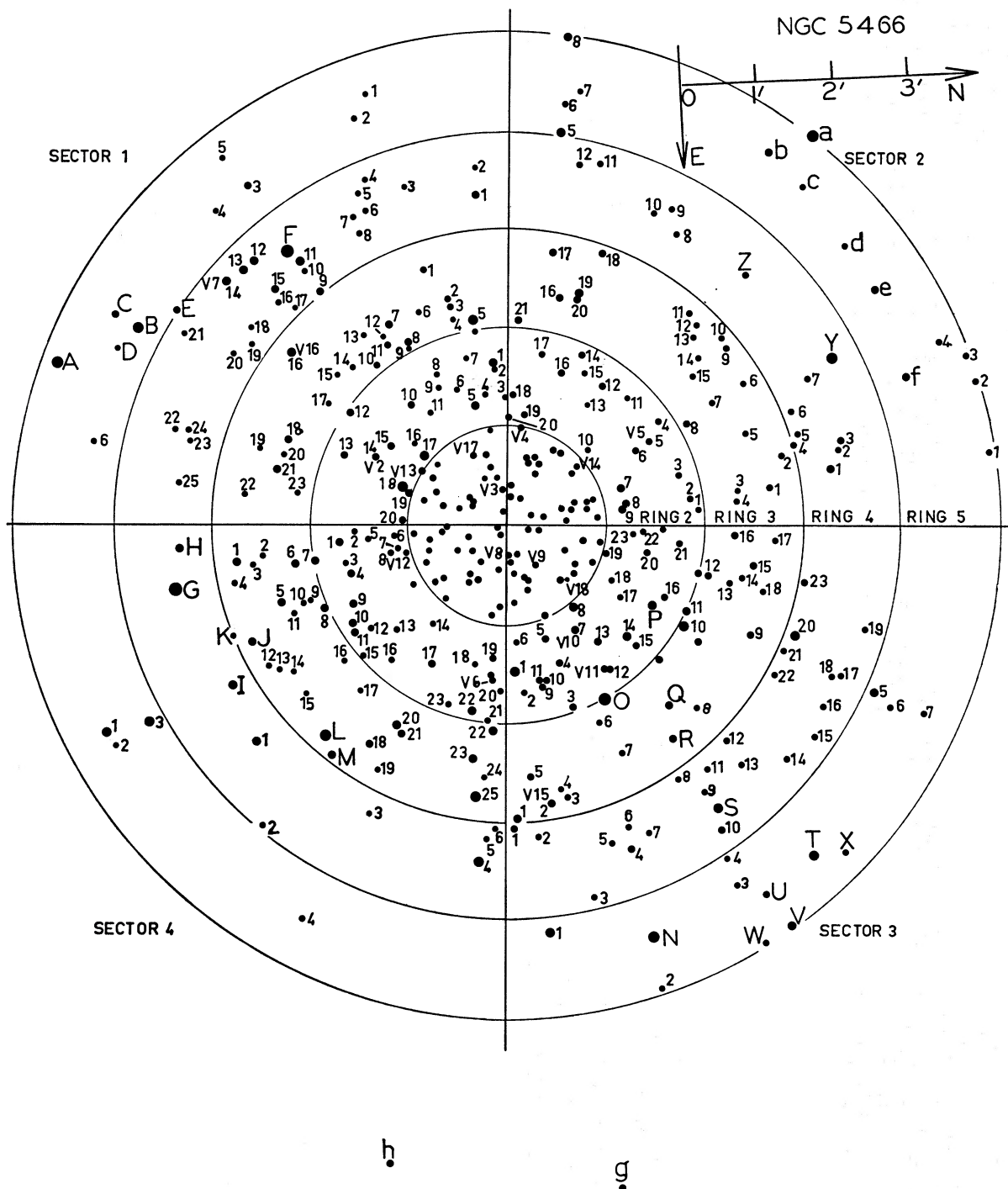


FIG. 2. NGC 5466, star chart.

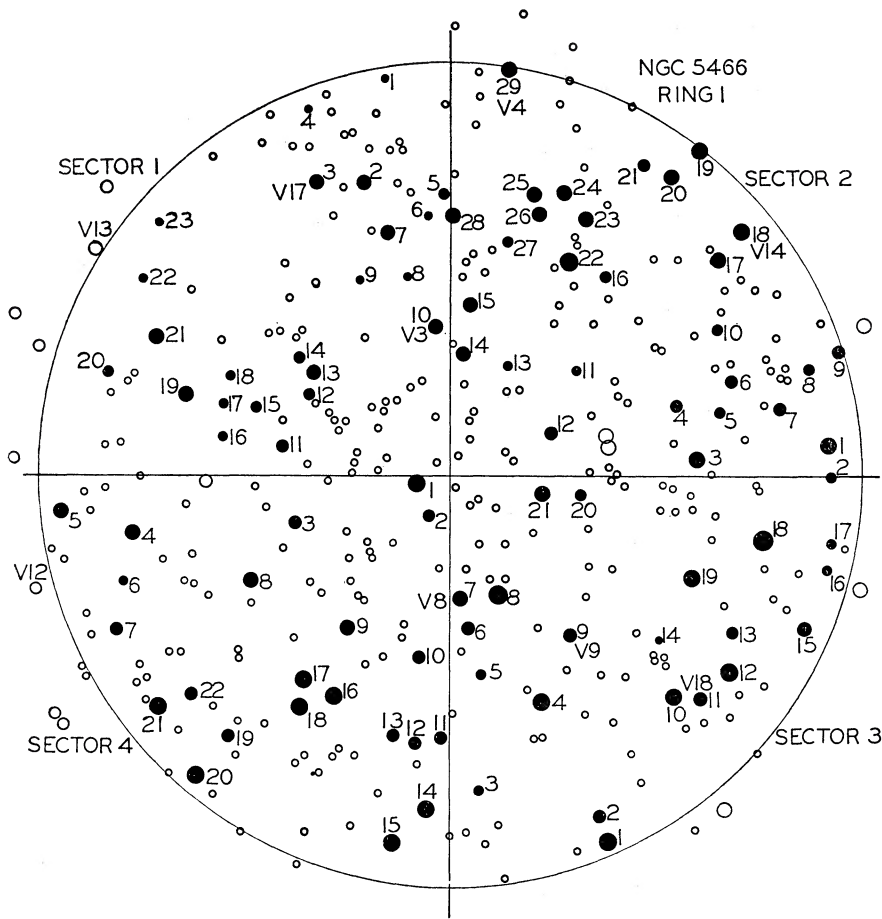


FIG. 3. NGC 5466, chart of central region only.

very well defined. One extremely blue star, 3-4-12, with the color index -0.49 is present, and resembles the very blue stars found by Sandage in M3. Fainter than $V=18.2$ the photometric results are based upon

extrapolation of the sequences, and open circles are plotted to indicate their tentative nature. The open squares show observations of the integrated colors of small areas between individually distinguishable images

TABLE III. NGC 5466, standard stars.

