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THE OLD(EST) OPEN CLUSTER: MELOTTE 66

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ABSTRACT

A new color-magnitude diagram has been constructed from iris photometry of seven B and six V plates, calibrated with Hawarden's photoelectric sequence supplemented by new photometry. Main-sequence fitting results in a giant branch clump that is significantly fainter than that for younger disk clusters or the horizontal branches of globular clusters. The implications of this are discussed in terms of the chemical abundance of the cluster. The age of Melotte 66 appears to be at least a billion years older than that of NGC 188, previously thought to be the oldest disk cluster.

Subject headings: clusters: open — stars: abundances — stars: evolution

I. INTRODUCTION

One of the major obstacles to understanding the evolution of stellar populations within the Galaxy has been the absence of a cluster population that bridges the apparent gap in age between the oldest disk cluster, NGC 188, which appears to be about 5×10^9 years old, and the globular clusters near 13–14 $\times 10^9$ years (Demarque and McClure 1977*a*). As a result, the discovery and study of any cluster which populates this age range is of particular importance for both stellar and galactic evolution.

Eggen and Stoy (1963) suggested that Melotte 66 may resemble the oldest known disk cluster NGC 188 or a globular cluster. Hawarden (1976) obtained both photoelectric and photographic photometry for the cluster, and found an age near that of NGC 188, and metallicity significantly lower than the solar value. In addition, he suggested that the color-magnitude (C-M) diagram morphology appeared unusual, in that (1) significant scatter in $B - V$ exists among the brighter giant stars, with giants of the outer cluster region being bluer than those near the center; (2) no apparent subgiant branch was found; and (3) a significant blue straggler population was found.

A program has been undertaken to redetermine and improve the C-M diagram for Melotte 66 in order to confirm these morphological features which are of interest to stellar evolution and mass loss theory, and to improve on the age and metallicity determination which are of importance to galactic evolution. In addition, spectra of a group of the brightest giant stars were obtained to discover whether the bluer giants exhibit spectral features different from stars on the normal giant branch. The observations will be discussed in § II. Section III will deal with the reddening and metal abundance of the cluster, § IV with the C-M diagram, and § V with peculiar stars discovered on the giant branch, and § VI will summarize the results.

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II. THE OBSERVATIONS

a) Photoelectric UBV Photometry

An early investigation of Melotte 66 by Eggen and Stoy (1963) included a photoelectric sequence of 20 stars, extending just past 15th mag in V. A new photoelectric sequence was established in Hawarden's (1976) photometric survey, extending the standard list to a visual magnitude of 17.6. Additional photoelectric UBV observations were obtained in 1977 at the CTIO 1 m telescope for 12 stars included in Hawarden's list and two new standards fainter than 17th mag were added. The new photoelectric observations obtained at Cerro Tololo are listed in Table 1.

TABLE 1

NEW PHOTOELECTRIC OBSERVATIONS OBTAINED AT CERRO TOLOLO

Star	V	$B - V$	$U - B$	n
1101	17.36	0.58	...	1
1121	16.86	0.60	...	1
1123	16.33	0.66	...	1
1126	16.72	0.58	...	1
1230	15.92	1.02	...	2
2159	17.57	0.66[a]	...	2
2217	14.08	1.27	1.14:	2
2238	16.33	0.84	...	2
3227	13.06	0.64	0.08	2
3252	15.76	0.75	...	1
4108	17.44	0.58[a]	...	2
4121	17.60	0.49	...	1
4264	14.78	1.12	...	1
4326	12.78	1.28	1.31	2

[a] Value for $(B - V)$ adopted from only one night's observation.

TABLE 2

ADOPTED PHOTOELECTRIC VALUES FOR STARS IN MELOTTE 66

Star	V	$B-V$	Note
E7	10.29	0.43	H
E13	11.65	1.19	E
E14	11.60	1.04	E
E15	12.45	0.48	E
1101	17.30	0.64	HT
1104	16.98	0.64	H
1121	16.85	0.60	HT
1123	16.31	0.66	HT
1126	16.70	0.61	HT
1230	15.90	1.03	HT
2133	13.18	1.50	H
2141	16.35	0.66	H
2142	16.50	0.62	H
2159	17.57	0.66	T
2217	14.07	1.28	HT
2238	16.32	0.88	HT
2239	11.84	1.58	H
2261	13.60	1.25	H
2277	13.80	1.84	H
3148	14.78	1.15	H
3213	14.42	1.15	H
3227	13.05	0.63	HT
3252	15.73	0.72	HT
4108	17.44	0.58	T
4110	14.55	1.12	H
4121	17.48	0.69	HT[a]
4264	14.75	1.13	HT
4326	12.76	1.27	HT

[a] Values have been smoothed from $V = 17.61$, $B - V = 0.52$, to be consistent with photographic results.

The photoelectric values adopted for reducing photographic observations are listed in Table 2. Values noted E were used exclusively in the reduction of a fourth ring, exterior to Hawarden's survey area, and are from the photoelectric observations of Eggen and Stoy. For stars denoted H, Hawarden's photoelectric data were used; a T indicates a CTIO observation. In those cases for which two sets of observations are available, denoted HT, the adopted values represent an attempt to evaluate the quality and quantity of individual observations. An exception is the star 4121; as in Hawarden's photometric reduction, the photoelectric data were found to be incompatible with the photographic results, and a "smoothed" photographic value for the color and magnitude were used. It should be noted that the smoothed values deduced in the reduction procedure are nearly identical to those found and adopted by Hawarden.

b) *Photographic Photometry*

New photographic material was obtained for this study at Cerro Tololo Inter-American Observatory. Five B and four V plates were taken with the Yale–CTIO 1 m telescope and two B and two V plates were exposed at the prime focus of the 4 m telescope. Table 3 lists the characteristics of the photographic material.

Measurements for all plates were conducted on the Cuffey iris photometer at Yale University Observatory for stars in three rings of diameter 3′, 5′, and 7′ on the numbering system of Hawarden (1976). An additional ring of diameter 10′ was measured from four plate pairs on the Cuffey iris photometer at the University of Victoria, British Columbia. The photographic data are listed in Table 4. An identification chart for stars not measured by Hawarden (1976) is shown in Figure 1 (Plate 3).

