MAGNITUDES AND COLORS FOR STARS IN TWO NEW GALACTIC CLUSTERS

JURGEN STOCK
Warner and Swasey Observatory, Case Institute of Technology
Received August 1, 1955; revised September 26, 1955

ABSTRACT

For two new clusters discovered on objective-prism plates, magnitudes and colors were obtained photographically. One, in Vulpecula, is not a main-sequence cluster The other cluster, in Perseus, consists of main-sequence stars, beginning with B9. Its distance is 300 pc, and the total absorption at 4700 A is 1.5 mag.

INTRODUCTION

From the examination of spectral plates taken at the Warner and Swasey Observatory along the galactic equator, 21 objects were found (Stock 1954) which are suspected of being galactic clusters. Most of these objects do not show a conspicuous concentration of stars, the presence of a cluster being indicated only by stars of similar spectral types and apparent magnitudes. In order to make certain of their reality, photometric studies have been undertaken. The present report deals with two such groups, one in Vulpecula and the other in Perseus. Magnitude and color data have been obtained in order to determine their color-magnitude diagrams.

THE CLUSTER IN VULPECULA

The position of this cluster is R.A. = $19^h33^m.7$; Dec. = $25°.1$ (1950). Plates were taken in the three spectral regions proposed by Becker (1946):

1. Eastman Kodak II*a*-O + Schott GG5 filter; λ = 4700 A
2. Eastman Kodak 103*a*-E + Schott RG1 filter; λ = 6400 A
3. Eastman Kodak II*a*-O + Schott UG2 filter; λ = 3700 A

The blue and red material was used only because no ultraviolet magnitude sequence was available. Eight plates were obtained in each spectral region.

In an area of 60′ in diameter, 158 stars, all brighter than 13.7 mag. (4700 A), were selected and measured with the Eichner iris-type photometer. A magnitude sequence was established photoelectrically for the blue and the red, reaching 12.6 mag. in the blue. The magnitudes and colors of stars fainter than 12.6 mag. are based on an extrapolation of the calibration-curves. The photoelectric observations were carried out at the Case Observatory. For all stars, observations on two nights and for some on three were obtained. The observing procedure and the relations between the Case magnitudes and colors and the Johnson-Morgan $B-V$ system are the same as described by Blanco (1954). The equations

$$m_{4700} = V + 0.53(B-V), \qquad m_{6400} = V - 0.35(B-V),$$

which were determined empirically, transfer the magnitudes and colors to the photographic system employed in this investigation. The sequence stars are listed at the end of the catalogue. The mean errors of the photographic magnitudes obtained for this cluster are given in Table 1. The spectral types were estimated on two objective-prism plates. The complete data for this cluster are given in Table 2. The identification of the stars is shown in Figure 1.

TABLE 1

THE MEAN ERRORS OF MAGNITUDES AND COLORS

	Vul	Per		Vul	Per
m_{4700}	0^m.024	0^m.023	$c_{4700/6400}$	0^m.037	0^m.033
m_{6400}	0 028	024	$c_{3700/4700}$		0 038
m_{3700}		0 030			

