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THE OPEN CLUSTER NGC 6716

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ABSTRACT

NGC 6716 is a young open star cluster in Sagittarius. Lindoff (1971) obtained photoelectric photometry for 12 stars and photographic *UBV* photometry for 115 stars in the cluster field down to $V = 13.8$. We have expanded this work to include more photoelectric standards and iris photometry for 332 stars in the cluster field down to $V = 16$. We derive a reddening $E(B-V) = 0.17$ mag, a distance modulus of 8.69 ± 0.15 mag ($d = 547$ pc), and an age of around 100 million years for the cluster. Of the stars studied, 75 were judged as likely cluster members, 63 as possible members, and 194 as probable nonmembers.

Key words: photometry–open clusters–stellar evolution

1. Introduction

NGC 6716, also called Collinder 393, is a poorly concentrated open cluster (concentration class IV 1p; Ruprecht 1966) located at R.A. = $18^h51^m.6$, Dec. = $-19°58'$, and galactic coordinates $\ell = 15°.4$, $b = -9°.6$ (epoch 1950). Trumpler (1930) estimated the distance as 1320 pc and found a spectral population of primarily B5–B8 main-sequence stars. Collinder (1931) revised the distance estimate to 950 pc. Through photographic photometry and an improved estimate of reddening, Barhatova (1950) derived a distance of 760 pc.

Lindoff (1971) established 12 photoelectric standards in the range $V = 8.28$–13.29 in the cluster field as a calibration sequence for *UBV* photographic photometry of 115 stars to $V = 13.79$. He obtained $E(B-V) = 0.13$ mag, $A_v = 0.4$ mag, a distance of about 600 pc, and an age around 150 million years.

There are other stars within 15″–20″ of some of Lindoff's photoelectric standards. With the small number of standards there is a risk of significant calibration error. It seemed worthwhile to expand the standards list and to obtain photographic photometry for the fainter stars in the cluster field.

2. Photoelectric Photometry

Lindoff divided the cluster field into five concentric regions: a central circle 2′ in radius and four rings each 2′ thick. He assigned the brighter stars numbers from 1–115 working counterclockwise outward from the central circle. We added more stars in each region for a total of 417 stars. An identification chart of the cluster, adapted from Lindoff's original Figure 5, is shown as Figure 1.

UBV photoelectric photometry of 27 stars in the field of NGC 6716 was carried out over nine nights in 1986, two nights in 1987, and seven nights in 1988 at the Mount Laguna Observatory of San Diego State University. Observations of stars brighter than $V = 14$ were made with the 0.61-m Smith telescope, while fainter stars were observed with the 1.0-m telescope. EMI 6256 photomultipliers, cooled to −10° C and run at 1300 volts, were used. Apertures of 36″ or 48″ were used with the 0.61-m telescope, to minimize the effects of image excursion and seeing; a 31″ aperture was used with the 1.0-m telescope. *UBV* standard and extinction stars were selected from the lists of Crawford and Golson (1971), McClure (1976), and Landolt (1983). Because of the southern declination of the cluster, we only observed NGC 6716 when it was within about one hour either side of the meridian; its meridian air mass is $X = 1.65$. To improve accuracy, multiple observations were made in each filter, star centering in the aperture was periodically checked, and a second observational sequence was taken for the fainter stars. Some photoelectric standards were observed at air masses comparable to that of the cluster, to allow more direct brightness comparisons, while others were observed at lower air masses for accurate transformation coefficients; typical transformation errors are ± 0.010 mag in V, 0.012 mag in $(B-V)$, and 0.024 mag in $(U-B)$.

Table 1 displays the photoelectric information on the

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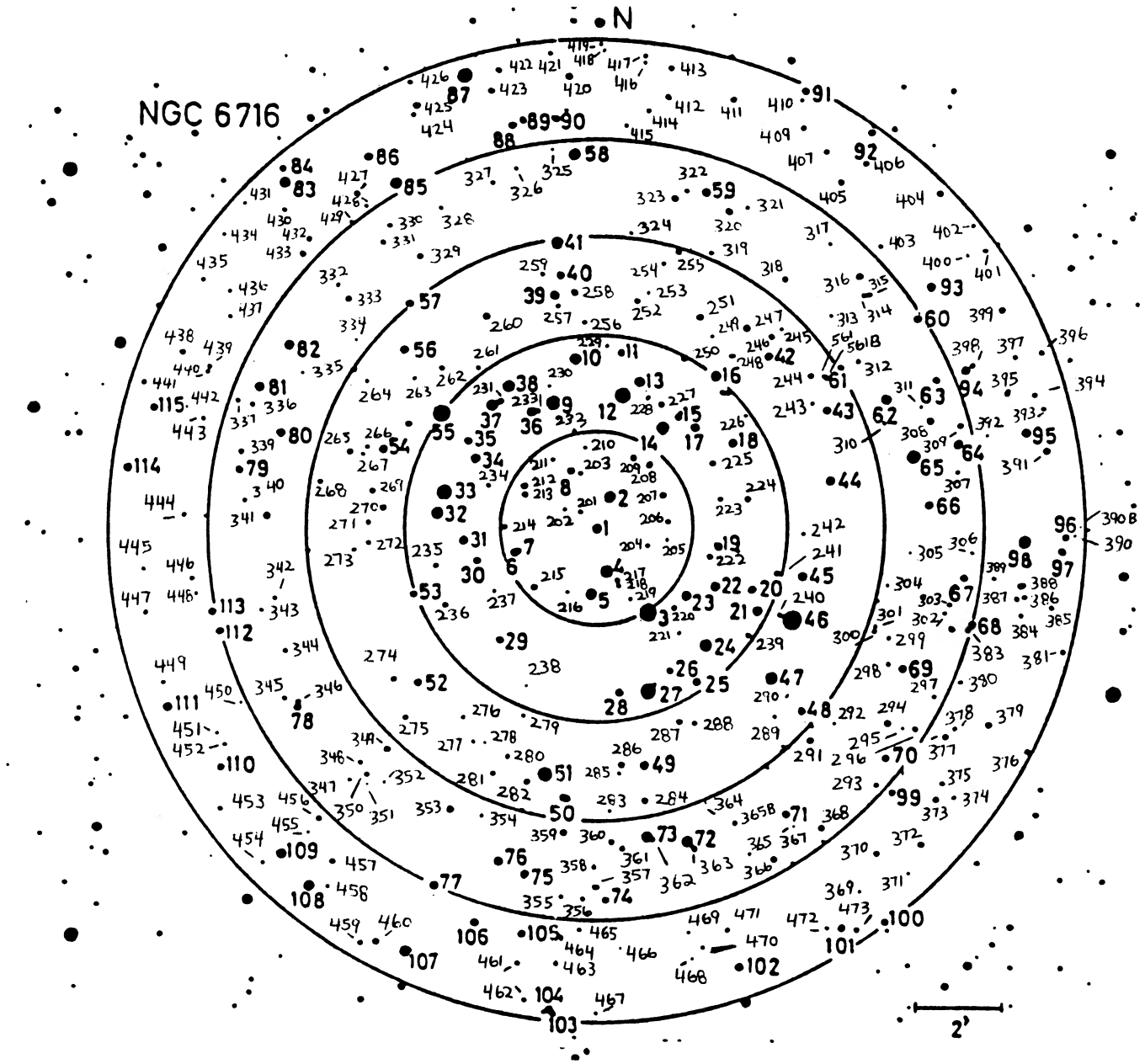