TABLE 3

DATA ON PHOTOGRAPHIC EXPOSURES

Telescope	Plate	Date	Emulsion	Filter	Exp. (min.)
1 m	1771	1976 Dec. 8/9	103a-D	GG495	30
	1772	1976 Dec. 8/9	103a-D	GG495	30
	1787	1976 Dec. 10/11	103a-D	GG495	30
	1814	1976 Dec. 12/13	103a-O	GG385	20
	1815	1976 Dec. 12/13	103a-O	GG385	20
	1822	1976 Dec. 14/15	103a-O	GG385	20
	1823	1976 Dec. 14/15	103a-O	GG385	20
	1861	1977 Jan. 25/26	103a-O	GG385	30
	1862	1977 Jan. 25/26	103a-D	GG495	40
4 m	3395	1977 Nov. 1/2	IIa-O	GG385	15
	3396	1977 Nov. 1/2	IIa-O	GG385	5
	3397	1977 Nov. 1/2	IIa-D	GG495	15
	3398	1977 Nov. 1/2	IIa-D	GG495	5

Because there were not great numbers of photoelectric standards, and they were not particularly well distributed with a breadth of color in discrete magnitude intervals, an internal solution for the color equation was not attempted. Values for the color terms appropriate to the emulsions used were applied. These were determined from other photographic photometry of clusters done by the authors with the same plate and filter combinations. An examination of the residuals from the calibration curve with respect to color disclosed no systematic problems with the adopted color equation. The color equations used are as follows: for 103a-D visual plates, $V_{pg} = V - 0.13(B - V)$; for 103a-O blue plates, $B_{pg} = B + 0.09(B - V)$; and for IIa-O blue plates, $B_{pg} = B - 0.05(B - V)$.

An examination was made as well of the difference in derived photographic magnitudes and colors between the 1 m and 4 m plates. No systematic differences were detected within the field of the cluster examined, i.e., the central 7′. The problems with field errors in the 4 m telescope discussed by Herzog and Illingworth (1976) and McClure and Twarog (1977) lie well outside this region.

c) *Spectroscopy*

Spectra at 121 Å mm^{-1} were obtained of nine giant stars in Melotte 66 by using the image-tube spectrograph on the Yale CTIO 1 m telescope. A slit width corresponding to 2.5 Å at the plate was used, and the spectra were widened to 0.3 mm. Baked IIIa-J plates developed for 5 minutes in D19 were used for all spectra. Numerous spectra of bright field stars were also obtained for comparison, using the same equipment. Spectral peculiarities of giants in Melotte 66 will be discussed in § V.

III. REDDENING AND METAL ABUNDANCE

The reddening of Melotte 66 was found by Eggen and Stoy (1963) to be $E(B - V) = 0.13$ mag, a

TABLE 4

PHOTOGRAPHIC VALUES

STAR	V	B−V	STAR	V	B−V	STAR	V	B−V	STAR	V	B−V
1101	17.27	0.62	1139	16.54	0.66	2112	17.16	0.65	2154	16.83	1.12
1102	17.10	0.65	1140	16.91	0.62	2113	16.31	0.79	2155	17.16	0.62
1103	16.30	0.91	1141	14.66	0.75	2114	16.09	0.58	3101	14.98	1.10
1104	17.04	0.68	1142	17.03	0.68	2117	16.37	0.61	3102	17.41	0.66
1105	15.52	1.04	1143	17.44	0.67	2118	16.36	0.41	3103	17.49	0.63
1106	16.09	0.70	1144	17.12	0.66	2119	16.88	0.70	3104	17.43	0.65
1107	17.25	0.63	1145	17.23	0.73	2120	14.47	1.09	3105	17.43	0.64
1108	15.72	0.59	1147	16.49	0.72	2121	16.97	0.67	3106	16.23	0.61
1109	17.44	0.69	1148	15.79	0.27	2122	16.49	0.63	3107	17.01	0.67
1110	17.36	0.63	1149	13.78	0.63	2123	15.43	1.08	3108	17.13	0.71
1111	16.09	1.05	1150	13.40	0.67	2124	16.62	0.67	3109	17.15	0.66
1112	16.40	0.71	1151	17.38	0.62	2125	17.22	0.68	3110	16.70	0.49
1113	15.99	1.09	1152	17.21	0.59	2126	17.18	1.03	3111	17.28	0.71
1114	15.45	0.74	1153	16.90	0.66	2127	16.82	1.00	3112	15.56	1.08
1115	17.41	0.72	1154	17.22	0.62	2128	16.85	1.03	3114	16.87	0.72
1116	17.33	0.61	1156	17.51	0.71	2129	15.81	0.96	3115	17.18	0.74