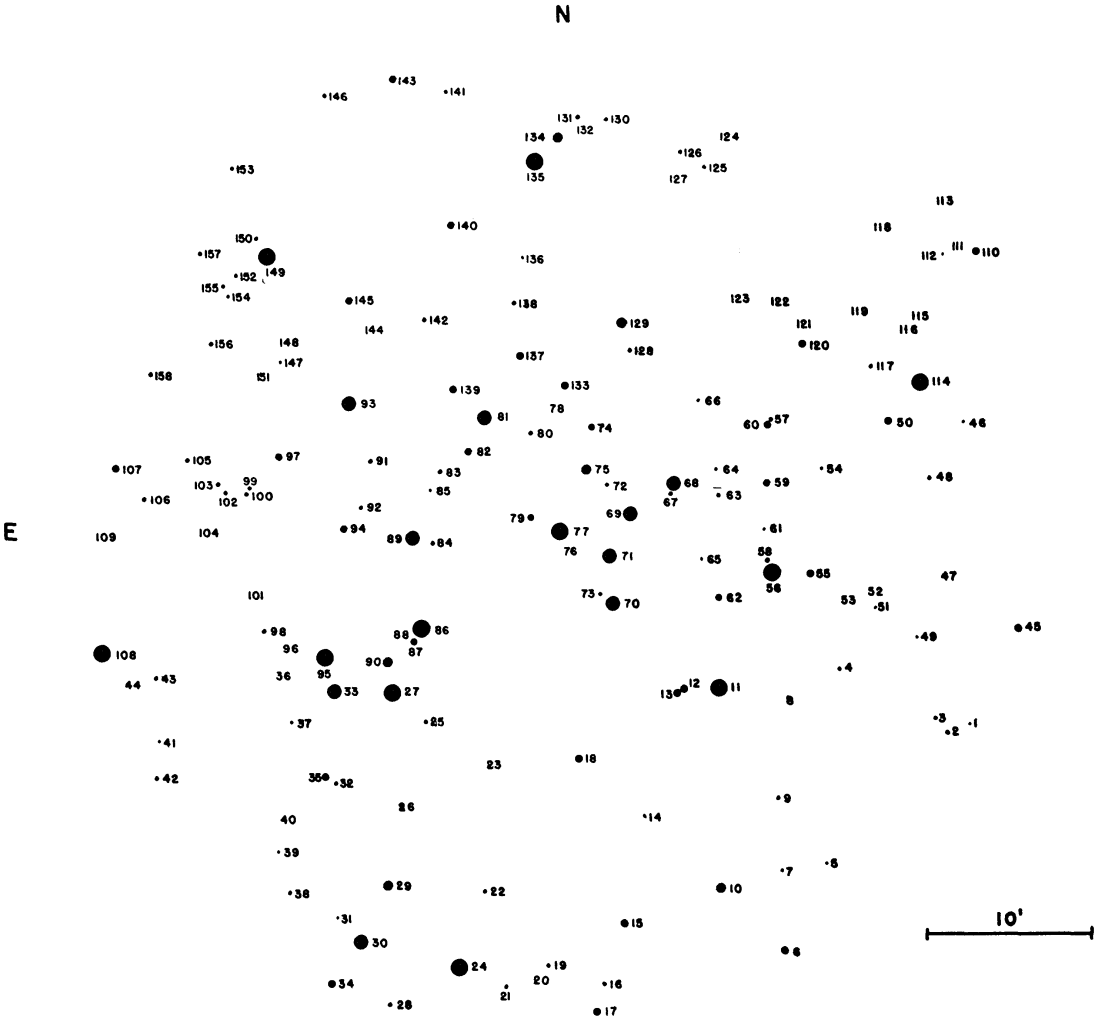

FIG 1.—Identification chart for the cluster in Vulpecula

TABLE 2*

MAGNITUDES, COLORS, AND SPECTRAL TYPES OF STARS WITHIN THE REGION OF VULPECULA CLUSTER

No.	m_{4700}	$c_{4700/6400}$	Sp.	No.	m_{4700}	$c_{4700/6400}$	Sp.
1	13 37	0 77		51	13 62	0 97	
2	12 97	0 90		52	13 67	0 72	
3	12 22	2 38	M2†	53	13 61	0 66	
4	12 97	0 79		54	13 11	0 49	
5	13 52	1 09		55	11 97	0 45	
6	11 56	0 21	A0	56	8 63	0 00	B7
7	13 00	0 63		57	12 24	0 95	
8	13 13	0 84		58	12 96	0 39	
9	12 90	0 65		59	11 84	0 47	
10	10 66	1 14	K5	60	11 38	0 45	A:
11	8 70	0 07	B8	61	13 32	0 52	
12	11 22	0 52		62	11 25	0 32	F0
13	11 10	0 55		63	12 80	0 65	
14	13 15	1 62		64	13 28	0 63	
15	11 33	0 75		65	13 42	1 43	
16	12 89	0 52		66	13 36	1 52	
17	11 84	0 44		67	12 05	0 47	
18	11 70	0 40		68	9 87	0 21	A1:
19	12 76	0 62		69	9 13	0 12	A0
20	13 10	1 83		70	9 62	0 20	A3
21	12 07	2 07		71	9 62	0 18	A2
22	12 23	0 43		72	12 45	0 48	
23	13 72	1 44		73	12 07	0 37	
24	8 68	0 70	F9	74	11 01	0 30	
25	12 48	0 48		75	10 26	0 21	A4
26	13 26	0 44		76	13 07	0 66	
27			†	77	8 19	0 13	A0
28	12 92	0 67		78	13 41	0 53	
29	10 80	0 47	F6	79	11 43	0 50	G
30	9 85	0 60	F9	80	12 47	0 52	
31	13 31	0 45		81	9 05	0 18	A1
32	12 46	0 79		82	11 82	0 37	
33	9 66	0 25	A3	83	12 55	0 63	
34	11 37	0 37	F6	84	12 48	0 66	
35	11 21	0 47	F9	85	13 17	0 57	
36	13 02	0 74		86	8 81	0 11	A1
37	13 07	0 55		87	11 08	0 61	
38	12 87	0 76		88	13 10	0 67	
39	13 08	0 65		89	9 43	0 14	A0
40	13 07	0 62		90	10 20	0 23	A1
41	13 00	1 87		91	12 92	0 55	
42	12 31	0 36		92	12 36	0 48	
43	12 57	0 42		93	9 65	0 21	A1
44	13 16	0 48		94	11 39	0 72	
45	11 80	0 53		95	8 68	0 91	G8 III
46	13 32	0 54		96	13 24	2 86	M5 5†
47	13 35	0 67		97	11 35	0 31	
48	12 61	0 91		98	12 56	0 53	
49	13 55	1 47		99	12 32	0 57	
50	11 62	1 44		100	12 10	0 48	