FIG. 1–Identification chart for stars in NGC 6716.

standard stars. The standard stars lie in the range V = 8.30–15.54, with most observed on two different nights.

3. Photographic Photometry

Five plates of NGC 6716 were taken in 1976 by Freddie Talbert of San Diego State University, using the Naval Observatory 1.5-m telescope in Flagstaff, Arizona. The material consists of two V plates (20-min exposures), two B plates (10 min each), and one U plate (64 min). The image quality appears good on all the plates.

Image diameters were measured using a Cuffey-type iris photometer (Cuffey 1956) in the Astronomy Department laboratory at San Diego State. The photometer was always turned on at least three hours before use, to allow the electrical components to stabilize and reach peak sensitivity. Photoelectric standards were measured throughout a session, with some measured both at beginning and end to check for instrumental drift; such drift was found to be nominal, equivalent to less than 0.03 mag over several hours. Typical scatter in the photographic calibrations is ± 0.05 mag. A few stars, such as numbers 8 and 87, had close companions and were not measured.

U, B, V magnitude and color-index data derived from the photographic photometry are listed in Table 2. The

TABLE 1

Photoelectric Standards in NGC 6716

Star	Region	V	B	U	B-V	U-B	Remarks
1	1	12.97	14.01	14.41	1.05	0.40	p.n.m.
2	1	11.70	11.96	12.11	0.26	0.15	member
3	2	9.16	9.22	8.98	0.06	-0.24	member
4	1	11.08	11.26	11.45	0.19	0.19	member
9	2	10.63	10.88	11.02	0.25	0.14	member
18	2	12.23	13.81	13.91	1.58	0.10	n.m.
20	2	13.09	13.60	13.54	0.50	-0.06	member
21	2	12.22	12.86	12.93	0.65	0.06	member
22	2	12.65	13.73	14.60	1.08	0.87	p.n.m.
24	2	11.38	12.95	14.83	1.56	1.89	n.m.
25	2	12.95	13.56	13.73	0.61	0.16	member
27	2	9.79	9.83	9.53	0.04	-0.30	member
30	2	13.64	14.30	14.28	0.66	-0.02	member
31	2	13.01	14.62	16.31	1.61	1.69	n.m.
35	2	13.35	13.84	13.84	0.49	0.00	p.m.
46	3	8.30	8.33	7.93	0.03	-0.40	member
55	2	9.23	9.34	9.07	0.12	-0.27	member
63	4	13.65	14.78	15.50	1.12	0.72	p.n.m.
65	4	10.80	10.96	11.04	0.16	0.06	member
71	4	13.23	13.71	13.88	0.49	0.17	member
83	5	11.59	11.85	12.08	0.26	0.23	member
98	5	11.38	12.09	12.32	0.71	0.24	member
224	2	14.48	15.07	15.30	0.59	0.24	p.n.m.
242	3	15.01	15.99	16.92	0.97	0.93	poss.
256	3	15.54	16.21	16.02	0.67	-0.19	n.m.
275	3	14.49	15.45	16.41	0.96	0.96	poss.
329	4	14.67	15.36	15.88	0.69	0.52	poss.

member = cluster member
p.m. = probable member
poss. = possible member
p.n.m. = probable non-member
n.m. = non-member

criteria used to assign cluster membership will be discussed below.

4. Cluster Properties

That NGC 6716 lies in a crowded part of the Milky Way is evident from Figures 2 through 5, which display color-magnitude and color-color diagrams (hereafter, CMD and CCD). Considerable field-star contamination is contributed especially by stars in the outer two rings. A main sequence is also present, traceable down to at least $V = 14$ on the CMD and to $(B-V) = 1.5$ on the CCD. No red stars comparable in brightness to the brightest main-sequence stars were found in the 20′ field studied.