1119	17.49	0.63	1157	17.35	0.64	2132	17.43	0.64	3117	15.49	0.70
1120	15.89	1.07	1158	17.21	0.61	2133	13.20	1.48	3118	17.45	0.76
1121	16.89	0.58	1159	17.08	0.60	2134	17.48	0.70	3119	16.40	0.65
1122	17.42	0.59	1160	17.33	0.67	2135	17.29	0.71	3120	16.39	1.07
1123	16.29	0.67	1161	17.03	0.78	2136	17.14	0.66	3121	14.48	1.05
1124	16.89	0.96	1164	17.47	0.64	2140	17.10	0.66	3122	14.30	0.53
1125	16.80	0.86	1166	17.52	0.67	2141	16.37	0.63	3123	16.53	0.69
1126	16.71	0.63	1169	17.47	0.66	2142	16.54	0.57	3124	17.35	0.62
1127	16.21	1.00	2101	17.27	0.69	2143	15.78	1.02	3125	17.52	0.67
1128	17.16	0.97	2102	15.78	0.68	2144	17.20	0.71	3126	15.87	1.05
1129	15.67	1.02	2103	17.34	0.63	2145	16.95	0.67	3127	17.37	0.67
1130	16.58	0.62	2104	17.44	0.69	2146	15.87	0.80	3128	17.29	0.80
1131	17.30	0.64	2105	17.46	0.59	2147	17.29	0.59	3129	16.04	0.66
1132	15.36	1.13	2106	17.03	0.73	2148	16.86	0.60	3130	16.38	0.70
1134	17.48	0.66	2107	14.70	1.14	2149	16.19	1.00	3131	16.97	0.70
1135	14.48	1.05	2108	15.30	0.84	2150	16.58	0.57	3132	17.24	0.68
1136	17.46	0.74	2109	17.19	0.64	2151	16.06	0.62	3133	14.08	1.29
1137	17.10	0.69	2110	17.47	0.71	2152	15.50	0.67	3134	17.28	0.73
1138	17.51	0.62	2111	16.62	0.65	2153	17.20	0.71	3135	17.47	0.70
3136	17.24	0.98	4103	16.61	0.62	4154	16.70	0.62	1232	17.26	0.68
3137	17.31	0.74	4105	15.86	1.03	4155	16.09	1.03	1233	17.15	0.84
3138	17.13	0.73	4107	16.29	0.54	4156	17.36	0.72	1234	17.14	0.63
3139	16.46	0.75	4108	17.39	0.60	4157	17.49	0.62	1235	16.98	0.67
3140	16.33	0.86	4109	17.46	0.67	4158	17.48	0.66	1236	17.41	0.60
3141	16.32	0.67	4110	14.57	1.09	4159	17.38	0.63	1237	16.53	0.57
3142	15.95	1.10	4112	16.56	0.70	4160	17.43	0.69	1238	17.47	0.68
3143	17.20	0.68	4113	14.45	0.72	1201	15.26	1.02	1239	16.16	1.19
3144	17.26	0.73	4114	17.18	0.64	1202	16.57	0.55	1240	15.58	0.78
3145	15.57	0.44	4115	17.08	0.69	1203	14.25	1.00	1241	16.16	0.69
3147	16.86	0.68	4116	15.79	0.96	1204	16.13	1.04	1242	12.92	1.55
3148	14.71	1.17	4117	16.77	0.91	1205	14.48	1.04	1244	14.25	0.96
3151	16.08	0.33	4118	14.54	1.11	1207	17.48	0.67	1245	14.45	1.13
3152	16.24	0.93	4119	13.20	0.45	1208	16.99	0.57	1246	13.61	0.60
3154	17.19	0.70	4120	16.97	0.67	1209	16.78	0.64	1247	17.16	1.07
3156	16.45	0.70	4122	16.58	0.64	1210	15.95	1.03	1248	16.75	0.68
3157	17.15	0.68	4123	15.75	1.05	1211	16.96	0.61	1250	15.16	1.07
3158	16.53	0.68	4124	16.74	0.63	1212	17.05	0.57	1251	16.82	0.67
3160	16.99	0.63	4125	17.27	0.67	1213	15.75	0.91	1252	16.44	0.87
3162	17.40	0.68	4128	16.90	0.65	1214	15.44	0.83	1253	17.52	0.70
3163	16.16	0.54	4131	14.98	1.00	1215	16.65	0.56	1257	17.57	0.62
3164	16.86	0.71	4133	17.18	0.68	1216	16.69	0.57	2201	16.81	0.67
3165	17.47	0.66	4134	17.41	0.67	1218	16.72	0.75	2202	14.22	1.05
3166	17.37	0.65	4135	17.00	0.63	1219	16.78	0.60	2203	16.47	0.73
3167	16.51	0.64	4137	17.49	0.63	1220	16.50	0.68	2204	14.55	1.24
3169	17.13	0.67	4138	16.67	0.61	1221	16.60	0.56	2205	15.39	0.75
3170	16.68	0.82	4139	17.48	0.62	1223	16.15	0.69	2206	12.63	1.48
3171	16.20	1.04	4140	16.88	0.66	1224	17.04	0.60	2207	17.08	0.63
3174	17.09	0.73	4142	15.31	0.71	1225	15.65	0.77	2208	16.04	1.21
3175	17.47	0.69	4144	16.72	0.85	1226	17.32	0.64	2209	17.06	0.68
3176	17.47	0.70	4145	17.14	0.63	1227	17.43	0.60	2210	16.19	0.65
3177	17.43	0.67	4146	16.70	0.87	1228	17.53	0.66	2211	13.34	0.57
3180	17.17	0.82	4147	16.59	0.64	1229	15.22	0.77	2212	17.27	0.68
4101	15.49	0.31	4151	12.69	1.61	1230	15.86	1.05	2213	17.05	0.65
4102	15.71	0.84	4153	16.76	1.00	1231	17.04	0.65	2215	13.25	1.80