No.	<i>P</i>	<i>V</i>	<i>P</i> - <i>V</i>	No.	<i>P</i>	<i>V</i>	<i>P</i> - <i>V</i>
A ^a	14.43	14.05	+0.38	V	16.25	15.00	+1.25
B ^a	14.81	14.19	+0.62	W	17.80	17.51	+0.29
C ^a	16.66	16.88	-0.22	X	18.54	18.00	+0.54
D ^a	18.55	18.04	+0.51	Y	15.15	14.11	+1.04
E ^a	16.86	16.21	+0.65	Z	18.07	17.56	+0.51
F ^a	14.31	14.06	+0.25	a	14.93	13.68	+1.25
G ^a	14.96	13.63	+1.33	b	17.59	17.11	+0.48
H	16.65	16.80	-0.15	c	19.62	18.61	+1.01
I	16.37	15.72	+0.65	d	19.17	18.25	+0.92
J	16.72	17.03	-0.31	e	17.22	16.53	+0.69
K	18.61	18.06	+0.55	f	16.97	16.34	+0.63
L	14.67	14.76	-0.09	g	14.35	13.24	+1.11
M	18.25	17.80	+0.45	h	16.40	15.83	+0.57
N	14.79	13.58	+1.21	1-4-12 ^a	15.84	15.47	+0.37
O	14.63	14.21	+0.42	4-3-1 ^a	16.79	16.45	+0.34
P	15.12	14.00	+1.12	1-4-9	17.75	17.35	+0.40
Q	17.02	16.41	+0.61	1-4-16	19.14	18.54	+0.60
R	16.66	16.85	-0.19	1-4-17	18.64	18.11	+0.53
S	15.62	14.79	+0.83	3-4-21	18.42	17.96	+0.46
T	15.72	15.18	+0.54	3-4-22	19.58	18.61	+0.97
U	17.22	16.76	+0.46				

^a Photoelectric standard star.

TABLE IV. NGC 5466—catalogue of stars.

No.	<i>P</i>	<i>V</i>	<i>P</i> − <i>V</i>	No.	<i>P</i>	<i>V</i>	<i>P</i> − <i>V</i>	No.	<i>P</i>	<i>V</i>	<i>P</i> − <i>V</i>
S1R1				S1R4				S2R2			
1	18.01	17.56	+ .45	1	17.33	16.78	+ .55	1	16.85	16.20	+ .65
2	16.54	16.68	− .14	2	19.13	18.63	+ .50	2	17.42	16.90	+ .52
3	16.43	16.33	+ .10	3	19.58	18.95	+ .63	3	16.92	16.28	+ .64
4	18.58	18.03	+ .55	4	18.84	18.32	+ .52	4	16.63	16.89	− .26
5	17.15	16.68	+ .47	5	18.81	18.41	+ .40	5	16.79	16.64	+ .15
6	18.27	17.84	+ .43	6	18.74	18.23	+ .51	6	17.51	17.01	+ .50
7	16.59	16.87	− .28	7	18.81	18.26	+ .55	7	16.46	16.59	− .13
8	18.03	18.21	− .18	8	19.36	18.79	+ .57	8	16.59	16.86	− .27
9	18.60	18.11	+ .49	9	17.73	17.32	+ .41	9	15.77	14.96	+ .81
10	16.65	16.62	+ .03	10	18.48	17.96	+ .52	10	17.94	17.48	+ .46
11	17.76	17.28	+ .48	11	16.61	16.78	− .17	11	18.93	18.67	+ .26
12	16.40	16.51	− .11	12	15.84	15.46	+ .38	12	15.54	14.66	+ .88
13	15.27	14.39	+ .88	13	16.20	15.42	+ .78	13	18.06	17.59	+ .47
14	16.42	16.71	− .29	14	16.69	16.62	+ .07	14	16.57	16.74	− .17
15	17.89	17.44	+ .45	15	17.63	17.11	+ .52	15	18.75	18.19	+ .56
16	18.81	18.28	+ .53	16	19.02	18.54	+ .48	16	16.54	16.74	− .20
17	18.87	18.41	+ .46	17	18.66	18.11	+ .55	17	15.72	14.97	+ .75
18	18.67	18.14	+ .53	18	19.67	19.02	+ .65	18	16.74	16.51	+ .23
19	16.07	15.31	+ .76	19	19.44	18.82	+ .62	19	17.39	16.88	+ .51
20	16.91	16.29	+ .62	20	19.36	18.76	+ .60	20	17.08	16.52	+ .56
21	16.17	15.43	+ .74	21	18.76	18.19	+ .57	S2R3			
22	17.88	17.39	+ .49	22	17.90	17.39	+ .51	1	16.63	16.85	− .22
23	19.09	18.78	+ .31	23	18.03	17.55	+ .48	2	16.44	16.07	+ .37
S1R2				24	19.39	18.76	+ .63	3	17.45	16.91	+ .54
1	16.63	16.79	− .16	25	19.52	18.87	+ .65	4	18.41	17.89	+ .52
2	18.38	17.92	+ .46	F	14.33	14.11	+ .22	5	18.19	17.69	+ .50
3	16.56	16.80	− .24	S1R5				6	18.18	17.71	+ .47
4	18.64	18.10	+ .54	1	17.62	17.27	+ .35	7	18.48	18.00	+ .48
5	15.96	15.63	+ .33	2	16.61	16.73	− .12	8	16.61	16.79	− .18
6	18.14	17.68	+ .46	3	16.69	16.91	− .22	9	17.20	16.64	+ .56
7	18.44	17.97	+ .47	4	18.84	17.79	+1.05	10	19.17	18.72	+ .45
8	18.83	18.39	+ .44	5	19.40	18.87	+ .53	11	16.61	16.80	− .19
9	17.70	17.24	+ .46	6	19.41	18.87	+ .54	12	19.16	18.64	+ .52
10	17.13	16.54	+ .59	A	14.45	14.05	+ .40	13	19.32	18.74	+ .58
11	18.55	18.06	+ .49	B	14.80	14.19	+ .61	14	18.95	18.37	+ .58
12	15.56	14.65	+ .91	C	16.65	16.87	− .22	15	18.80	18.21	+ .59
13	16.62	16.82	− .20	D	18.56	18.05	+ .51	16	16.51	16.64	− .13
14	16.69	16.56	+ .13	E	16.85	16.20	+ .65	17	16.58	16.62	− .04
15	14.85	13.56	+1.29	S2R1				18	17.62	17.14	+ .48
16	18.03	17.52	+ .51	1	16.58	16.90	− .32	19	15.37	14.42	+ .95
17	15.46	14.54	+ .92	2	18.08	17.62	+ .46	20	16.60	16.38	+ .22
18	15.38	14.51	+ .87	3	16.52	16.73	− .21	21	16.64	16.90	− .26
19	16.18	15.82	+ .36	4	17.58	17.16	+ .42	S2R4			
20	17.27	16.71	+ .56	5	17.74	17.26	+ .48	1	16.62	16.85	− .23
V 13	16.55	16.63	− .08	6	18.09	17.65	+ .44	2	19.06	18.47	+ .59
S1R3				7	17.00	16.38	+ .62	3	17.76	17.27	+ .49
1	17.99	17.52	+ .47	8	17.60	17.11	+ .49	4	16.72	16.05	+ .67
2	17.89	17.43	+ .46	9	17.50	17.01	+ .49	5	19.22	18.62	+ .60
3	18.47	18.01	+ .46	10	18.18	17.75	+ .43	6	18.15	17.67	+ .48
4	18.58	18.08	+ .50	11	17.67	17.31	+ .36	7	19.12	18.57	+ .55
5	16.56	16.70	− .14	12	17.74	17.25	+ .49	8	19.19	18.65	+ .54
6	18.10	17.61	+ .49	13	18.80	18.51	+ .29	9	19.11	18.66	+ .45
7	16.78	16.13	+ .65	14	16.70	16.37	+ .33	10	18.73	18.19	+ .54
8	16.47	16.56	− .09	15	16.30	15.66	+ .64	11	18.65	18.11	+ .54
9	18.31	17.84	+ .47	16	17.35	16.81	+ .54	12	18.86	18.40	+ .46
10	17.78	17.29	+ .49	17	16.82	16.23	+ .59	Y	15.13	14.10	+1.03
11	17.47	16.95	+ .52	18	16.46	16.35	+ .11	Z	18.10	17.61	+ .49
12	18.51	17.99	+ .52	19	16.57	16.80	− .23	S2R5			
13	18.83	18.28	+ .55	20	16.43	16.56	+ .13	1	18.69	18.05	+ .64
14	18.82	18.30	+ .52	21	17.02	16.44	+ .58	2	19.18	18.61	+ .57
15	19.12	18.58	+ .54	22	15.20	14.01	+1.19	3	19.64	18.98	+ .66
16	16.52	16.52	.00	23	16.07	15.34	+ .73	4	19.41	18.72	+ .69
17	18.99	18.51	+ .48	24	16.56	16.71	− .15	5	16.79	16.12	+ .67
18	16.37	15.93	+ .44	25	16.60	16.41	+ .19	6	17.68	17.31	+ .37
19	19.11	18.67	+ .44	26	16.45	15.76	+ .69	7	19.06	18.58	+ .48
20	18.85	18.40	+ .45	27	18.41	18.31	+ .10	8	16.31	15.87	+ .44
21	16.68	16.94	− .26	28	16.55	16.72	− .17	a	14.91	13.68	+1.23
22	19.51	18.91	+ .60	29	16.82	16.83	− .01	b	17.60	17.13	+ .47
23	18.56	18.07	+ .49								