The zero-age main sequence (ZAMS) of Mermilliod (1981) was fitted to the CMD and CCD for stars in the central region and the first two rings to determine reddening, distance modulus, and age. The photometic data are not inconsistent with a reddening of $E(B-V) = 0.17 \pm 0.03$ mag. FitzGerald (1968) derived a color excess of 0.1–0.2 mag for objects at 500 pc distance in this region from star counts. If we assume that $R = 3.0$, then $A_v = 0.51$ mag. The apparent distance modulus of the cluster is 9.20 ± 0.15 mag; with the derived visual absorption, $(m-M)_0 = 8.69 \pm 0.15$ mag, corresponding to a distance of 547 ± 38 pc. The most luminous star in the cluster (star 46, HD 175043; B7 IV) then has an absolute magnitude $M_v = -0.9$.

To be considered a likely member of NGC 6716, the apparent magnitude and color indices of a star had to place it within ± 0.3 mag in V and ± 0.1 mag in each color index of the ZAMS on **BOTH** the CMD and CCD. Possible members were considered to be stars near the ZAMS, but not within the above tolerances, on both diagrams. In cases where a star was close to the ZAMS on one diagram but not the other, or where $(U-B)$ was not available, a decision was made with greater weight being assigned to the CMD position.

In Table 3 the relative numbers of likely members, possible members, and probable nonmembers are listed by region. The percentage to which each number corresponds is listed next to it in parentheses.

NGC 6716 appears to have a main-sequence turnoff

TABLE 2

Photographically Measured Stars in NGC 6716

Star	Region	V	B	U	B-V	U-B	Remarks
5	1	11.91	12.37	12.45	0.46	0.08	member
6	1	13.06	14.78	14.36	1.72	-0.42	n.m.
7	1	13.85	14.41	16.58	0.56	2.18	poss.
10	2	11.74	12.89	13.64	1.14	0.76	p.n.m.
11	2	13.62	14.17	14.10	0.54	-0.07	p.m.
12	2	10.07	10.15	10.02	0.09	-0.13	member
13	2	12.27	12.79	12.84	0.52	0.05	member
14	2	11.09	11.27	11.37	0.17	0.10	member
15	2	14.48	14.62	14.43	0.14	-0.19	p.n.m.
15B	2	15.61	16.41	16.28	0.81	-0.13	poss.
16	2	11.98	12.40	12.53	0.42	0.13	member
16B	2	14.83	15.26	15.14	0.43	-0.12	p.n.m.
16C	2	14.83	15.23	15.05	0.39	-0.18	p.n.m.
17	2	12.60	13.23	13.29	0.64	0.05	member
19	2	12.90	14.84	14.91	1.94	0.07	n.m.
23	2	12.20	12.74	12.78	0.54	0.04	member
26	2	13.98	14.44	14.41	0.47	-0.03	p.m.
27B	2	15.87	16.28	16.11	0.40	-0.16	p.n.m.
28	2	13.55	14.96	16.18	1.41	1.22	p.n.m.
29	2	13.79	14.32	14.28	0.53	-0.04	p.m.
32	2	11.12	11.41	11.46	0.29	0.04	member
33	2	10.07	10.11	9.78	0.05	-0.33	member
34	2	12.40	13.76	14.76	1.36	1.00	p.n.m.
36	2	12.85	13.41	13.44	0.57	0.03	member
37	2	11.61	12.01	12.18	0.40	0.17	member
38	2	11.63	12.03	12.15	0.40	0.11	member
39	3	12.44	13.70	14.91	1.25	1.21	p.n.m.
40	3	13.28	14.79	15.99	1.50	1.20	p.n.m.
41	3	11.21	11.39	11.53	0.18	0.14	member
42	3	13.70	15.26	15.65	1.55	0.39	n.m.
43	3	13.40	14.86	16.07	1.45	1.21	p.n.m.
44	3	12.87	14.45	15.95	1.59	1.50	p.n.m.
45	3	12.50	14.04	15.46	1.53	1.42	p.n.m.