1979ApJ...233..188A

TABLE 4—*Continued*

STAR	V	B-V	STAR	V	B-V	STAR	V	B-V	STAR	V	B-V
2216	17.15	0.72	2254	16.52	1.00	3217	17.24	0.91	4203	15.22	1.11
2217	14.11	1.29	2255	17.07	0.64	3219	14.67	1.16	4204	16.42	1.00
2218	17.31	0.68	2256	17.25	0.63	3220	16.00	0.62	4205	14.52	1.20
2220	17.28	0.74	2259	13.32	1.02	3221	17.25	0.73	4206	10.79	1.15
2221	14.53	1.10	2260	16.41	0.66	3222	10.98	0.40	4207	17.44	0.71
2222	15.30	0.69	2261	13.64	1.24	3223	16.78	0.91	4208	15.75	0.78
2223	17.39	0.66	2262	15.79	0.71	3226	16.68	0.90	4209	16.56	0.69
2224	17.09	0.55	2263	17.37	0.66	3227	13.01	0.66	4210	15.11	1.11
2225	17.21	0.70	2264	17.49	0.69	3228	17.39	0.79	4211	17.38	0.68
2226	14.08	1.18	2265	13.40	0.51	3229	13.93	1.28	4212	17.48	0.56
2227	16.32	0.70	2266	16.75	0.95	3230	15.48	0.89	4213	17.44	0.68
2228	16.67	1.05	2267	16.70	0.60	3234	16.86	0.94	4214	13.14	0.92
2229	16.56	0.63	2268	16.55	0.62	3235	14.66	1.14	4215	12.96	1.09
2230	17.20	0.72	2269	14.27	1.01	3236	17.40	0.62	4216	17.01	0.61
2231	17.16	0.65	2270	15.41	0.39	3238	16.98	0.63	4218	16.95	0.68
2232	16.12	0.74	2271	16.83	1.06	3239	15.95	0.99	4219	13.85	0.59
2233	15.44	1.05	2272	16.64	0.95	3251	15.53	0.90	4220	16.92	0.77
2234	17.24	0.64	2273	17.04	0.65	3249	17.12	0.76	4221	15.66	0.64
2235	16.60	1.05	2274	16.36	0.96	3246	16.31	1.03	4222	17.40	0.68
2236	16.47	0.64	2275	14.95	0.88	3245	17.22	0.74	4223	15.30	0.70
2237	17.52	0.63	2276	16.42	0.73	3244	13.69	0.65	4224	16.80	0.67
2238	16.32	0.91	2277	13.81	1.77	3242	17.06	0.49	4225	16.86	0.91
2239	11.84	1.58	2278	16.22	0.91	3241	17.35	0.77	4226	16.86	0.93
2240	16.60	0.98	2279	17.04	0.65	3252	15.66	0.74	4227	15.55	1.06
2241	16.51	0.66	2280	16.86	1.03	3253	16.83	1.16	4228	16.13	0.66
2242	16.49	0.63	3201	15.88	0.89	3255	11.63	0.58	4229	13.69	1.38
2243	17.40	0.59	3205	16.15	0.70	3256	16.45	0.59	4230	14.79	0.88
2244	14.47	1.06	3207	17.44	0.73	3258	17.13	0.70	4231	17.27	0.67
2245	15.61	1.01	3208	15.88	0.79	3259	14.42	1.09	4232	15.09	0.73
2246	16.77	0.63	3209	16.35	1.13	3260	14.56	1.18	4233	16.40	1.03
2249	16.54	0.69	3210	17.46	0.70	3261	17.34	0.68	4236	17.29	0.62
2250	17.03	0.67	3211	17.28	0.69	3262	17.34	0.63	4237	16.44	0.88
2251	16.77	0.85	3213	14.40	1.18	3263	17.11	0.70	4238	15.49	1.08
2252	16.30	0.68	3214	16.31	0.84	4201	15.97	0.69	4239	17.23	0.62
2253	14.80	0.78	3216	15.87	0.82	4202	16.65	0.67	4241	16.81	0.74
4242	17.52	0.65	1323	15.61	0.95	2321	15.90	0.66	3311	17.41	0.68
4245	16.59	1.05	1324	16.35	1.62	2323	15.10	0.97	3313	16.51	0.83
4247	15.98	0.71	1325	17.20	0.54	2324	17.43	0.73	3314	13.02	1.44
4248	16.53	0.65	1326	14.30	0.55	2325	17.49	0.66	3318	16.77	0.83
4249	16.47	0.73	1328	15.44	1.21	2326	16.09	1.05	3319	15.98	1.01
4250	16.58	0.78	1329	17.49	0.61	2329	14.39	1.10	3321	17.41	0.73
4252	17.04	0.68	1330	16.83	0.70	2330	17.35	0.69	3323	16.91	1.09
4253	17.27	0.63	1331	17.09	0.65	2332	17.28	0.65	3324	16.46	1.16
4254	17.25	0.69	1332	14.52	1.08	2333	17.18	0.67	3326	17.46	0.68
4258	17.29	0.66	1333	17.27	0.77	2334	14.72	0.80	3327	16.20	1.28
4259	16.73	1.01	1334	17.12	0.91	2335	17.28	0.65	3328	14.66	1.15
4260	17.46	0.69	1335	16.94	0.64	2336	15.75	0.69	3331	17.34	0.76
4262	15.32	1.08	1336	15.59	1.10	2337	16.27	0.31	3332	16.66	1.18
4264	14.73	1.12	1337	16.51	0.82	2338	14.22	1.05	3334	13.44	0.96
4265	14.07	1.27	1338	16.51	0.98	2339	16.22	0.86	3335	16.25	0.78
4266	14.55	1.09	1339	17.08	0.66	2341	14.80	0.67	3336	15.32	0.78
1301	17.29	0.61	1340	16.16	0.72	2342	13.48	1.26	3337	17.30	0.75
1302	15.35	1.05	1341	17.46	0.73	2343	16.75	0.71	3338	16.76	0.75
1303	16.30	0.72	1344	17.10	0.73	2344	17.33	0.89	3340	17.27	0.88
1304	17.36	0.58	1345	17.23	0.95	2345	17.14	0.69	3343	14.22	0.60
1305	16.83	0.93	1346	17.10	0.63	2346	16.77	0.64	3346	15.78	1.02
1307	17.44	0.62	1347	16.36	0.81	2348	16.07	1.08	3347	17.03	0.70
1308	17.14	0.59	1348	15.76	0.72	2349	16.25	0.75	3348	16.68	1.07
1309	17.00	0.80	2301	17.25	0.69	2350	16.07	0.79	3350	17.47	0.73
1310	13.90	0.70	2303	13.37	0.92	2352	16.34	1.06	3351	17.43	0.72
1311	14.51	0.22	2304	16.19	0.67	2353	17.04	0.58	3354	17.35	0.66
1312	16.15	0.69	2305	14.22	1.11	2356	16.47	0.72	3355	16.81	1.06
1313	16.62	0.59	2307	14.92	0.77	2357	16.98	0.95	3356	17.37	0.71
1314	17.18	0.58	2308	13.01	0.91	2360	15.16	0.79	3359	16.97	1.07
1316	16.36	1.02	2309	13.48	1.28	3301	15.58	0.68	3363	16.29	1.04
1318	17.44	0.70	2312	16.75	0.98	3303	16.68	0.89	3364	14.82	1.20
1319	16.05	0.63	2314	16.68	0.95	3304	16.52	0.75	3365	16.89	0.95
1320	17.11	1.07	2315	16.59	0.89	3305	17.23	0.67	3366	14.01	1.04
1321	13.16	1.49	2317	17.26	0.67	3307	15.20	1.17	3368	15.98	0.77
1322	13.44	0.57	2318	17.40	0.71	3310	17.12	0.80	3369	16.85	0.76