TABLE IV. (Continued)

No.	P	V	P-V	No.	P	V	P-V	No.	P	V	P-V
c	19.29	18.66	+ .63	17	18.81	18.26	+ .55	2	17.36	16.81	+ .55
d	19.04	18.30	+ .74	18	18.79	18.26	+ .53	3	18.55	18.04	+ .51
e	17.21	16.53	+ .68	O	14.63	14.21	+ .42	4	17.56	17.06	+ .50
f	16.97	16.33	+ .64	Q	17.02	16.41	+ .61	5	18.44	17.92	+ .52
				R	16.66	16.85	- .19	6	18.94	18.44	+ .50
S3R1				S3R4				7	18.49	17.99	+ .50
1	15.83	15.00	+ .83	1	17.49	16.98	+ .51	8	16.72	16.08	+ .64
2	18.01	17.56	+ .45	2	18.50	18.03	+ .47	9	16.82	16.17	+ .65
3	18.80	18.28	+ .52	3	19.30	18.75	+ .55	10	16.63	16.86	- .23
4	15.47	14.56	+ .91	4	16.52	15.83	+ .69	11	16.25	15.68	+ .57
5	18.75	18.21	+ .54	5	18.99	18.50	+ .49	12	18.63	18.07	+ .56
6	17.89	17.43	+ .46	6	19.06	18.50	+ .56	13	18.84	18.29	+ .55
7	16.90	16.65	+ .25	7				14	18.28	17.81	+ .47
8	16.54	16.74	- .20	8	18.60	18.25	+ .35	15	18.24	17.76	+ .48
9	16.75	16.61	+ .14	9	18.70	18.14	+ .56	16	16.97	16.38	+ .59
10	15.22	14.43	+ .79	10	17.98	17.48	+ .50	17	16.13	15.39	+ .74
11	16.57	16.59	- .02	11	18.91	18.40	+ .51	18	18.62	18.10	+ .52
12	15.75	14.90	+ .85	12	17.22	17.71	- .49	19	17.06	16.48	+ .58
13	16.72	16.52	+ .20	13				20	18.11	17.65	+ .46
14	18.17	18.08	+ .09	14	19.29	18.65	+ .64	21	16.61	16.41	+ .20
15	16.71	17.02	+ .69	15	19.68			22	14.87	13.60	+ .27
16	18.29	17.83	+ .46	16	19.65	18.37	+1.28	23	18.36	17.92	+ .44
17	17.69	17.32	+ .37	17	18.73	18.20	+ .53	V 6	16.82	16.45	+ .37
18	15.12	14.38	+ .74	18	19.44	18.75	+ .69	V 12	16.58	16.68	- .10
19	16.57	16.81	- .24	19	17.97	17.81	+ .16	S4R3			
20	18.45	17.98	+ .47	20	16.61	16.85	- .24	1	16.80	16.45	+ .35
21	17.36	16.84	+ .52	21	18.41	17.92	+ .49	2	18.22	17.74	+ .48
				22	19.24	18.64	+ .60	3	19.44	18.76	+ .68
				23	18.08	17.56	+ .52	4	19.36	18.79	+ .57
				S	15.62	14.78	+ .84	5	16.69	16.97	- .28
S3R2				S3R5				6	16.61	16.86	+ .25
1	15.45	14.51	+ .94	1	16.71	16.58	+ .13	7	16.30	15.58	+ .72
2	18.51	17.99	+ .52	2	19.00	17.50	+1.50	8	17.92	17.47	+ .45
3	16.37	15.66	+ .71	3	18.95	18.37	+ .58	9	19.32	18.86	+ .46
4	17.59	17.09	+ .50	4	19.21	18.49	+ .72	10	19.67	18.90	+ .77
5	17.00	16.39	+ .61	5	16.69	16.98	- .29	11	19.02	18.44	+ .58
6	18.15	17.69	+ .46	6	19.03	18.11	+ .92	12	19.44	18.79	+ .65
7	16.78	16.54	+ .24	7	18.94	18.46	+ .48	13	19.60	18.94	+ .66
8	15.86	15.06	+ .80	N	14.79	13.57	+1.22	14	19.19	18.63	+ .56
9	16.94	16.36	+ .58	T	15.72	15.19	+ .53	15	19.46	18.87	+ .59
10	16.62	16.89	- .27	U	17.21	16.76	+ .45	16	18.91	18.39	+ .52
11	16.83	16.21	+ .62	V	16.24	15.01	+1.23	17	19.16	18.54	+ .62
12	16.74	16.08	+ .66	W	17.80	17.53	+ .27	18	15.78	14.93	+ .85
13	15.48	14.55	+ .93	X	18.52	18.02	+ .50	19	18.77	18.26	+ .51
14	17.72	17.25	+ .47	S4R1				20	15.48	14.54	+ .94
15	18.12	17.65	+ .47	1	16.58	16.72	- .14	21	16.05	15.40	+ .65
16	17.31	16.75	+ .56	2	17.60	17.12	+ .48	22	16.95	16.33	+ .62
17	18.88	18.34	+ .54	3	16.46	16.56	- .10	23	16.66	16.94	- .28
18	18.68	18.75	- .07	4	15.87	15.09	+ .78	24	19.50	18.85	+ .65
19	15.89	15.19	+ .70	5	15.50	14.67	+ .83	25	15.44	14.58	+ .86
20	16.55	16.80	- .25	6	18.89	18.39	+ .50	J	16.71	17.04	- .33
21	18.06	17.59	+ .47	7	16.99	16.36	+ .63	L	14.72	14.74	- .02
22	18.37	18.87	+ .50	8	16.39	16.02	+ .37	M	18.25	17.79	+ .46
23	18.68	17.81	+ .87	9	16.22	15.49	+ .73	S4R4			
V 11	16.75	16.69	+ .06	10	16.51	16.70	- .19	1	16.85	16.17	+ .68
P	15.11	14.00	+1.11	11	16.64	16.46	+ .18	2	18.89	18.36	+ .53
S3R3				12	16.94	16.37	+ .57	3	19.35	18.66	+ .69
1	16.79	16.11	+ .68	13	16.56	16.83	- .27	4	18.03	17.63	+ .40
2	16.61	16.59	+ .02	14	16.83	16.19	+ .64	5	19.42	18.76	+ .66
3	18.14	17.64	+ .50	15	16.52	15.82	+ .70	6	18.96	18.41	+ .55
4	18.96	18.45	+ .51	16	15.57	14.75	+ .82	G	14.95	13.63	+1.32
5	17.83	17.34	+ .49	17	16.38	15.73	+ .65	H	16.64	16.80	- .16
6	18.88	18.43	+ .45	18	16.33	15.75	+ .58	I	16.47	15.77	+ .70
7	18.64	18.09	+ .55	19	17.75	17.30	+ .45	K	18.60	18.05	+ .55
8	17.87	17.38	+ .49	20	16.70	16.07	+ .63	S4R5			
9	16.67	16.88	- .21	21	16.10	15.34	+ .76	1	16.56	15.89	+ .67
10	15.39	14.41	+ .98	22	16.97	16.46	+ .51	2	19.10	18.56	+ .54
11	16.57	15.88	+ .69	S4R2				3	16.70	16.99	- .29
12	17.48	16.97	+ .51	1	16.59	16.85	- .26	4	18.74	18.21	+ .53
13	19.12	18.53	+ .59								
14	19.42	18.84	+ .58								
15	17.21	16.64	+ .57								
16	16.60	16.84	- .24								