47	3	11.38	11.70	11.83	0.32	0.13	member
48	3	13.59	14.53	15.06	0.94	0.53	member
49	3	12.59	14.40	16.18	1.81	1.78	n.m.
50	3	13.09	14.46	15.05	1.37	0.60	n.m.
50B	3	13.94	14.68	15.88	0.73	1.20	poss.
51	3	10.38	12.06	14.07	1.68	2.01	n.m.
52	3	13.31	14.82	14.23	1.50	-0.59	n.m.
53	3	13.80	15.14	15.12	1.34	-0.12	n.m.
54	3	13.01	13.58	13.47	0.57	-0.10	member
56	3	13.11	14.55	14.75	1.45	0.20	n.m.
57	4	12.83	15.41	15.91	2.58	0.50	n.m.
58	4	11.46	12.44	13.02	0.99	0.58	p.n.m.
59	4	12.69	13.43	13.61	0.75	0.18	p.m.
60	4	13.49	14.97	16.26	1.48	1.29	p.n.m.
61	4	13.97	14.96	15.26	1.00	0.29	poss.
62	4	12.16	13.40	15.28	1.31	1.81	n.m.
64	4	12.47	12.98	13.08	0.51	0.10	member
66	4	13.04	13.70	13.78	0.67	0.08	member
67	4	13.47	15.39	16.30	1.92	0.91	n.m.
68	4	13.09	13.71	13.57	0.62	-0.14	member
69	4	13.09	14.59	15.56	1.50	0.98	p.n.m.
70	4	13.83	14.55	14.62	0.72	0.07	member
72	4	11.36	11.72	11.82	0.37	0.10	member
73	4	11.74	12.20	12.32	0.45	0.12	member
74	4	13.79	14.99	15.85	1.20	0.86	p.n.m.
75	4	12.92	13.62	13.60	0.70	-0.02	p.m.
76	4	12.29	14.11	15.47	1.82	1.36	p.n.m.
77	4	12.43	12.70	13.24	0.33	0.47	poss.
78	4	13.46	13.93	13.84	0.47	-0.09	p.m.
79	4	13.29	15.19	-----	1.90	-----	p.n.m.
80	4	12.67	13.38	13.44	0.70	0.06	p.m.
81	4	12.39	13.88	15.34	1.49	-0.54	n.m.
82	4	12.30	13.80	15.20	1.45	1.44	p.n.m.
84	5	13.65	15.03	16.02	1.38	0.99	p.n.m.
85	5	11.30	11.84	11.97	0.54	0.13	p.m.
86	5	13.12	14.55	15.95	1.44	1.40	p.n.m.
88	5	13.67	15.02	16.53	1.35	1.51	n.m.
89	5	13.55	15.63	16.97	2.08	1.34	p.n.m.
90	5	13.21	15.06	16.69	1.85	1.62	n.m.
93	5	12.50	14.31	16.29	1.81	1.98	n.m.
94	5	12.75	13.31	13.37	0.57	0.05	member
95	5	12.48	13.80	14.54	1.30	0.76	p.n.m.
96	5	13.18	14.25	14.91	1.07	0.66	p.n.m.
97	5	13.53	15.37	16.70	1.85	1.32	p.n.m.
97B	5	15.63	16.97	-----	1.34	-----	p.n.m.
98B	5	14.81	16.26	-----	1.46	-----	p.n.m.
99	5	13.53	15.30	14.66	1.77	-0.63	n.m.
100	5	13.43	14.13	14.06	0.70	-0.08	member
101	5	13.89	14.51	16.55	0.62	2.04	poss.
102	5	12.65	13.41	13.41	0.77	0.00	member
103	5	13.61	15.53	-----	1.91	-----	p.n.m.
104	5	12.37	14.25	15.63	1.87	1.38	p.n.m.
105	5	13.33	14.79	15.93	1.46	1.14	p.n.m.
108	5	11.37	13.13	15.01	1.75	1.88	n.m.
109	5	11.90	13.15	13.85	1.25	0.70	p.n.m.
110	5	13.26	15.35	15.34	2.09	-0.02	n.m.
111	5	12.17	12.66	12.66	0.49	0.00	member
112	5	13.10	13.62	13.57	0.51	-0.05	member
113	5	13.41	14.20	14.45	0.80	0.24	member
114	5	12.25	13.63	15.43	1.38	1.80	n.m.
201	1	15.57	16.14	-----	0.57	-----	p.n.m.
202	1	15.75	16.59	-----	0.84	-----	poss.
203	1	15.33	15.78	16.43	0.45	0.65	n.m.
204	1	15.54	16.28	16.20	0.74	-0.08	poss.
205	1	15.72	16.58	16.39	0.86	-0.19	poss.
206	1	15.42	15.90	15.60	0.48	-0.30	n.m.
207	1	14.76	15.90	16.45	1.14	0.55	poss.
209	1	14.79	15.46	15.33	0.67	-0.13	poss.
210	1	15.65	16.69	-----	1.04	-----	poss.
211	1	15.65	16.53	-----	0.88	-----	poss.
212	1	14.26	15.98	-----	1.72	-----	p.n.m.
213	1	14.97	16.48	-----	1.51	-----	p.n.m.
214	1	14.59	15.68	16.51	1.09	0.83	p.m.