1979ApJ...233..188A

TABLE 4—*Continued*

STAR	V	B−V	STAR	V	B−V	STAR	V	B−V	STAR	V	B−V
3370	17.04	1.07	4345	17.25	0.68	1431	14.84	0.69	1471	17.01	1.00
3371	17.17	1.00	4346	17.34	0.76	1432	14.93	0.67	1472	15.51	0.69
3372	17.03	0.76	4347	14.42	1.10	1433	16.56	0.65	1474	16.56	0.99
3373	16.02	0.70	4348	17.08	0.77	1434	15.47	0.66	1476	16.46	1.20
4304	17.18	0.73	4349	16.12	0.37	1435	15.93	1.11	2402	13.93	0.74
4305	17.10	0.62	4351	13.26	1.40	1437	15.63	0.71	2403	17.06	0.78
4306	15.89	0.69	4352	16.94	1.20	1438	13.74	0.79	2404	16.84	0.94
4307	16.89	0.88	4353	15.50	0.96	1439	17.06	0.56	2405	17.19	0.64
4308	16.97	0.93	4354	16.27	0.93	1440	17.33	0.56	2407	16.28	1.21
4309	15.36	1.01	4355	14.82	1.12	1441	16.35	0.62	2408	12.05	1.20
4311	17.12	0.88	4357	17.20	0.85	1443	15.31	0.97	2409	16.96	0.89
4312	16.00	0.83	4358	16.58	0.68	1444	14.61	0.70	2410	14.01	1.39
4313	16.59	0.62	1401	13.64	0.47	1445	15.29	0.79	2411	14.99	0.94
4314	15.53	0.25	1402	16.81	0.77	1446	16.44	0.80	2412	17.05	0.63
4316	16.55	0.71	1403	16.77	0.93	1447	16.85	0.79	2416	17.30	0.73
4317	17.39	0.36	1405	13.90	0.53	1448	14.81	0.76	2417	17.31	0.75
4318	16.44	0.67	1406	15.82	0.59	1449	17.17	0.63	2418	17.01	0.93
4319	16.86	1.00	1408	17.01	0.62	1451	16.78	0.59	2421	14.68	0.60
4320	16.09	1.14	1409	16.97	0.56	1453	16.90	0.58	2424	15.79	0.83
4325	17.31	0.62	1410	16.11	0.99	1454	17.05	0.63	2425	17.27	0.63
4326	12.76	1.31	1411	17.14	0.47	1455	16.08	0.83	2426	16.18	0.68
4327	16.42	0.64	1412	16.31	0.65	1456	13.14	0.57	2427	16.79	0.62
4328	17.40	0.62	1413	17.00	0.65	1457	16.78	0.65	2428	14.75	0.53
4329	13.70	0.74	1414	15.91	0.77	1458	15.25	1.13	2429	16.47	0.78
4330	15.09	1.18	1416	17.20	0.89	1459	16.89	1.12	2430	16.97	0.92
4331	16.59	0.63	1418	15.02	0.60	1460	15.60	0.66	2431	15.33	0.64
4332	16.95	0.64	1419	16.92	0.58	1462	16.16	0.72	2432	16.10	1.47
4334	11.58	1.43	1421	15.12	0.58	1463	16.88	0.65	2433	16.41	0.69
4335	15.76	1.06	1422	16.75	0.86	1464	16.99	0.93	2434	17.11	0.60
4337	15.73	0.64	1423	13.57	0.50	1465	13.76	0.99	2435	11.85	0.38
2441	16.76	0.58	3422	15.54	0.67	3465	15.24	0.86	4439	15.01	1.04
2442	16.10	0.96	3423	17.03	0.73	3466	15.87	0.86	4440	15.07	0.83
2443	14.62	1.35	3424	12.27	1.34	3467	17.11	0.84	4443	14.90	1.22
2444	16.72	0.66	3425	15.61	1.03	3468	14.00	0.71	4444	17.22	0.72
2445	17.30	0.51	3426	14.65	0.83	3469	11.41	1.63	4445	16.84	0.98
2446	12.20	0.93	3427	16.77	0.88	3470	15.76	1.19	4446	15.53	0.86
2447	15.33	0.99	3428	15.15	0.79	3471	16.34	0.78	4447	16.37	0.72
2449	16.10	0.90	3430	14.07	1.21	3472	17.02	0.87	4448	17.11	0.65
2450	15.93	0.86	3432	16.37	0.72	3473	14.50	1.11	4449	17.17	0.92
2451	16.04	1.18	3435	15.16	0.62	3474	16.40	0.91	4450	17.10	0.91
2452	16.86	0.92	3436	16.98	0.74	4401	17.07	0.66	4451	15.43	1.16
2455	16.08	1.12	3437	17.26	0.69	4402	13.85	0.99	4452	15.71	0.89
2457	16.98	0.65	3438	15.29	1.05	4405	17.19	0.70	4453	13.48	0.53
2458	17.19	0.80	3439	16.10	0.96	4406	17.32	0.71	4454	17.16	1.00
2459	16.80	0.66	3440	16.63	0.70	4407	15.03	0.63	4455	16.24	0.66
2460	14.80	0.75	3441	14.81	1.11	4408	15.79	0.88	4456	17.25	0.66
2461	17.29	0.59	3442	15.53	1.10	4409	14.43	0.98	4457	17.20	0.62
2465	17.18	0.70	3443	16.01	0.97	4410	16.88	0.90	4458	17.22	0.81
2466	15.00	0.80	3444	17.21	0.74	4411	16.60	0.85	4459	16.36	0.79
2468	17.21	0.55	3445	16.27	0.78	4412	17.00	0.93	4460	16.04	1.08
2469	17.06	0.81	3446	16.41	0.86	4413	16.58	0.96	4461	15.65	1.54
2472	16.40	0.74	3448	17.31	0.64	4417	17.21	0.70	4463	16.54	1.12
3401	16.54	0.97	3450	15.50	0.67	4418	12.63	0.91	4464	16.87	0.69
3403	15.43	1.01	3452	15.34	1.45	4419	16.82	0.95	4465	15.90	0.70
3404	15.02	0.64	3453	14.80	0.70	4420	16.17	0.78	4466	15.19	0.71
3405	16.31	0.84	3454	15.83	0.68	4424	16.56	0.67	4467	11.81	1.18
3406	13.90	1.30	3455	14.79	1.01	4425	15.47	0.79	4470	16.60	0.78
3407	13.02	1.19	3456	14.94	0.93	4426	15.34	0.72	4471	16.35	0.76
3408	15.85	0.68	3457	17.10	0.82	4427	16.62	0.91	4472	15.01	0.68
3410	16.20	1.49	3458	16.85	0.72	4431	17.34	0.65	4473	17.03	0.61
3413	17.11	0.91	3459	17.00	1.03	4433	17.05	0.67	4474	17.17	0.87
3414	16.85	1.08	3460	16.56	0.93	4434	15.77	0.81	4476	17.00	0.62
3419	17.34	0.78	3462	17.16	0.95	4435	15.29	1.09	4477	16.31	0.82
3420	17.31	0.63	3463	15.85	1.06	4436	11.63	0.64	4478	16.93	1.04
3421	16.45	0.90	3464	15.54	1.01	4438	17.07	0.66			

determination based on displacement in the *UBV* color-color diagram. Hawarden (1976) deduced a similar value (0.14 mag) for reddening from the color-color diagram, and a value for $\delta(U - B)_{0.6}$ which implied a metal abundance for the cluster of [Fe/H] = -0.64 relative to the Hyades. Partly because he could not easily reconcile this metal deficiency and the large age implied in his analysis with the apparent presence of a main-sequence gap, Hawarden ultimately adopted a higher value for the reddening of 0.17 mag, which was consistent with a value of [Fe/H] = -0.54 relative to the Hyades.

Dawson (1978) has observed eight giant stars using the DDO photometric system and, by using Janes's (1977) calibration, has found $E(B - V) = 0.14$ mag for Melotte 66 in exact agreement with Hawarden's original direct determination from *UBV* photometry. The mean cyanogen anomaly observed by Dawson for the giants, δCN = -0.07 mag, implies a value of [Fe/H] = -0.63 relative to the Hyades (CN = $+0.07$) using the slope of Janes's (1975) calibration. Thus there is agreement in both reddening and metal abundance determined from photoelectric *UBV* and DDO photometry.

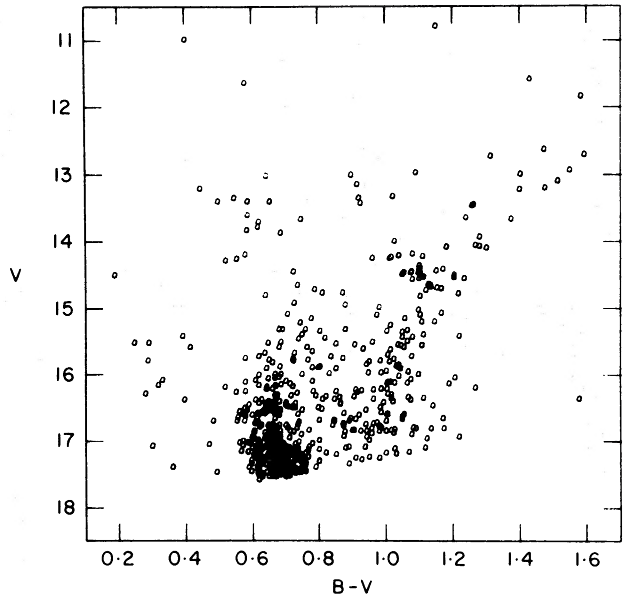

FIG. 3.—The observed C-M diagram for the area within 7′ of the cluster center (rings I, II, and III).