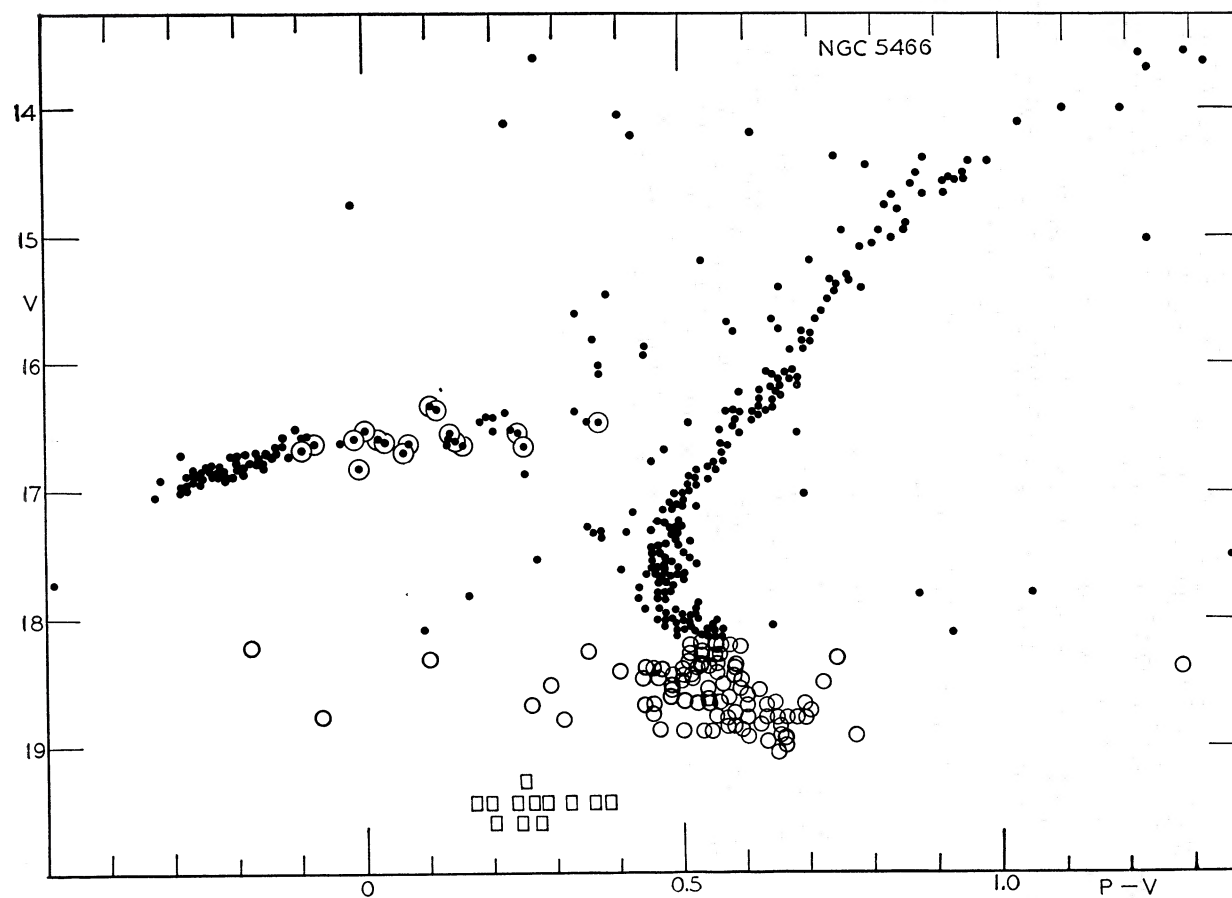


FIG. 4. NGC 5466, color-magnitude relation.