TABLE 2 (continued)

Star	Region	V	B	U	B-V	U-B	Remarks
215	1	14.43	14.70	14.61	0.27	-0.09	p.n.m.
216	1	15.67	17.10	-----	1.43	-----	p.n.m.
217	1	14.52	15.89	-----	1.37	-----	p.n.m.
218	1	15.44	15.87	16.09	0.43	0.22	p.n.m.
219	1	15.55	16.63	16.85	1.08	0.22	poss.
220	2	14.72	15.20	15.22	0.47	0.02	p.n.m.
221	2	15.51	16.23	16.36	0.72	0.13	p.m.
222	2	14.50	14.93	16.27	0.44	1.33	n.m.
223	2	15.50	16.49	-----	0.99	-----	poss.
226	2	15.76	16.27	16.43	0.52	0.15	p.n.m.
227	2	14.75	15.15	14.83	0.40	-0.32	n.m.
228	2	15.43	15.63	15.45	0.20	-0.19	p.n.m.
229	2	15.66	16.72	16.82	1.06	0.10	poss.
230	2	15.66	16.43	16.31	0.77	-0.12	p.n.m.
231	2	14.75	16.19	-----	1.44	-----	p.n.m.
232	2	15.32	15.97	-----	0.65	-----	p.n.m.
233	2	15.26	16.25	16.49	0.99	0.23	p.m.
234	2	15.27	15.95	16.03	0.68	0.08	p.n.m.
235	2	14.95	15.96	16.11	1.01	0.15	p.m.
236	2	14.67	15.11	16.23	0.44	1.12	n.m.
238	2	15.35	16.40	-----	1.05	-----	poss.
239	2	14.54	15.26	-----	0.72	-----	poss.
240	2	14.85	16.02	16.73	1.17	0.71	p.m.
241	2	14.89	16.62	-----	1.74	-----	p.n.m.
243	3	15.53	16.02	15.71	0.50	-0.31	p.n.m.
244	3	15.05	15.36	15.44	0.31	0.08	p.n.m.
245	3	15.56	16.35	16.04	0.79	-0.31	p.m.
246	3	15.00	15.73	15.04	0.74	-0.70	poss.
247	3	14.24	14.96	15.31	0.72	0.35	member
251	3	14.32	15.14	16.10	0.82	0.96	poss.
252	3	15.23	16.42	16.60	1.20	0.17	n.m.
253	3	15.71	16.66	16.37	0.95	-0.29	poss.
254	3	15.60	16.52	16.51	0.92	-0.02	poss.
255	3	14.41	14.94	14.96	0.54	0.02	p.n.m.
257	3	15.43	16.54	16.79	1.11	0.25	poss.
258	3	14.19	15.59	16.50	1.40	0.91	p.n.m.
259	3	15.83	16.62	16.80	0.80	0.17	p.m.
260	3	14.05	14.46	16.07	0.41	1.61	n.m.
261	3	15.68	16.33	16.30	0.66	-0.03	p.n.m.
262	3	15.12	16.18	16.24	1.06	0.06	poss.
263	3	15.67	16.35	15.91	0.68	-0.44	n.m.
264	3	15.51	16.61	16.82	1.10	0.21	poss.
265	3	14.65	15.75	16.44	1.10	0.69	p.m.
266	3	15.59	16.65	16.69	1.07	0.03	poss.
267	3	15.57	16.69	16.85	1.11	0.16	poss.
268	3	15.14	15.97	-----	0.82	-----	poss.
269	3	15.04	16.35	16.46	1.31	0.10	n.m.
270	3	14.35	14.64	16.78	0.30	0.13	p.n.m.
271	3	15.30	16.35	16.66	1.05	0.31	p.m.
272	3	15.13	16.91	16.00	1.79	-0.91	n.m.
273	3	15.53	16.32	15.50	0.80	-0.82	poss.
274	3	14.58	15.04	16.29	0.46	1.25	n.m.
276	3	15.52	16.98	16.54	1.46	-0.44	n.m.
277	3	15.49	17.00	16.64	1.51	-0.36	n.m.
278	3	15.10	16.85	16.59	1.75	-0.26	n.m.
281	3	14.64	16.16	16.29	1.53	0.12	n.m.
282	3	14.45	14.90	14.88	0.46	-0.02	p.n.m.
283	3	15.58	16.42	16.53	0.85	0.11	member
284	3	14.29	14.78	14.78	0.49	0.00	p.n.m.
286	3	14.67	15.19	15.14	0.52	-0.05	p.n.m.
287	3	14.51	15.83	16.65	1.31	0.82	p.n.m.
288	3	15.36	16.33	16.59	1.28	0.26	n.m.
289	3	15.51	16.15	16.07	0.59	-0.08	p.n.m.
290	3	15.98	15.83	15.34	-0.15	-0.49	n.m.
291	4	13.81	14.96	15.06	1.14	0.10	n.m.
292	4	15.56	16.18	15.94	0.63	-0.24	p.n.m.
293	4	15.10	15.72	15.50	0.63	-0.22	p.n.m.
294	4	14.10	14.60	14.59	0.49	-0.01	p.n.m.
295	4	15.48	16.07	16.08	0.59	0.01	p.n.m.
297	4	15.42	16.29	16.21	0.86	-0.07	poss.
298	4	15.50	16.85	16.24	1.35	-0.61	n.m.
299	4	15.43	15.77	16.32	0.34	0.55	n.m.
300	4	14.84	15.56	16.76	0.71	0.20	p.m.
302	4	15.51	16.19	16.09	0.68	-0.10	p.n.m.
303	4	15.16	16.36	16.73	1.20	0.37	n.m.
304	4	15.14	16.43	16.37	1.30	-0.06	n.m.
307	4	15.31	15.66	15.78	0.36	0.11	p.n.m.
308	4	14.18	15.44	16.32	1.27	0.87	p.n.m.
309	4	14.78	15.35	15.28	0.51	-0.07	p.n.m.
310	4	15.28	16.24	16.35	0.96	0.06	poss.
311	4	15.78	16.37	16.15	0.60	-0.22	n.m.
312	4	15.16	15.48	15.22	0.32	-0.26	n.m.
313	4	15.63	16.06	15.74	0.42	-0.32	n.m.
314	4	15.00	16.34	16.43	1.34	0.09	n.m.
315	4	15.10	16.01	16.29	0.91	0.28	member
316	4	14.07	14.60	14.55	0.72	-0.01	member
317	4	15.69	16.15	15.69	0.46	-0.46	n.m.
319	4	15.13	16.51	-----	1.20	-----	p.n.m.
320	4	14.09	15.62	15.61	1.54	-0.02	n.m.
321	4	15.45	15.63	16.25	0.19	0.61	n.m.
322	4	15.03	16.15	16.52	1.12	0.37	poss.
323	4	14.10	15.04	15.40	0.95	0.35	member
324	4	15.48	16.69	-----	1.21	-----	poss.
325	4	15.69	16.25	15.97	0.56	-0.28	n.m.
326	4	15.38	16.28	16.55	0.91	0.26	member
327	4	15.53	15.87	15.66	0.44	-0.21	n.m.
328	4	15.65	16.64	-----	0.99	-----	poss.
330	4	15.26	16.17	16.46	0.91	0.29	member
331	4	15.26	16.42	16.80	1.17	0.37	poss.
332	4	15.61	15.98	15.93	0.37	-0.05	p.n.m.
333	4	15.11	14.94	14.79	-0.18	-0.15	n.m.
336	4	15.06	16.46	16.64	1.40	0.17	n.m.
337	4	15.07	16.07	16.58	1.00	0.51	member
339	4	14.65	16.30	-----	1.65	-----	p.n.m.
340	4	15.39	16.41	16.53	1.03	0.12	poss.
341	4	13.95	15.41	16.54	1.45	1.13	p.n.m.
342	4	15.49	16.13	16.03	0.64	-0.10	p.n.m.
343	4	15.28	15.80	15.49	0.53	-0.31	n.m.