IV. THE COLOR-MAGNITUDE DIAGRAM

a) *Features of the Diagram*

C-M diagrams are shown in Figure 2 for rings I and II, Figure 3 for rings I, II, and III, and Figure 4 for ring IV alone. For rings I, II, and III the photographic data listed in Table 4 have been combined with Hawarden's (1976) data weighted in the ratio 2:1 according to the number of plates measured in each study. The C-M diagram for ring IV is from the data of Table 4 only. Essentially all of Hawarden's (1976) comments apply to our C-M diagrams as well. Figures 2 and 3 show a steep giant branch that appears to have intrinsic scatter in $B - V$, the latter effect also being confirmed by further photoelectric measurements of Hawarden (1978). We also find a well-defined deficiency of stars (or gap) near the main-sequence turnoff similar to that found by Hawarden (1976). Since this is a richer cluster, the giant branch is better populated than that of NGC 188, and there is a well-defined giant branch clump which presumably represents the helium

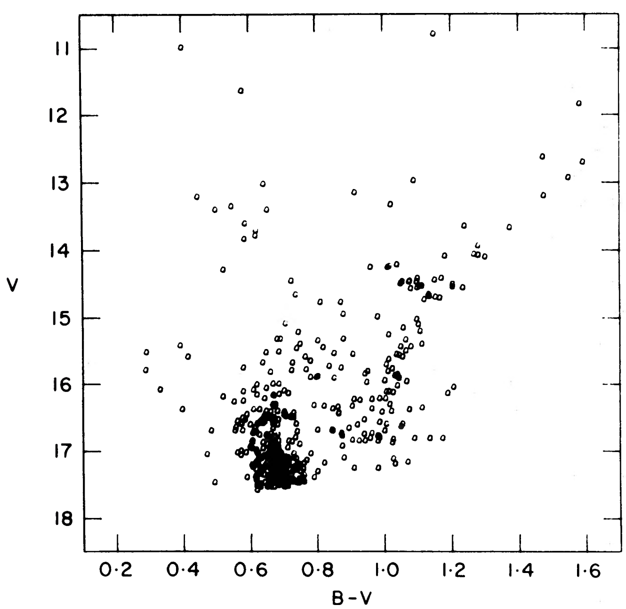

FIG. 2.—The observed C-M diagram for the area within 5′ of the cluster center (rings I and II).

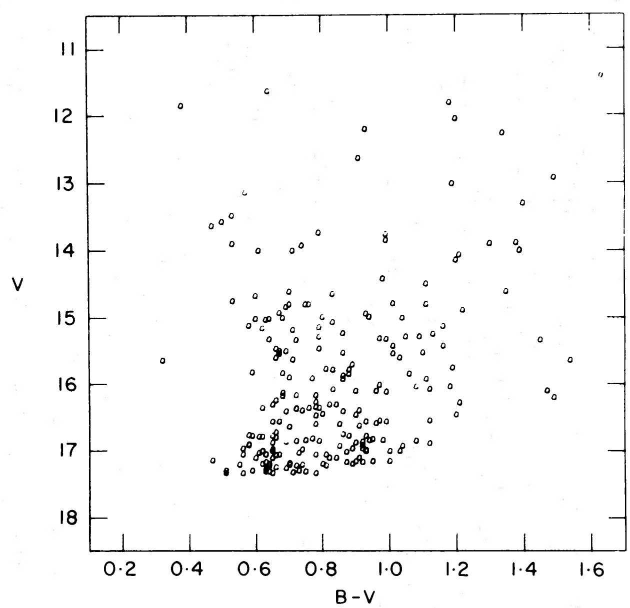

FIG. 4.—The observed C-M diagram for the annulus between 7′ and 10′ radii. This area is equal to that represented in Fig. 2, and twice that represented in Fig. 1.

core, hydrogen-shell–burning horizontal-branch phase (see Cannon 1970 for a discussion of old cluster giant branch clumps). A horizontal subgiant branch is again difficult to detect, although number counts discussed in § IV*b* suggest the possibility of a few cluster members in this region of the C-M diagram. In addition, there appear to be numerous blue stars above the main-sequence turnoff, also pointed out by Hawarden (1976). We shall now discuss number counts to determine the significance of excess stars in various areas of the C-M diagram.

b) *Number Counts*

We have counted stars in the four rings represented in Figures 2–4 for groups in various regions of the C-M diagram. In addition, for stars brighter than 16th *V* mag, we have counts in Hawarden's outer ring (which will be referred to as ring V) between 10′ and 12′.24. In addition to Hawarden's star count areas, therefore, we have counts in the extra ring between 7′ and 10′ which gives a further check on the background star field. The areas for which star counts have been done are shown in Figure 5. These include: *A*, bright blue stars; *B*, above the turnoff; *C*, turnoff; *D*, horizontal subgiant branch; *E*, lower giant branch; *F*, giant branch; *G*, upper giant branch. Ratios of areas of rings I, II, III, IV, and V are 0.36:0.67:1:2:2. Table 5 lists the results of the star counts. For each area, the numbers of stars are listed per unit area. Column (7) of Table 5 lists the probable number of cluster members based on counts in the inner three rings compared with those in rings IV and V, assuming all stars in the outer two rings are field stars. These numbers are really only lower limits, since undoubtedly there are cluster members included in rings IV and V which raise the background level somewhat.

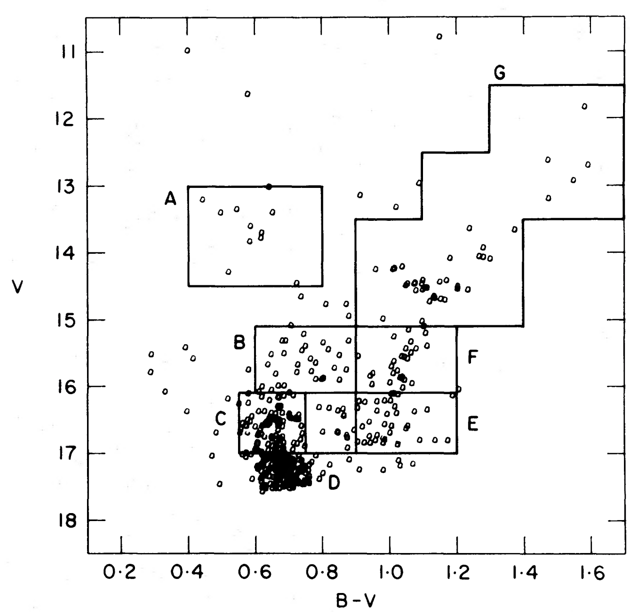

FIG. 5.—The C-M diagram for rings I and II, with lines outlining the areas in which star counts listed in Table 5 have been obtained.