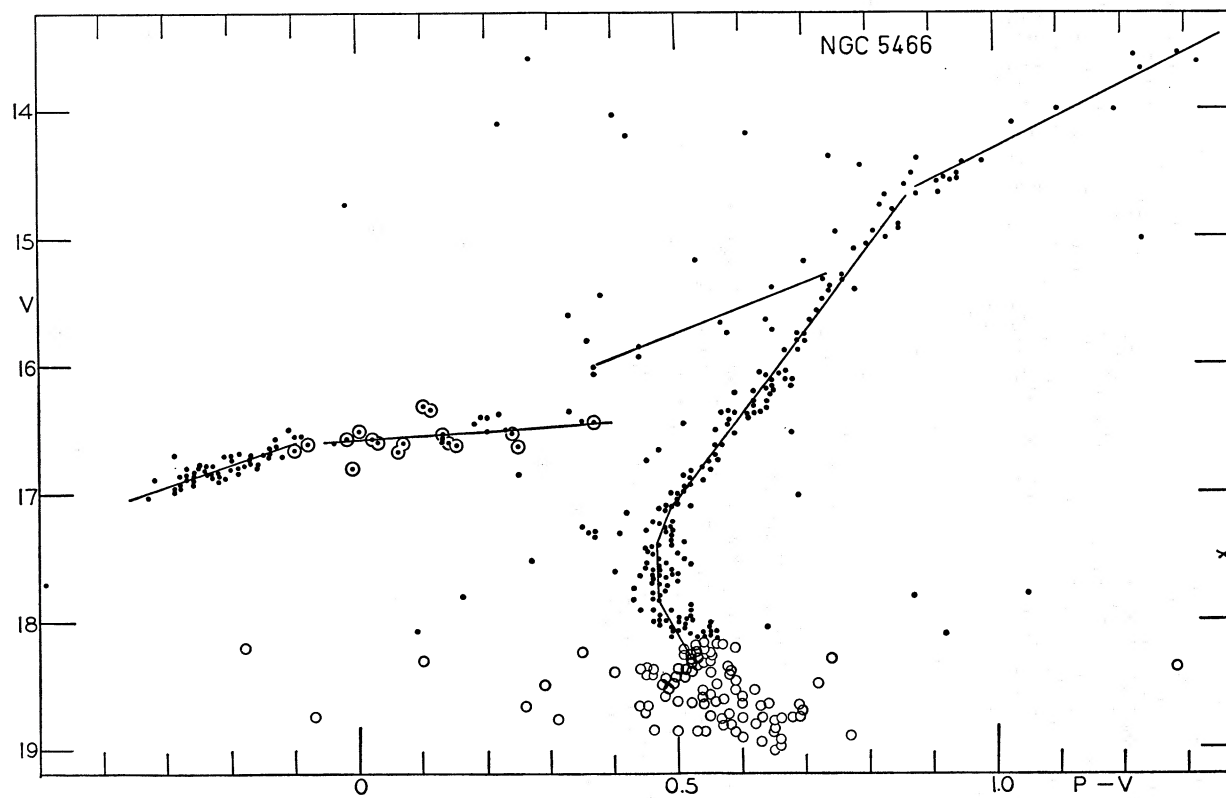


FIG. 5. NGC 5466, color-magnitude relation, with branches indicated.

TABLE V. Probable errors of catalogue magnitudes.

Magnitude interval	<i>P</i>	<i>V</i>	<i>P</i> − <i>V</i>
13.5–17.0	±0.010	±0.009	±0.013
17.0–18.2	0.011	0.012	0.016
18.2–18.7	0.016	0.013	0.021
18.7–19.7	0.028	0.019	0.034

near the cluster's nucleus. Because individual stars are difficult to observe photoelectrically fainter than the 19th magnitude, this attempt to derive integrated colors for stars fainter than those measured individually seemed of interest. Four areas near the center of the cluster in ring 1, were chosen, in which no stars bright enough for individual measurement appeared on the photographic chart. Photoelectric measures of these areas were made with several different diaphragm openings. Thus the integrated color refers to the light from a number of faint stars whose light entered the diaphragm at the same time. The results are in Table VI. First, all four areas were measured with the smallest diaphragm, whose size, when projected on the photographic chart, assured that no light from individually visible images entered the diaphragm. Next, two of the areas were observed with successively larger diaphragms, only the largest of which might have been suspected of including light from individually distinguishable images. The average integrated color of

TABLE VI. Photoelectric integrated colors of areas containing very faint stars only.

Area	Diaphragm Size (mm)	<i>P</i>	<i>V</i>	<i>P</i> − <i>V</i>
a	0.6	17.84	17.65	0.19
b	0.6	16.85	16.59	0.26
y	0.6	17.54	17.16	0.38
e	0.6	19.02	18.76	0.26
y	0.4	17.73	17.49	0.24
y	0.6	16.42	16.10	0.32
y	1.2	14.93	14.76	0.17
y	2.2	13.35	12.99	0.36
b	0.4	17.34	17.07	0.27
b	0.6	15.80	15.60	0.20
b	1.2	14.73	14.48	0.25
b	2.2	13.68	13.42	0.26

stars fainter than the limiting magnitude in Fig. 4 is 0.26, and is evidently not sensitive to observational difficulties associated with varying diaphragm size and interference of visible images. Obviously the points plotted as open squares in Fig. 4 do not show the trend of the color-magnitude relation, since the luminosity function, which is unknown, would be necessary for a proper interpretation of the meaning of the integrated color in terms of the color-magnitude relation for the stars beyond the observed limits.