TABLE 2 (continued)

Star	Region	V	B	U	B-V	U-B	Remarks
344	4	15.43	15.99	15.83	0.55	-0.16	p.n.m.
345	4	15.21	15.74	15.67	0.52	-0.07	p.n.m.
346	4	14.73	15.34	15.44	0.61	0.10	p.n.m.
352	4	15.68	16.62	16.18	0.93	-0.44	poss.
353	4	14.03	15.64	16.55	1.62	0.90	n.m.
354	4	15.49	16.38	16.34	1.89	-0.04	n.m.
355	4	15.10	15.51	15.17	0.46	-0.34	n.m.
356	4	15.06	16.11	16.55	0.06	0.43	n.m.
357	4	14.88	15.98	16.33	1.10	0.35	poss.
357B	4	15.99	16.80	16.65	0.81	-0.14	n.m.
358	4	15.57	16.78	16.60	1.20	-0.18	poss.
359	4	14.10	15.35	-----	1.25	-----	p.n.m.
360	4	14.61	15.13	15.00	0.52	-0.13	p.n.m.
361	4	14.58	15.68	16.38	1.11	0.70	p.n.m.
362	4	14.85	15.40	15.34	0.55	-0.06	p.n.m.
363	4	14.13	14.76	14.75	0.63	-0.10	p.m.
363B	4	15.54	16.64	16.92	1.11	0.27	poss.
364	4	15.55	15.90	15.99	0.35	0.08	p.n.m.
366	4	14.34	16.15	16.74	1.81	0.59	n.m
370	5	14.68	15.13	15.07	0.45	-0.06	p.n.m.
373	5	14.10	14.75	16.82	0.65	2.07	poss.
374	5	15.23	16.84	15.90	1.60	-0.94	n.m.
375	5	15.09	16.32	16.69	1.23	0.37	n.m.
382	5	14.27	15.72	16.60	1.45	0.87	n.m.
383	5	14.33	15.20	15.24	0.87	0.04	poss.
384	5	15.22	16.90	16.48	1.68	-0.42	n.m.
386	5	14.82	16.69	16.78	1.87	0.09	n.m.
387	5	14.96	16.20	16.56	1.24	0.36	n.m.
388	5	14.19	15.66	-----	1.47	-----	p.n.m.
389	5	15.37	16.20	16.12	0.84	-0.09	poss.
390	5	15.30	15.74	15.55	0.45	-0.20	n.m.
391	5	13.85	15.41	16.50	1.56	0.08	n.m.
393	5	15.01	15.67	15.69	0.66	0.02	p.n.m.
394	5	15.11	16.37	16.74	1.26	0.36	n.m.
395	5	14.70	15.64	15.86	0.94	0.21	p.m.
395B	5	15.69	16.33	16.11	0.64	-0.22	p.n.m.
397	5	15.57	16.83	-----	1.25	-----	poss.
398	5	14.82	16.25	-----	1.43	-----	p.n.m.
403	5	15.42	16.67	15.76	1.24	-0.91	n.m.
404	5	14.21	15.86	16.29	1.65	0.42	n.m.
405	5	14.46	15.50	-----	1.03	-----	poss.
408	5	13.61	14.28	-----	0.68	-----	poss.
411	5	14.96	16.43	-----	1.47	-----	p.n.m.
412	5	15.19	16.14	15.91	0.95	-0.23	poss.
413	5	14.92	16.41	-----	1.49	-----	p.n.m.
414	5	15.48	16.08	-----	0.59	-----	p.n.m.
415	5	15.52	16.21	-----	0.69	-----	p.n.m.
416	5	15.61	16.50	16.47	0.88	-0.03	p.m.
417	5	15.35	16.74	16.59	1.38	-0.15	n.m.
420	5	14.08	15.50	16.42	1.42	0.91	p.n.m.
421	5	15.57	16.62	16.69	1.05	0.07	poss.
422	5	14.58	15.11	15.00	0.54	0.11	p.n.m.
423	5	14.43	16.26	14.95	1.83	-1.31	n.m.
426	5	14.71	15.37	-----	0.66	-----	poss.
427	5	14.90	16.14	16.62	1.25	0.47	n.m.
428	5	15.46	16.49	16.49	1.04	0.00	poss.
429	5	15.33	16.75	16.83	1.41	0.08	n.m.
430	5	15.44	16.14	16.01	0.70	-0.13	p.n.m.
432	5	14.74	16.12	16.59	1.38	0.47	n.m.
433	5	14.52	15.86	16.69	1.35	0.82	p.n.m.
436	5	15.25	16.18	16.02	0.93	-0.16	poss.
437	5	15.45	16.32	16.01	0.88	-0.31	poss.
438	5	14.62	15.59	16.16	0.96	0.57	member
439	5	15.07	15.70	15.65	0.63	-0.05	p.n.m.
442	5	15.50	16.56	-----	1.07	-----	poss.
444	5	15.20	15.90	-----	0.70	-----	p.n.m.
445	5	15.37	16.81	16.14	1.43	-0.67	n.m.
446	5	15.20	16.54	-----	1.34	-----	p.n.m.
447	5	15.08	15.72	15.44	0.64	-0.28	n.m.
448	5	15.70	15.83	-----	0.13	-----	p.n.m.
449	5	15.26	16.40	16.71	1.14	0.31	poss.
450	5	16.04	16.75	16.53	0.71	-0.22	n.m.
451	5	15.68	16.47	16.05	0.80	-0.42	poss.
452	5	15.14	16.12	16.17	0.90	0.05	p.m.
453	5	14.72	15.34	16.43	0.70	0.91	poss.
454	5	15.50	16.92	16.30	1.41	-0.62	n.m.
457	5	14.76	16.31	16.29	1.45	-0.02	n.m.
458	5	15.33	16.19	15.97	0.85	-0.22	poss.
459	5	15.03	16.30	-----	1.28	-----	p.n.m.
462	5	15.33	16.70	-----	1.37	-----	p.n.m.
463	5	15.39	16.87	-----	1.48	-----	p.n.m.
464	5	15.40	16.38	16.30	0.97	-0.08	poss.
465	5	15.23	16.35	16.00	1.11	-0.35	poss.
467	5	15.35	15.78	-----	0.42	-----	p.n.m.
468	5	15.94	16.18	-----	0.24	-----	p.n.m.
469	5	15.50	16.75	-----	1.26	-----	p.n.m.
470	5	15.26	16.65	-----	1.38	-----	p.n.m.
471	5	15.20	16.77	-----	1.58	-----	p.n.m.
472	5	15.26	16.34	16.48	1.07	0.14	poss.
473	5	14.50	16.31	-----	1.81	-----	p.n.m.
561	2	14.21	14.69	14.65	0.48	-0.04	p.n.m.