* Values of the columns are as follows: first: current number, referring to the chart in Fig 1; second: apparent magnitude at $\lambda = 4700$ A; third: color index $c_{4700/6400} = m_{4700} - m_{6400}$; fourth: spectral type

† 3—Spectrum from an infrared objective-prism plate
27—Close double star
96—Spectrum from an infrared objective-prism plate

The following stars have been observed photoelectrically: 42, 43, 46, 48, 52, 59, 60, 79, 82, 83, 85, 86, 88, 89, 90, 117, 121, 127, 184, 185

TABLE 2—*Continued*

No.	m_{4700}	$c_{4700/6400}$	Sp.	No	m_{4700}	$c_{4700/6400}$	Sp.
101	13 18	0 71		130	12 46	0 56	
102	12 52	0 53		131	12 92	1 73	
103	12 98	0 51		132	13 46	1 43	
104	13 28	1 95		133	11 83	0 58	
105	12 31	1 56		134	10 70	0 32	A1
106	12 20	0 43		135	8 49	0 10	A0
107	11 53	0 43		136	13 11	0 69	
108	8 60	0 23	A2	137	11 88	0 41	
109	13 25	0 58		138	12 10	0 68	
110	11 87	0 72		139	11 05	0 26	A4
111	13 19	0 74		140	11 82	0 77	
112	13 45	0 88		141	12 77	0 57	
113	13 24	0 74		142	12 92	0 46	
114	8 07	1 61	K5 V	143	11 29	0 41	G3:
115	13 22	0 91		144	13 29	0 82	
116	13 22	0 69		145	11 30	0 23	
117	12 63	0 86		146	12 40	0 43	
118	13 47	0 59		147	13 53	0 68	
119	13 71	1 51		148	13 52	0 64	
120	11 45	0 43	F5	149	8 79	0 32	A3
121	13 32	0 46		150	12 18	1 97	
122	13 02	0 64		151	13 34	2 04	
123	13 10	0 59		152	12 06	0 69	
124	13 56	0 61		153	12 76	1 76	
125	12 66	0 63		154	13 15	1 62	
126	12 57	0 43		155	12 10	0 54	
127	13 40	0 66		156	12 27	0 64	
128	12 29	0 50		157	12 94	0 64	
129	10 32	0 22	A4	158	12 72	0 59	