Distance estimates for NGC 5466 were made by

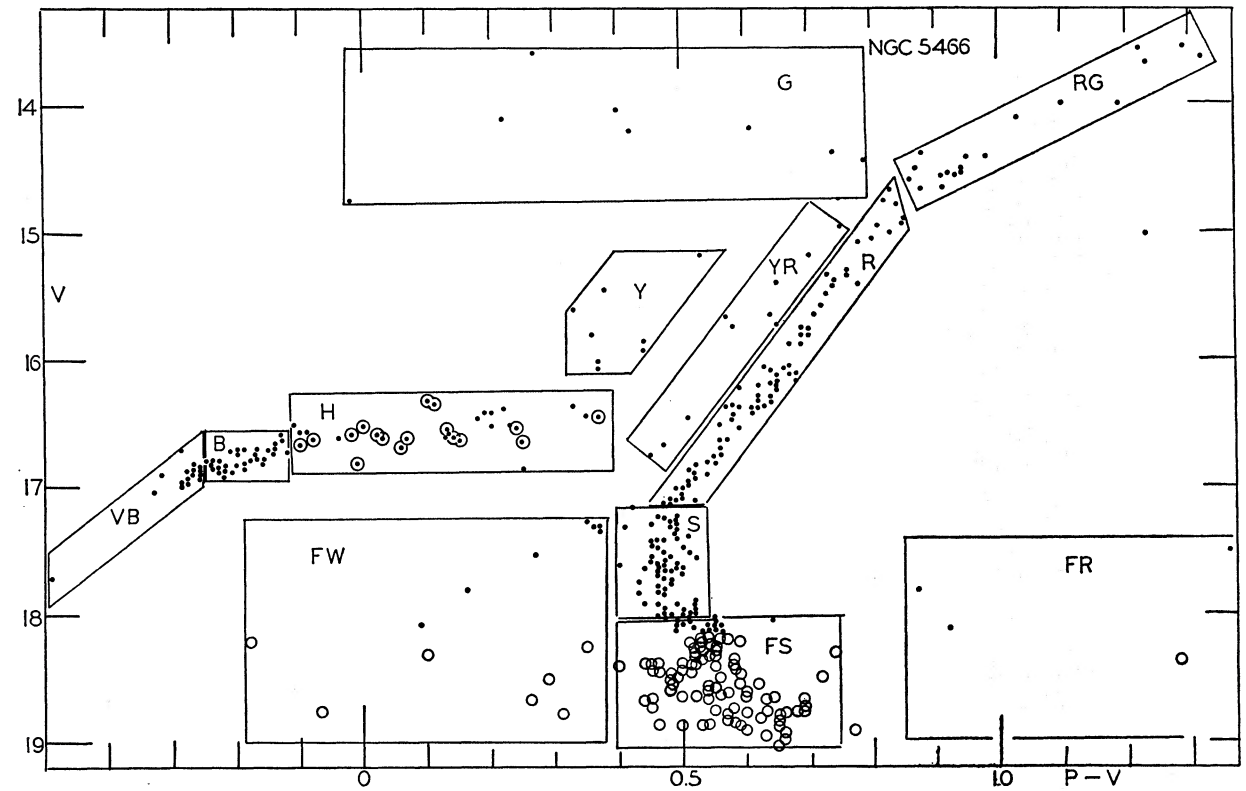
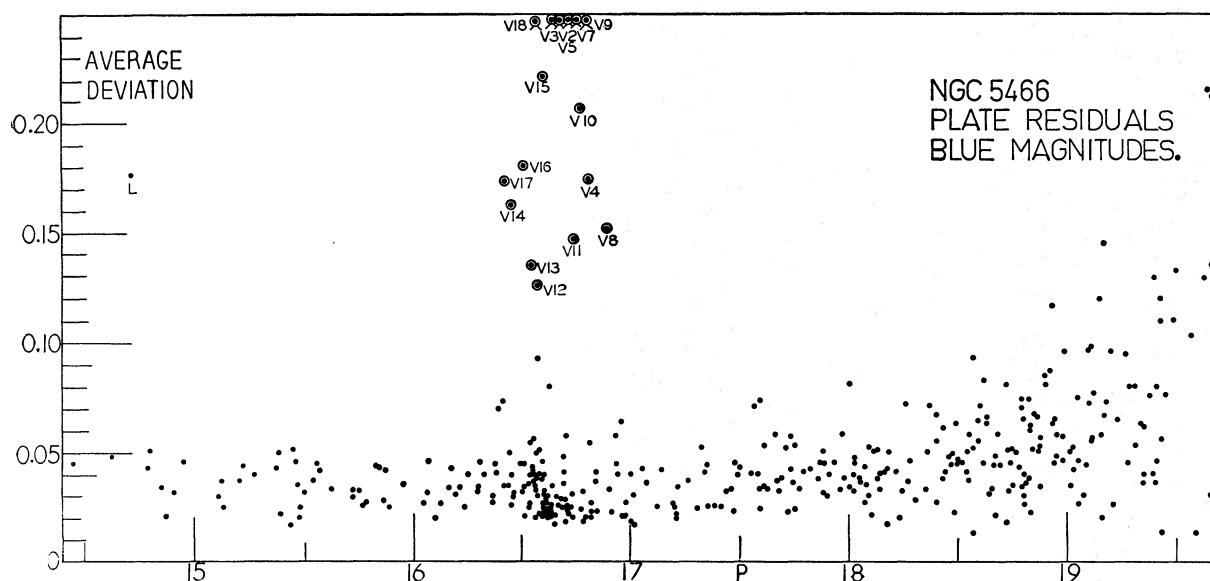


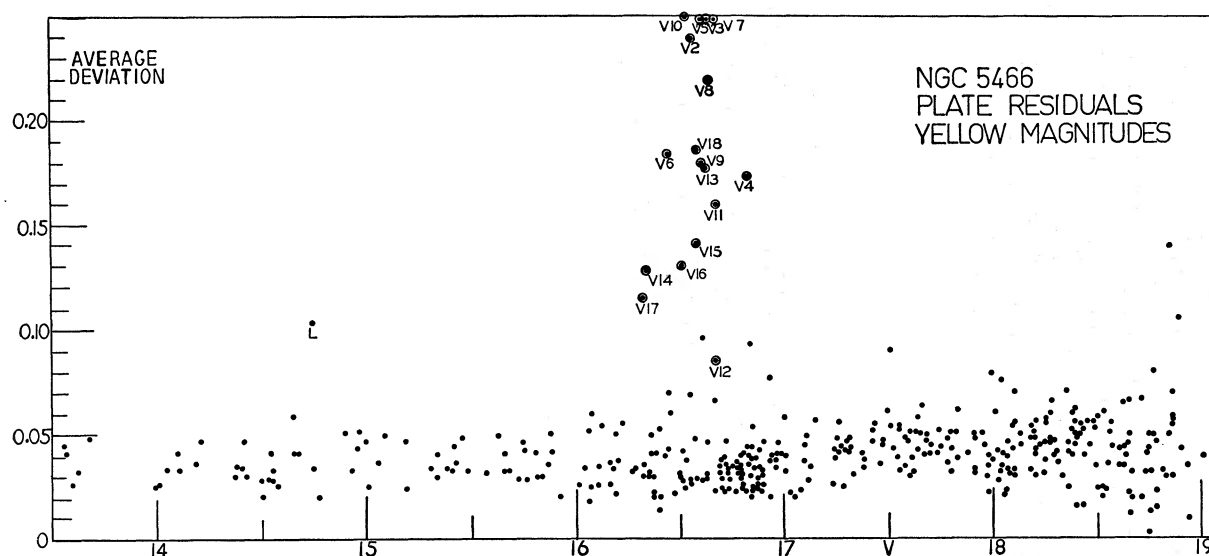
FIG. 6. NGC 5466, areas in color-magnitude relation.

FIG. 7. Plate residuals as a function of P magnitude.

comparing the branches outlined in Fig. 5 with the corresponding branches in M3. For M3, the modulus 15.67 was adopted (Sandage and Johnson 1956). Very little absorption is to be expected in the high galactic latitude involved and the extreme blueness of some of the stars in both clusters is evidence of its absence. Isolating various parts of the color-magnitude relation and using the designations of Fig. 6, we obtain the following values of the difference in distance modulus between NGC 5466 and M3: RG , 0.85; R , 0.94; H , 0.93; B , 0.87. The known variables give 0.91. Taking a weighted mean, we obtain the adopted value 0.89, which results in the distance modulus 16.56 for NGC 5466. The distance is then 20.5 kpc.