TABLE 5

STAR COUNTS

Area	Ring I	Ring II	Ring III	Ring IV	Ring V	Members
A (bright blue)....	13.9	9.0	5.0	4.5	4.5	7.0
B (above turnoff)..	30.6	28.4	13.0	13.0	12.5	17.5
C (turnoff)........	130.6	76.1	20.0	15.5	...	87.0
D (subgiants)......	22.2	7.5	13.0	9.0	...	8.0
E (lower giants)....	36.1	34.3	21.0	11.5	...	34.0
F (giants).........	38.9	22.4	11.0	9.0	5.5	25.5
G (upper giants)...	33.3	38.8	17.0	10.5	4.5	40.0

Chi-square tests show that the hypothesis that the counts are distributed at random in the five rings can be rejected at the 95% confidence level for all areas of the C-M diagram listed in Table 5 except for areas *A* and *D*. We wish to point out four features of interest in these counts. (1) There appears to be a significant number of stars in area *B*, blue stars above the turnoff. (2) The subgiant branch as pointed out by Hawarden (1976) appears to be very sparse. However, comparison with NGC 188 (see Fig. 2 of McClure and Twarog 1977), which has a very similar difference in $B - V$ between the turnoff and base of the giant branch, indicates that within the errors the subgiant branches of the two clusters could be comparable. The subgiant branch of Melotte 66, nevertheless, is definitely not as well defined as that in NGC 188. It appears possible that the abundance of blue stragglers (or ill-defined turnoff) may be responsible for the scattered subgiant branch. (3) The giant branch extends significantly fainter than the turnoff, especially if the turnoff is considered to extend up into area *B*. This is a characteristic of metal-richness (see isochrones for various metal abundances from Ciardullo and Demarque 1977), so it is surprising that this turnoff–giant branch base difference in Melotte 66 is larger than in the more metal-rich cluster NGC 188. (4) The upper giant branch star density is higher for ring II than ring I, whereas in other areas such as the turnoff, the star density is highly concentrated toward ring I. This phenomenon is mainly due to the giant branch clump stars which appear to be less centrally concentrated than fainter stars in the cluster. Hawarden (1975) has discussed this effect in Melotte 66 along with a similar effect in several other clusters. The phenomenon of the central area of the cluster being deficient in upper giant branch stars relative to main-sequence stars is probably a result of dynamical evolution of the system after mass loss has occurred on the initial hydrogen-burning giant branch. What makes this idea particularly appealing is that it can also explain a major discrepancy between the C-M diagrams of Melotte 66 and NGC 188. The NGC 188 giant branch (Fig. 3 of McClure and Twarog 1977) is very deficient in upper giant branch stars relative to Melotte 66. In fact, no giant branch clump can be seen at all for NGC 188 even though the main-sequence turnoff, subgiant, and lower giant branches are as populated as those in Melotte 66. McClure and Twarog (1977) showed that large numbers of NGC 188 giant branch stars are found in the outskirts of the cluster beyond the central measured area, probably the result of dynamical relaxation after mass loss, just as the clump stars in Melotte 66 have been spread out from ring I to ring II. The difference in the latter case is that a relatively larger area of the cluster has been measured, so that the stars have all been included in the C-M diagram for Melotte 66.

c) Comparison with Theoretical Isochrones

The C-M diagram for rings I and II is shown in Figure 6, superposed on isochrones for heavy-element abundance $Z = 0.007$. The isochrones are interpolated from those published by Ciardullo and Demarque (1977) and converted to the (M_v, $B - V$)-plane as described by Demarque and McClure (1977*a*). The isochrones are based on evolutionary tracks computed by Mengel *et al.* (1979). A helium abundance of $Y = 0.30$ was chosen for the fit to Melotte 66. For this helium abundance the Hyades cluster fits the same series of isochrones for $Z = 0.03$ and a distance modulus of 3.30 mag approximately that was suggested by van Altena (1974), Hanson (1975), and Anthony-Twarog and Demarque (1977).

There are two points we wish to discuss here. First, the giant branch clump is approximately 1 mag fainter than those in other clusters when the C-M diagram is fitted to a main-sequence for the appropriate metal abundance of Melotte 66. For all other old clusters, which have accurate metal abundance, reddening, and C-M diagram data, we find that the giant branch clump luminosity lies in the range $0.5 \leq M_v \leq 1.0$ mag when the main sequence is fitted to theoretical main sequences of the appropriate metal abundance, and helium abundance $Y = 0.30$.

One way to fit the C-M diagram to make the clump luminosity $M_v = 1.0$ mag would be to use solar abundance isochrones, rather than isochrones appropriate to the observed metal abundance of the cluster. The metal abundance determination for Melotte 66 seems certain, however (§ III), and solar abundance appears to be unreasonable.

The question arises, then, whether an absolute magnitude for the clump at $M_v = +2.0$ mag could be reconciled with stellar evolution theory. Examination of theoretical calculations (e.g., Gross 1973, Fig. 1) shows that the zero-age horizontal branch rises in luminosity at the cool, high mass end, and this rise is a function of increasing total mass. The open cluster clump stars, which are very near the giant branch, most likely sit on the rising part of the horizontal branch. It seems reasonable, therefore, that a very old cluster like Melotte 66 should have a fainter clump than younger open clusters which have higher mass turnoffs. A problem still exists, of course, in that the globular cluster horizontal branches have absolute magnitudes brighter than $M_v = +1.0$ mag. The horizontal-branch luminosity is *very* sensitive to helium abundance (Gross 1973; Sweigart and Gross 1976),

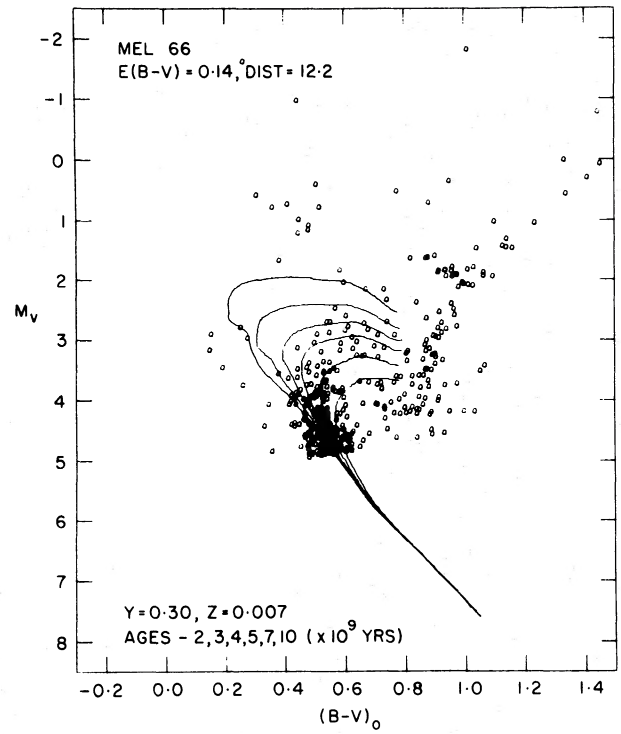

FIG. 6.—The C-M diagram fitted to isochrones of Ciardullo and Demarque (1977) converted to the observational plane. Notice that the giant branch clump is about 1 mag fainter than normal for open clusters.

however, and the faintness of the Melotte 66 clump stars could reflect a low helium abundance for the old disk population relative to the halo. The helium abundance difference between halo and disk suggested by Gross (1973) and Demarque and McClure (1977*b*) is just the amount needed to make an old disk cluster like Melotte 66 have a horizontal branch 1 mag fainter.