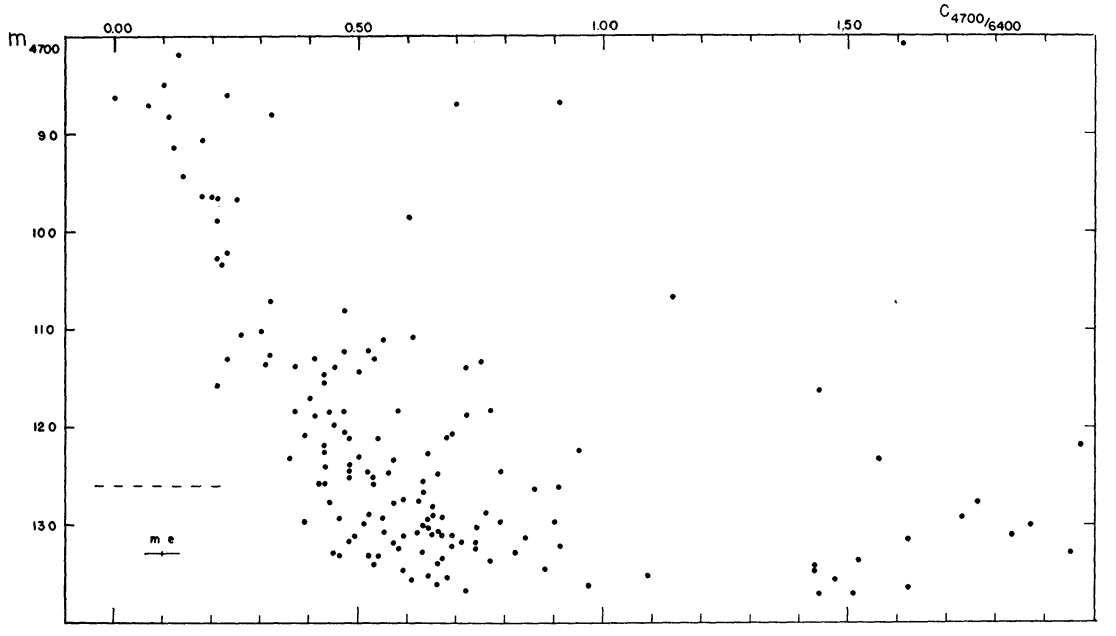

FIG. 2.—Color-magnitude diagram of the cluster in Vulpecula. The limit of the photoelectric sequence is indicated by the dashed line. The line (m e.) in the lower left of the diagram represents the mean errors of magnitudes and colors.

The color-magnitude diagram for all stars measured is shown in Figure 2. The limit of the photoelectric sequence and the mean errors of the colors and magnitudes are indicated. Most of the brighter stars follow a well-defined sequence. Part of the scattering can be attributed to the accidental errors of the data. The sequence formed by the brighter stars continues to the limit of the survey with increasing scatter, probably due to the increasing number of field stars. The slope of the sequence in the color-magnitude diagram is steeper than would be expected for main-sequence stars, thus indicating higher luminosity for the brighter stars. The cluster shows only little reddening. Its distance cannot be determined, since the cluster stars cannot be assumed to have the luminosity of main-sequence stars.

THE CLUSTER IN PERSEUS

The center of this cluster is at R.A., 2^h11^m3; Dec., 59°0 (1950). On blue spectral plates this cluster shows a rather conspicuous group of early A-type stars. It is located about 2° north of the Perseus double cluster. Six plates were taken in each of the three spectral regions mentioned in the previous section. On all plates 209 stars in an area of 60′ in diameter were measured. The limit in magnitude is 13.0 (4700 A). A sequence in the