3. VARIABLE STARS AND PROBABLE ERRORS

Most of the catalogued yellow magnitudes in Table IV are based upon the average of 11 measures per star, that being the number of plates which gave measurable images for all stars brighter than 18.5. Similarly, the blue magnitudes come from an average of nine measures per star. The plates were taken during two observing sessions lasting three days each and separated by 22 days. They should show up conspicuously stars with short-period variability. In order to find any new variable stars present in the data on which Table IV is based, the residuals of the individual measures from the average value were computed for each star. The

FIG. 8. Plate residuals as a function of V magnitude.

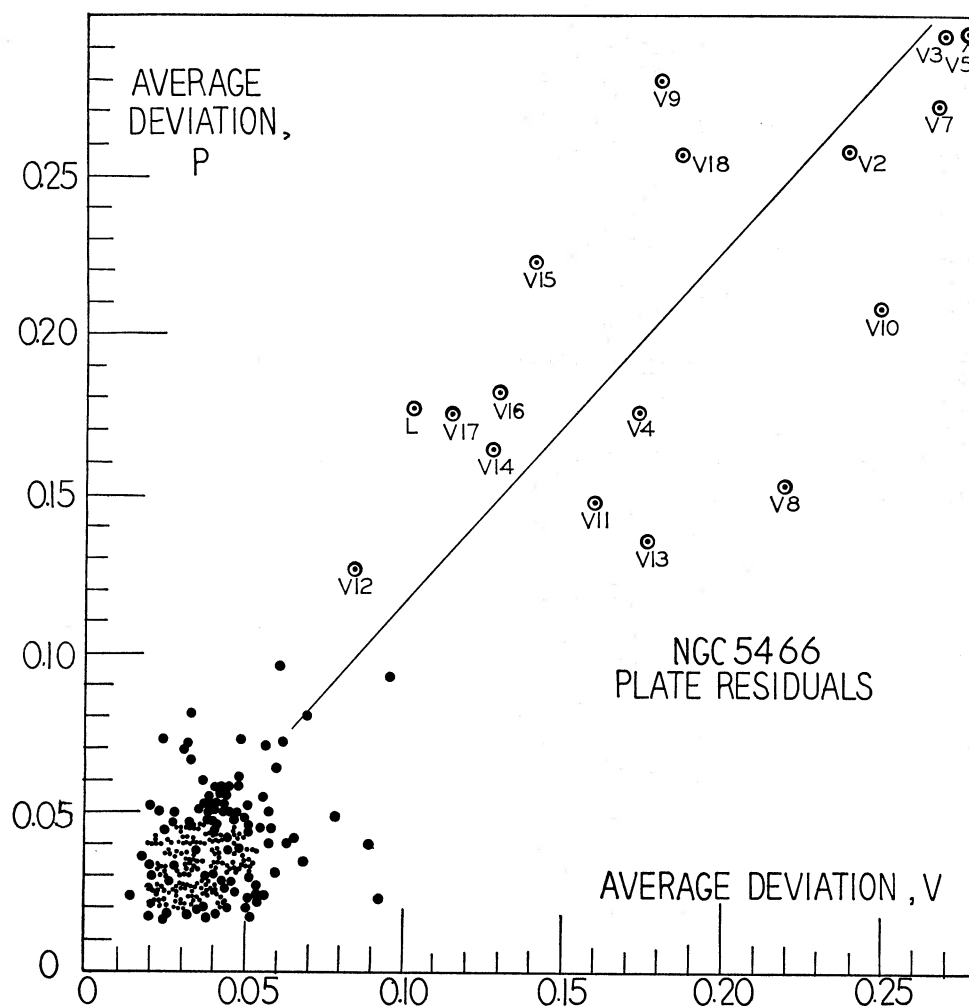


FIG. 9. Plate residuals P related to plate residuals V , for stars brighter than 18.0 only.

average of the absolute values of these residuals is customarily referred to as the average deviation, A.D. Variability is indicated by an unusually large value of the average deviation. Ability to detect variables of small amplitude depends, however, upon how large the errors of measurement are. For this reason, Figs. 7 and 8 and Table VIIIA are of fundamental importance. Here, the average deviations in yellow and blue light are plotted against the corresponding V and P magnitudes. Known variables are circled and labeled for identification. Without exception, they come from the H branch in Fig. 6, and occur near $V=16.5$.

Figures 7 and 8, and Table VIIIA were used in deriving the probable errors of the magnitudes and colors tabulated in Table V. Well-known statistical relations, combined with the number of measurable images in each magnitude interval, were used. Known variables were omitted from the calculations in Table VIIIA, but included in Table VIIIB.

To search for new variable stars, diagrams similar to Figs. 7 and 8 were plotted for each of the areas of the color-magnitude relation in Fig. 6. An additional diagram, Fig. 9, showing whether or not for a given star,

high yellow residual was confirmed by high blue residual, was also consulted. Faint stars, whose inherently larger errors of measurement would obscure the desired information, are omitted from Fig. 9.

The results of the search for new variable stars are summarized in Table VII. Standard star L, a white giant located well above the horizontal branch at $V=14.74$, $P-V=-0.02$, has large residuals in both blue and yellow light; its designation as variable number 19 is suggested. It is not listed in the general catalogue of variable stars by Kukarkin, Parenago, Efremov, and Kholopov (1958). Star 2-3-17, with high residuals, and located in Region H of the color-magnitude relation is suggested for designation as variable number 20. Star 4-1-11, also in region H is suggested as variable number 21. Star 3-4-2 is suggested as variable number 22. It is quite red. Additional stars listed in Table VII are worthy of future investigation, but can only be regarded as suspects from the present study.

In order to determine whether stars of various regions of the color-magnitude relation showed a greater or smaller tendency toward small-range variation, dia-

TABLE VII. Variable stars and stars with high residuals. Average deviation of single observation. Stars brighter than $V=18.2$ only.