member = cluster member
p.m. = probable member
poss. = possible member
p.n.m. = probable non-member
n.m. = non-member

around $M_v = +0.6$ and $(B-V)_0 = -0.1$. The cluster is sparse, which makes isochrone fitting more uncertain, but its CMD is not very different from other clusters in the 50–150 million-year range. The cluster NGC 6405

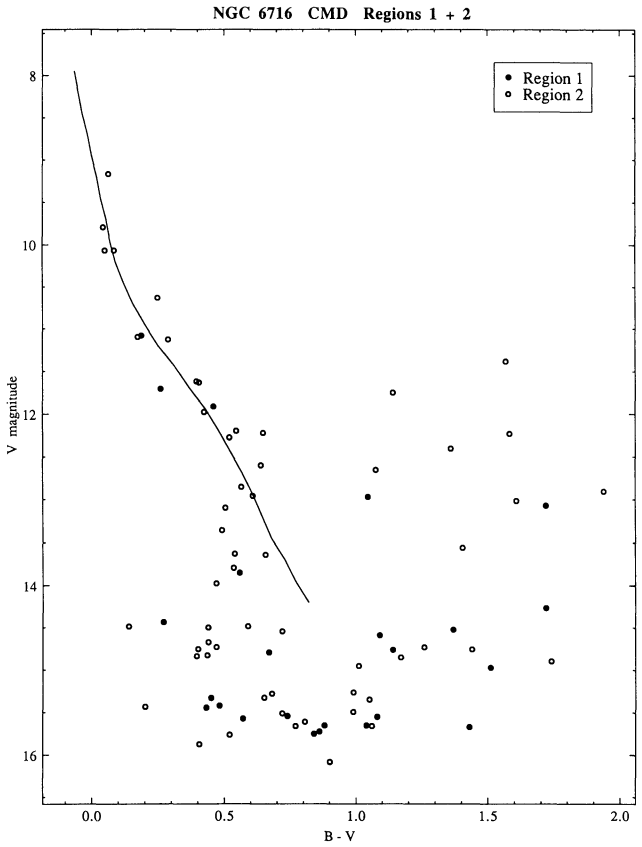

FIG. 2–Color-magnitude diagram, stars in the two innermost regions. The ZAMS of Mermilliod (1981), adjusted for reddening and distance, is also plotted.

(Messier 6) has a similar turnoff and an estimated age of 60 ± 10 million years (Barbaro, Dallaporta, and Fabrio 1969), but its luminous stars extend to $M_v = -3$; therefore, NGC 6716 is probably somewhat older. The isochrones of Maeder and Mermilliod (1981) and Mermilliod (1981) are based on stellar models incorporating a nonlocal treatment of core convection and the CMDs of 75 young open clusters in 14 age groups; from these we derive an age of $(1.05 \pm 0.20) \times 10^8$ years for NGC 6716 if its chemical composition is solar.

5. Discussion

Physical properties of astrophysical interest for NGC 6716 are gathered in Table 4. Our results in general agree with those from the earlier work by Lindoff. We have extended the observational sample to 332 stars and a limit of $V = 16$.

One important piece of information still missing from the discussion is the cluster metallicity. We had intended to obtain four-color photometry of F and late-A stars in the cluster, as a supplement to the primary observing program, but we were hampered by bad weather and a deterioration in the transmission characteristics of the u filter then available on the 0.61-m telescope. While it is

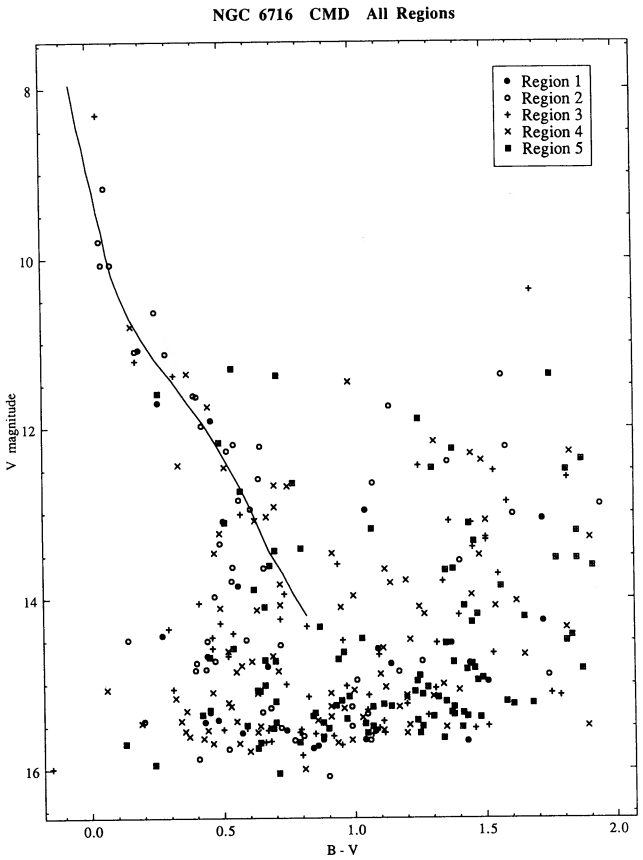

FIG. 3–Color-magnitude diagram, stars in all regions. The ZAMS of Mermilliod is also plotted.