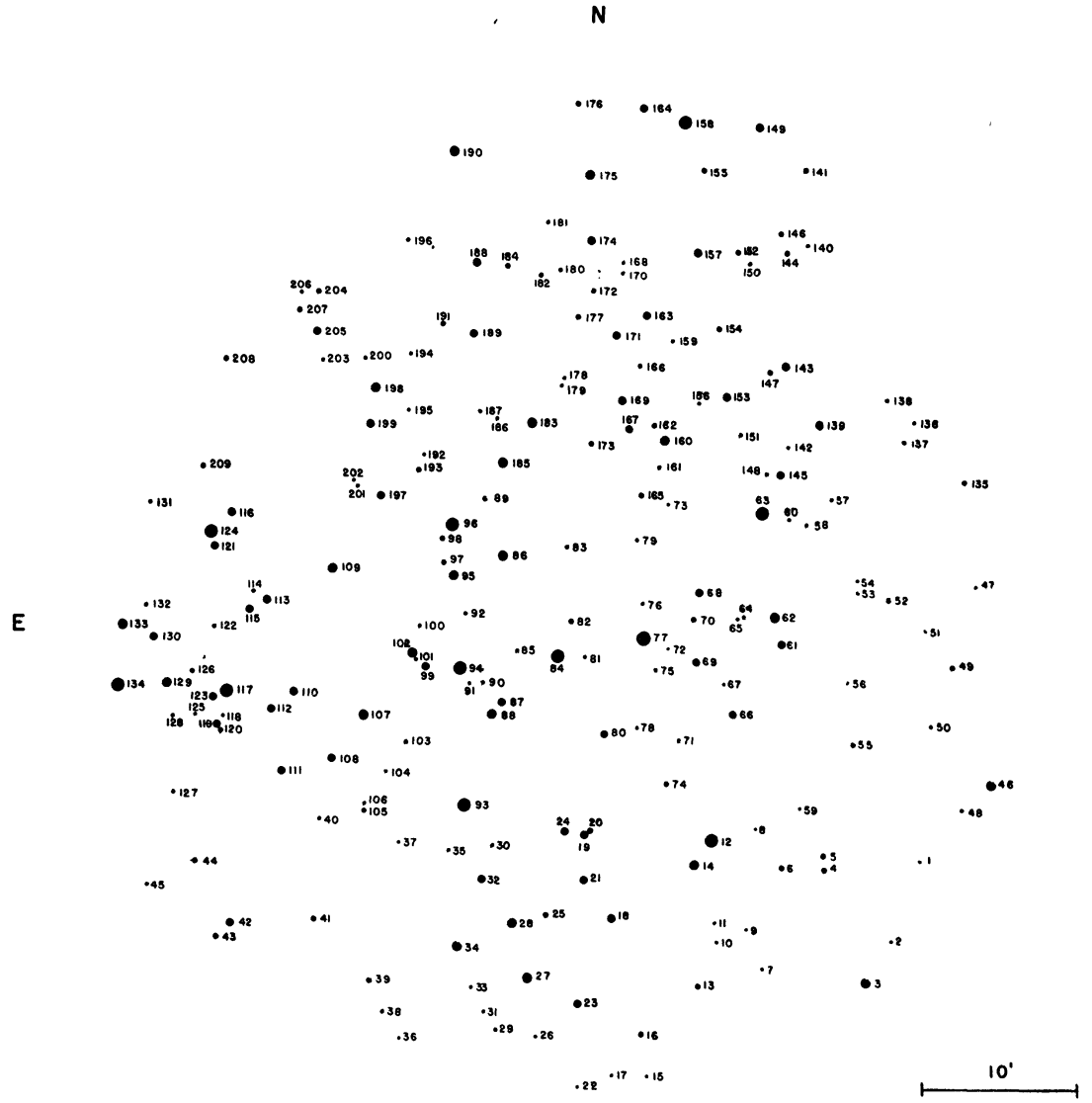

FIG. 3.—Identification chart for the cluster in Perseus

TABLE 3*

MAGNITUDES, COLORS, AND SPECTRAL TYPES OF STARS WITHIN THE REGION OF PERSEUS CLUSTER

No.	m_{4700}	$c_{4700/6400}$	$c_{3700/4700}$	Sp.	Membership	No.	m_{4700}	$c_{4700/6400}$	$c_{3700/4700}$	Sp.	Membership
1	12.41	2 49			n	51	12 40	1 05	+0 48		
2	12.4				†	52	11 60	1 04	+0 45		
3	10 09	1 91	+2 77	M0	n	53	12 61	0 76	+0 36		n
4	11 81	0 80	+0 33			54	12 47	0 93	+0 54		
5	11 83	0 87	−0 20		n	55	11 68	0 77	+0 35		
6	11.99	0 80	+0 34			56	12 58	1 06	+0 83		
7	12 83	0 85	+0.48		n	57	12 99	0 97	+0 66		
8	12.62	0 92	+0 01		n	58	12 17	0.99	+0 51		
9	12 17	0 87	+0 37			59	12 91	0 96	+0 34		
10	13 00	0 87	+0 84		n	60	12 66	0 82	+0 74		n
11	12 87	0 87	+0 54		n	61	10 89	1 63	+1 42		n
12	8.80	1 24	+1.19	G4 Ib	n	62	9 51	0 63	+0 22	A0	
13	11.31	0 68	+0 39			63	9 03	0 85	−0 46	OB	n
14	10.13	0 91	−0 14	OB	n†	64	12 87	1 08	+0 82		
15	12 35	0 92	+0 44			65	12 44	1 56	+1 23		n
16	11.58	0 54	+0 24		n	66	10 35	0 54	+0 40	A3	
17	12.39	0 84	+0 42			67	12 76	0 73	+0 71		n
18	10.62	0 61	+0 53	A1		68	10 69	0 74	+0 56	B8	
19	10 96:	0 89:	+0 54:		†	69	10 98	0 61	+0 47	A0	
20	11.39:	0 81:	+0 66:		†	70	11 69	0 86	+0 52		
21	10 87	0 62	+0 54	A1		71	12 46	0 86	+0 70		
22	12 93	0 73	+1 07		n	72	12 27	0 95	+0.46		