Star	A.D. P	A.D. V	C-M Region (Fig. 6)	Comments
V 1	...	...		Off chart
V 2	0.258	0.240	H	
V 3	0.295	0.270	H	Crowded, but resolved image
V 4	0.176	0.174	H	Blended image
V 5	0.328	0.300	H	
V 6	...	0.185	H	Poor resolution near to image
V 7	0.272	0.268	H	
V 8	0.153	0.220	H	
V 9	0.280	0.180	H	
V 10	0.208	0.250	H	
V 11	0.148	0.160	H	Poor resolution near to image
V 12	0.127	0.085	H	
V 13	0.136	0.177	H	
V 14	0.164	0.128	H	
V 15	0.223	0.141	H	
V 16	0.182	0.130	H	
V 17	0.175	0.115	H	
V 18	0.257	0.187	H	Poor, very close to bright image
L	0.177	0.103	G	
2-3-17	0.093	0.096	H	
3-5-2	0.096	0.061	FR	Very red
4-1-11	0.080	0.070	H	
1-1-6	0.072	0.062	S	Slight crowding of image
2-1-4	0.071	0.057	FW	Slightly blended image
2-3-7	0.049	0.079	S	
4-1-2	0.073	0.049	R	
4-1-22	0.064	0.060	YR	
1-2-16	0.040	0.090	S	
3-4-20	0.023	0.093	B	
1-1-1	0.081	0.033	S	
1-2-2	0.071	0.032	S	
3-4-21	0.067	0.033	S	
A few additional stars with residuals smaller than those listed above, but larger than usual for stars of the same brightness are:				
1-1-12			H	
2-1-20			H	
3-5-1			H	
4-3-23			VB	
1-2-12			RG	
3-2-12			R	
1-1-5			YR	
2-4-6			S	
Standard X				
2-5-1			FS	
3-5-6			FR	

grams similar to Figs. 7, 8, and 9 were plotted for each of the regions shown in Fig. 6. Table VIII summarizes the results. Evidently, subject to the uncertainties inherent in the probable errors of measurement, there is no reason to suppose that any of the areas contain stars with greater tendency toward small range variability

TABLE VIIIA. Average A.D. for single measurement as a function of magnitude, summarized from Figs. 7 and 8.

Magnitude interval	Average deviation P	Average deviation V
13.5-16.3	0.035	0.037
16.3-17.0	0.035	0.036
17.0-18.2	0.038	0.043
18.2-18.7	0.048	0.044
18.7-19.7	0.066	0.045

TABLE VIIIB. Average A.D. for single measurement relative to region of color-magnitude diagram.

Region	P	V
G	0.042	0.039
RG	0.035	0.036
R	0.032	0.037
H	0.133	0.125
B	0.033	0.033
VB	0.032	0.035
Y	0.039	0.040
YR	0.037	0.044
S	0.042	0.048
FS	0.061	0.045
FW	0.050	0.039
FR	0.075	0.047

than any other, except of course, the H branch and its known variables of conspicuously large range.

4. THE SPATIAL DISTRIBUTION OF THE CLUSTERS NORTH OF 50° GALACTIC LATITUDE

Improved distances are now available for most of the high-latitude globular clusters and we are in a position to draw some conclusions regarding their relationship to each other and to the Milky Way. To judge by their position in the sky, the clusters appear to form a definite group, although this is difficult to establish definitely from a statistical standpoint. The clusters north of 50° all lie inside a circular area of 700 square degrees, while if random distribution were involved, one might expect them to be distributed more evenly over the 3200 sq deg accessible to them. Thus they occupy only $\frac{1}{4}$ of the area of sky available to them on the basis of random distribution.

A more relevant analysis of their relationship must be based upon their distribution in space. Coordinates now available for the clusters are in Table IX. Figure 10 shows the space distribution of the clusters, projected on the XZ plane, relative to a cross section of the Milky

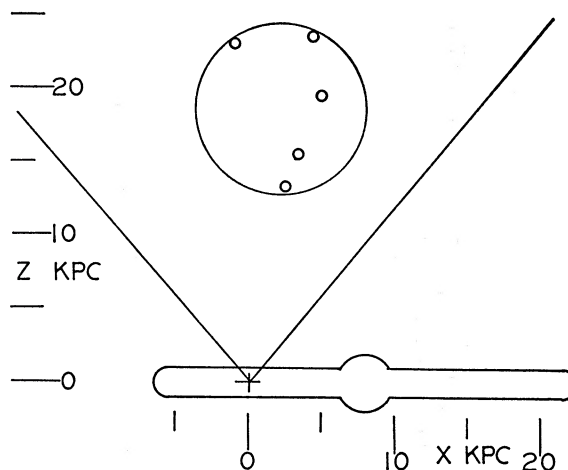
FIG. 10. Space distribution of globular clusters north of 50° galactic latitude.

TABLE IX. Coordinates of globular clusters north of 50° galactic latitude.

		1900		1	<i>B</i>	<i>X</i>	<i>Y</i>	<i>Z</i>	<i>D</i>
M3	5272	13 ^h 37.6	28°53	7°	78°	+2.31	+1.81	+13.3	13.6 kpc
M53	5024	13 08.0	18 42	305	79	+4.15	-1.94	+23.6	24.0
	5466	14 01.0	29 00	8	73	+4.86	+3.73	+19.6	20.5
	5053	13 11.5	18 13	309	78	+3.12	-1.14	+15.6	16.0
	4147	12 05.0	19 06	224	76	-1.07	-4.32	+22.97	23.4

Way system. Here, and also on a similar plot projecting them on the *YZ* plane, the entire group may be enclosed in a spherical volume whose radius is 6 kpc.

Thus the cluster group occupies only 860 cubic kiloparsecs, or only $\frac{1}{12}$ of the conical volume north of galactic latitude 50° out to a distance of 24 kpc, which one should consider accessible to them on the basis of random distribution in space. Thus the statistical material is by no means definitive, and improved distances for some of the clusters could alter the conclusion. One has the impression from Fig. 10 that the clusters form a definite group, too asymmetrically located relative to the Milky Way, and somewhat too far from the Milky Way plane, to be regarded as a typical part of the halo population.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the cooperation of Dr. I. S. Bowen and the staff of the Mt. Wilson Obser-

vatory. Dr. W. Baade, Dr. W. A. Baum, Dr. A. R. Sandage, and Dr. H. C. Arp were especially helpful. An Office of Naval Research Grant aided with travel expenses, and assisted with reductions. Several grants for travel and assistance by the Graduate School of Indiana University have also been particularly helpful. Mrs. Andrée Schmalberger has carried out efficiently most of the plate reductions.

REFERENCES

- Baade, W. 1926, *Hamb. Mitt.* **6**, No. 27.
 Christie, W. H. 1940, *Astrophys. J.* **91**, 10.
 Cuffey, J. 1954, *Astron. J.* **59**, 319.
 —. 1956, *Sky and Telescope* **XV**, 258.
 —. 1958, *Astrophys. J.* **122**, 222.
 Eggen, O. J. 1955, *Astron. J.* **60**, 65; *Lick Obs. Bull.* No. 552.
 Johnson, H. L. and Sandage, A. R. 1956, *Astrophys. J.* **124**, 379.
 Kukarkin, B. V., Parenago, P. P., Efremov, Yu. I., and Kholopov, P. N. 1958, *Publs. Acad. Sci. U.S.S.R.*, Moscow.
 Sandage, A. R. and Walker, M. F. 1955, *Astron. J.* **60**, 230.
 Sawyer, H. 1945, *Dunlap Obs. Publ.* **1**, No. 17.
 Shapley, H. 1930, "Star clusters," *Harvard Obs. Monographs*, No. 2.