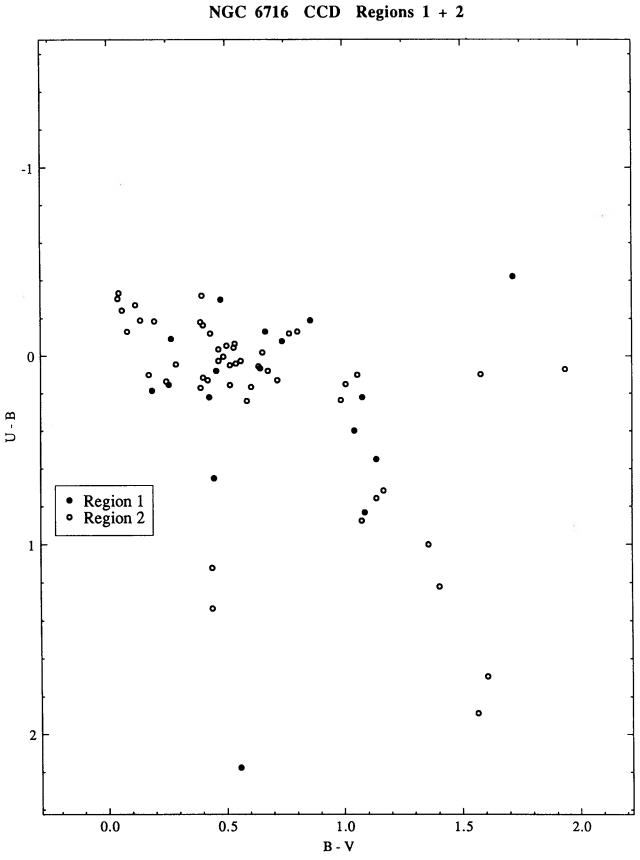

FIG. 4–Color-color diagram, stars in the two innermost regions.

TABLE 3

Cluster Membership by Region

Region	Likely Members	Possible Members	Probable Members
1	4 (17)	9 (37)	11 (46)
2	27 (47)	5 (9)	25 (44)
1 + 2	31 (38)	14 (17)	36 (44)
3	11 (18)	14 (23)	36 (59)
4	20 (22)	14 (16)	56 (62)
5	13 (13)	21 (21)	66 (66)

not unreasonable to expect near-solar metallicity for NGC 6716 because of its estimated age and proximity to the Sun and the galactic plane, (Fe/H) in affecting turnoff color and luminosity will also affect all the other derived parameters. A study of metallicities in the field of this cluster will perhaps also be useful in further separating cluster member from nonmember stars.

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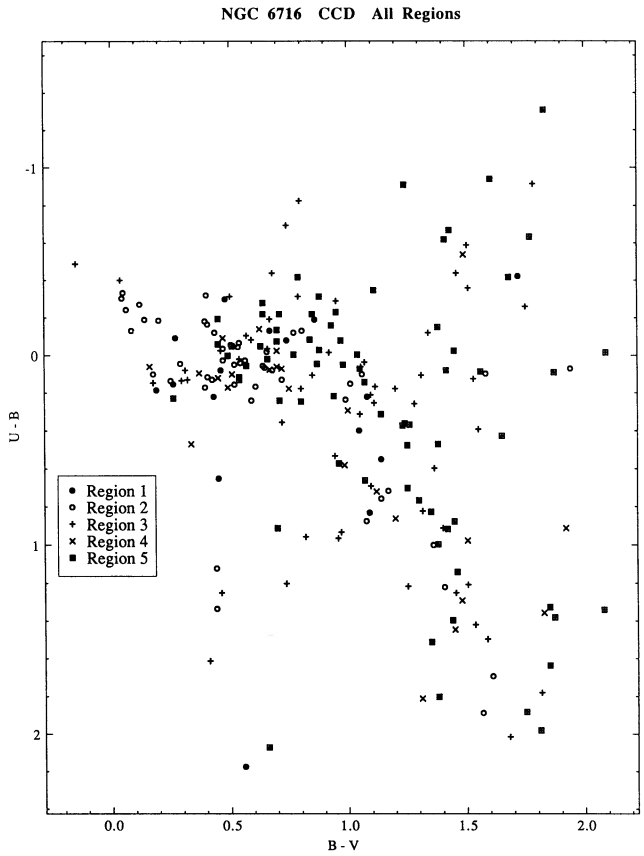

FIG. 5–Color-color diagram, stars in all regions.

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TABLE 4

Final Results for NGC 6716

Properties	Results
Angular Diameter	10.3′
Linear Diameter	1.64 pc
E(B-V)	0.17 ± 0.03 mag
Av	0.51 mag
Distance	547 ± 38 pc
Distance Modulus	8.69 ± 0.15 mag
# Stars Examined	417
# Stars Plotted	332
Distance From Galactic Plane	91.2 ± 6.3 pc
# Giant Members	0
Absolute Magnitude of Brightest Member	-0.9
Age of Cluster	(1.05 ± 0.20) x 10^8 years