23	10 54	0 46	+0 45	A2		73	12 66	1 19	+0 72		
24	11.13	0 73	+0 61	B9		74	11 89	0 89	+0 44		
25	11 75	1.01	+0 44			75	12 61	0 89			
26	12 94	0 78	+0 92		n	76	12 34	1 15	+0 66		
27	9 98	1 18	+1 19	G3	n	77	9 27	0 60	+0 38	B8	
28	9 80	0 56	+0 49	A0		78	12 20	0 83	+0 50		
29	12 44	0 94	+0 60			79	12 48	2 27			n
30	12 64	0.98	+0 68			80	10 62	0 69	+0 57	B9	
31	12.92	0 69	+0 23		n	81	12 73	0 97	+1 06		n
32	10.35	0 65	+0 70	A0		82	11 20	0 82	+0 60		
33	12 47	0 82	+0 37		n	83	12 23	1 01	+0 42		
34	10 07	0 61	+0 71	B9		84	9 38	0 64	+0 43	A0	
35	12 93	1 16	+0 98		n	85	12 43	0 94	+0 11		n
36	12.13	0 86	+0 74			86	9 65	0 64	+0 42	B8	
37	12.80	1 14				87	10 46	0 74	+0 63	A1	
38	12.89	0 90	+0 30		n	88	9 96	1 47	+1 50	K3	n
39	11.22	0 77	+0 71			89	12 00	1 04	+0 01		n
40	12 85	0 88	+0 32		n	90	12 48	1 16	+0 15		n
41	11 93	0 75	+0 60			91	12 72	1 01	+0 76		
42	10 73	0 78	+0 67	F5	n	92	12 67	1 19	+1 09		n
43	11 33	0 64	+0 51			93	9 02	0 44	+0 29	A6	
44	12 09	0 76	−0 07		n	94	9 40	0 57	+0 43	B9	
45	12 94	0 85	+0 78		n	95	10 14	0 60	+0 55	A2	
46	9 95	0 53	+0 28	B9		96	9 32	0 68	+0 39	A0	
47	12 54	1 18	+0 93		n	97	11 31	0 75	+0 62		
48	12 48	0 95	+0 54			98	11 29	0 99	+0 78	B8	n
49	11 65	0 87	−0 18		n	99	10 85	1 42	+1 46		n
50	12 74	0 72	+0 37		n	100	12 37	1 10	+0 98		n

* Values for the columns are as follows: first: current number, referring to the chart in Fig 3; second: apparent magnitude at $\lambda = 4700$ A; third: color index $c_{4700/6400} = m_{4700} - m_{6400}$; fourth: color index $c_{3700/4700} = m_{3700} - m_{4700}$; fifth: spectral type; sixth: stars not belonging to the cluster are indicated by the letter "n"

† 2—Close double star.
14—Also classified as OB by G. Gonzalez and G Gonzalez (1954).
19—Forms a double star with No 20 The images probably interfere somewhat.
20—See note for No 19.
110—Close double star.
116—Spectrum by G. Gonzalez and G Gonzalez (1954).

TABLE 3—*Continued*

No.	m_{4700}	$c_{4700/6400}$	$c_{3700/4700}$	Sp.	Membership	No.	m_{4700}	$c_{4700/6400}$	$c_{3700/4700}$	Sp.	Membership
101	12 26	0 88	+0 59	.		156	12 64	0 98	+0 61	..	
102	9 50	0 52	+0 50	A0		157	10 61	0 81	+0 52	B9	
103	12 36	0 99	+0 83			158	9 15	0 60	−0 02	F4	n
104	12 38	1 23	+0 34			159	12 13	1 04	+0 64	.	
105	11 95	1 07	+1.10		n	160	10 14	0 87	+0 67	B9	n
106	12 88	1 12	+0 54	.		161	12 26	1 00	−0 05		n
107	9 98	0 97	+1 33	G3 III:	n	162	11 93	1 17	+0 90	..	n
108	10 67	0 76	+0 74	A3	.	163	10 94	0.75	+0 52	A1	
109	10 11	0.65	+0 70	A1	.	164	10 83	1 21	+0 81	B6	n
110	. .	. .	..		†	165	11 49	0 88	+0 57	.	
111	10 62	0 60	+0 56	A5		166	12 63	0 99	+0 27	.	n
112	11 19	0 62	+0 64	.		167	10 95	0 91	+0 60	A2:	..
113	10 96	0 66	+0 53	A3	.	168	12 83	2 29	. .	..	n
114	12 55	0 87	+0 62			169	10 60	0 78	+0 56	A2:	
115	11 17	0 67	+0 54			170	12 18	0 96	+0 70	..	
116	11 18	0 94	−0 07	OB	n†	171	10 58	0 75	+0 48	A0:	.
117	9.37	0 48	+0 42	B9		172	12 02	1.02	+0 63	...	
118	12 50	0 57	+0 69		n	173	12 00	0 95	+0 18	.	n
119	10 72	0 73	+0 60		.	174	10 38	0.71	+0 50	B9:	.
120	11 31	0 85	+0 77			175	10 06	0 76	+0 53	A1	
121	11 16	0 94	+0 09		n	176	11 85	0 96	+0 57	...	
122	12 92	0 85	+0 75		n	177	11 72	1 08	−0 06	. .	n
123	11 02	0 65	+0 52	.		178	12 37	1 03	+0 64	...	.
124	9 29	0 47	+0 35	A0		179	12 36	1 04	+0 77	...	.
125	12 48	0 80	+0 60		n	180	12 67	0 99	+0 46	...	
126	11 98	0 83	+0 48			181	12 99	1.29	... ..	...	
127	12 62	2 31	. .		n	182	11 36	0 89	+0 50	...	
128	12 67	0 83	+0 58	.	n	183	9.73	0.73	+0 44	A0	.
129	9 84	0 47	+0 49	A0		184	11 86	0.94	+0 62	..	.
130	10 48	0 55	+0 56	A0:	.	185	10 15	0 69	+0.50	A0	.
131	12.53	0 73	+0 03		n	186	12 28	2.19	... ..	..	n
132	12 42	0 76	+0 78		n	187	12 17	1.08	+1 10	...	n
133	9 72	0 35	+0 42	B9		188	10 61	0.78	+0 50	A2	.
134	9 08	0 40	+0 40	A0		189	10 96	0 84	+0 63	..	.
135	11 38	0 81	+0 51			190	9 83	0 77	+0 58	A3	.
136	12 20	1 02	+0 36			191	11 26	0 85	+0 67	...	
137	12 72	0 91	+0 39			192	12 91	1 05	+0 91	...	n
138	12 54	0 81	−0 06	.	n	193	11 60	0 81	+0 69	.	.
139	10 68	0 62	+0 39	A0		194	12 96	1 01	+0 54	...	.
140	12 47	1 10	+0.76	.	.	195	12 90	0 99	+0 32	...	.
141	11 77	1 40	+0 01		n	196	12 40	1 00	+0 74	..	
142	12 48	1 58	+1.45	.	n	197	10 96	0 81	+0 68	A0	.
143	10 86	0 69	+0 43	A0		198	10 06	0 95	−0 14	OB	n
144	12 09	0 97	+0 44			199	10 84	0 73	+0 59	A0	
145	11 14	0 81	+0 49			200	12 50	1 10	+0 61	.	.
146	12 03	1 11	+0 49			201	12 95	2 17	. .	. ..	n
147	11 91	0 90	+0 48			202	12 55	0 96	+0 32	... ..	.
148	12 20	2 10	.		n	203	12 81	1 04	+0 77	.	.
149	11 02	1 67	+1 65		n	204	11.46	1 15	−0 11	...	n
150	12 88	1 02	+0 19		n	205	10 65	0 77	+0 67	A5:	
151	12 59	1 22	+0 72			206	12 18	1 01	+0 60	. .	.
152	11 39	0 95	+0 51			207	11 66	0 91	−0 06	...	n
153	11 17	0 78	+0 46			208	11 34	0 81	+0.15	...	n
154	12 01	1.05	+0 44			209	11 98	0 87	+0 69	...	...
155	11 88	0 93	+0 47								

Perseus double cluster, which was present on the plates, was included in the measuring program. The magnitudes for the sequence were taken from Becker's paper (1950). The red and ultraviolet magnitudes were corrected to obtain colors with the international zero point. The mean errors of the final data are given in Table 1. Systematic errors in the colors and magnitudes may be present because of field errors affecting the transfer from the h and χ Per clusters to the new cluster area. No provisions were made to determine field errors, as all the stars measured were within a region of 30′ in radius. Spectral types for the brighter stars in the area were estimated on one objective-prism plate. The complete data for this cluster are given in Table 3. The numbers refer to Figure 3.

The two color-magnitude diagrams for the new cluster in Perseus, which are shown in Figure 4, exhibit a normal main sequence, but with considerable scatter. The scatter exceeds the mean errors by so much that it must be considered to be real. It is possibly

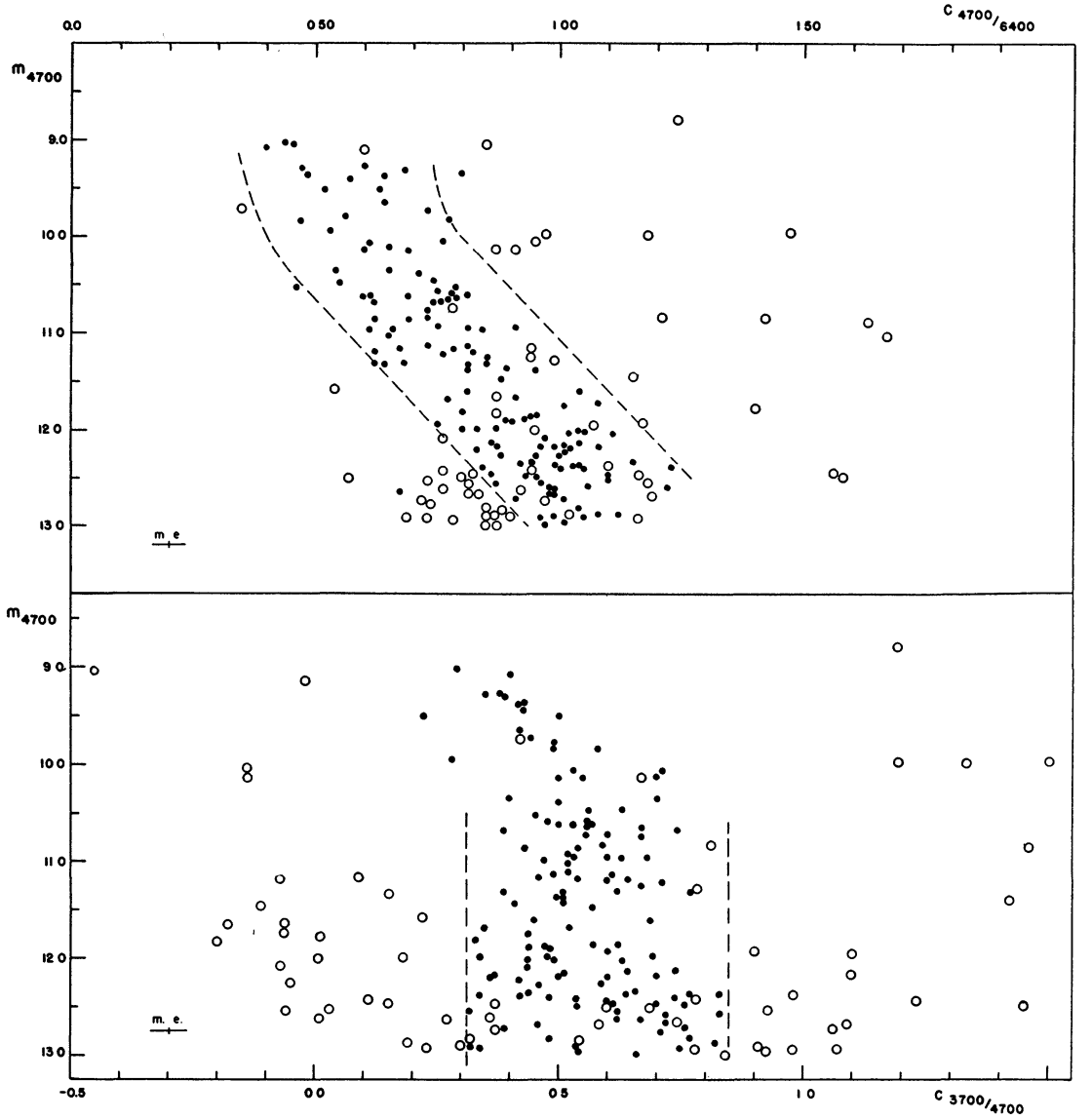

FIG. 4.—Color-magnitude diagrams of the cluster in Perseus. Open circles are stars not belonging to the cluster. The lines (m. e.) in the lower left of both diagrams represent the mean errors of magnitudes and colors. For the dashed curves see text.

produced by irregular absorption covering the cluster. This was already concluded from the spectral plate, where stars of the same spectral type were found over a range of several magnitudes. Because of the scattering, it is not possible to establish cluster membership for individual stars. Those definitely not belonging to the main sequence of the cluster may, however, be segregated. Stars which fall outside the dashed curves in one or both diagrams are considered not to be cluster members. They were plotted as open circles and indicated by the letter "n" in the last column of Table 3.

The distance of this main-sequence cluster may be estimated from the color-magnitude diagrams, even if some systematic errors in the photometric data are present. With the color excesses $E_{4700/6400} = 0.52$ mag. and $E_{3700/4700} = 0.38$ mag., and a ratio of absorption to combined color excesses of 1.63, as given by Becker and Stock (1954), a total absorption at 4700 A of 1.5 mag. is found. Comparison of the lower diagram in Figure 4 with Figure 2*b* of Becker and Stock (1954) yields a distance modulus of $m - M = 7.5$ mag., where the correction for absorption has been taken into account. It is of interest to note that the absorption found for this cluster is identical with that determined for the Perseus double cluster (Becker 1950). The diameter of the cluster comes out to be 7 pc, if its apparent diameter is assumed to be 80′. The area investigated covers a diameter of only 60′; however, some more A-type stars may be found outside this area.

Attention may be called to the OB stars found in the area. Spectra are available for four such stars. The following stars of Table 3 are also suspected to be of class OB on the basis of their colors: 5, 8, 44, 49, 85, 89, 121, 138, 141, 161, 177, 204, 207.

REFERENCES

Becker, W. 1946, *Veröff. Sternw. Göttingen*, No. 79.
———. 1950, *Zs. f. Ap.*, **30**, 164.
Becker, W., and Stock, J. 1951, *Zs. f. Ap.*, **31**, 153.
Blanco, V. M. 1954, *A.J.*, **59**, 396.
Gonzalez, G., and Gonzalez, G. 1954, *Bol. Obs. Tonanzintla y Tacubaya*, **9**, 21.
Stock, J. 1954, *A.J.*, **59**, 332.