If the clump in Melotte 66 is near $M_v = +2.0$ mag, this cluster may be similar in this respect to NGC 188. The C-M diagrams of NGC 188 constructed by Sandage (1962), Eggen and Sandage (1969), and McClure and Twarog (1977) show no well-defined clump. McClure and Twarog (1977), however, showed that a large number of giant stars in NGC 188 lie in the outskirts of the cluster, probably due to dynamical relaxation after mass loss, and these have not been included in the C-M diagram. These stars may be clump stars that have lost mass at the tip of the giant branch, but they point out that, if this is the case, the clump for NGC 188 is significantly fainter than $M_v = +1.0$ mag.

If we fit the turnoff considerably above the ZAMS, as shown in Figure 7, the clump absolute magnitude can be made to agree with the other younger disk clusters. Because of the plate limit, it is not possible to say definitely that the main sequence will not reach the theoretical ZAMS. Examination of the other old cluster NGC 188, however (see Demarque and

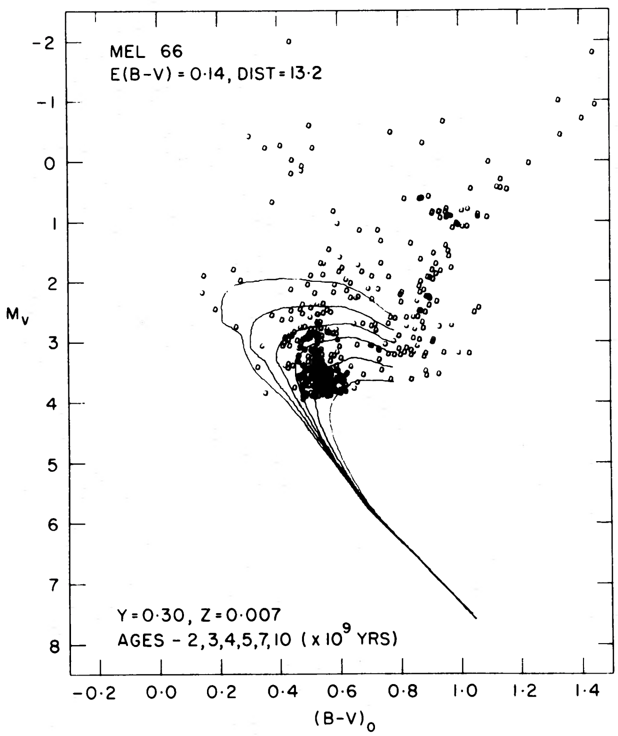

FIG. 7.—The C-M diagram fitted to the same isochrones as in Fig. 5, but forcing the clump absolute magnitude to $M_v = +1.0$ mag. The main-sequence fit does not appear to be good, but fainter photometry should be done to clarify whether it is possible that the turnoff could extend as faint as the theoretical ZAMS.

McClure 1977*a*, Figs. 6, 7), shows that the ZAMS is reached very close below the turnoff for that very old cluster.

Another possibility which solves a number of problems mentioned in connection with the C-M diagram morphology is that there is a variation in metal abundance in the cluster. A metal abundance spread has been suggested for globular clusters, especially ω Cen (e.g., Freeman and Rogers 1975; Butler, Dickens, and Epps 1978), but these are very massive objects, and we feel that this is much less likely in the case of Melotte 66, an open cluster. In any event, if the metal abundance varied between $Z = 0.007$ and 0.02, then the C-M diagram could fit with a clump near $M_v = +1.0$ mag such as shown in Figure 7. The fainter turnoff stars shown here fit an isochrone near $6\text{–}7 \times 10^9$ years for $Z = 0.02$, and the metal-poor turnoff which would be brighter fits the isochrone of about the same age for $Z = 0.007$. In this case stars observed are not faint enough to be on the ZAMS but, rather, are just turnoff stars scattered in luminosity because of the metal abundance spread. The unusual faintness of the base of the giant branch relative to the turnoff, and the blue stragglers, mentioned in § IV*b*, and the ill-defined subgiant branch are also explained in this way because metal abundance variations spread out the turnoff stars which are precursors of the subgiant and giant branches. Hawarden's (1976) value of metal abundance is at the low end of the range discussed here, but this is based on the very brightest turnoff stars to a great extent, and if there is a spread in metal abundance in the cluster these would be the most metal-poor. Finally, the large intrinsic width of the giant branch observed by Hawarden (1976, 1978) could be due to a metal abundance spread. We also find differences in CN strengths from our spectra of giants, as did Dawson (1978) from DDO photometry. This will be discussed in § V.

The second point we wish to discuss is the resulting age for Melotte 66. Regardless of whether or not the location of the ZAMS is chosen so that the clump giants have $M_v = +2.0$ or $+1.0$ (Fig. 6 or Fig. 7), the age of Melotte 66 as determined from the color of the turnoff is $6\text{–}7 \times 10^9$ years, compared with 5×10^9 years for NGC 188 (fit to the same series of isochrones by Demarque and McClure 1977*a*). If the metal abundance were as high as solar, the age would be reduced to some $3\text{–}4 \times 10^9$ years. Since the resulting age depends significantly on metal abundance assumed, it is important that the abundance determination be checked with further photometry, and perhaps spectroscopy, for the brighter stars. In addition, fainter photometry should be done to confirm the main-sequence fit in order to check the possibility that the clump is fainter than that for other clusters. The latter is very important, since the luminosity of the horizontal branch is very sensitive to helium abundance, and could be used as an excellent check of whether a difference in helium abundance exists between the disk and halo populations, as suggested by Gross (1973) and Demarque and McClure (1977*b*).

V. PECULIAR GIANT STARS

Spectra of stars on the giant branch of Melotte 66 discussed in § II*c* have revealed the existence of stars with much stronger CN bands than the majority of the giants. Figure 8 shows intensity tracings of a sample of Melotte 66 giants, as well as the well-known strong CN star α Ser, and the extreme Ba II star HD 116713. Note that the Melotte 66 giants 3314 and 4326 have stronger CN bands than other giants shown. In fact, 3314 has a CN anomaly as strong as that of α Ser. Due to the rather low resolution of the spectra it is not possible to tell whether 3314 may be a mild Ba II star, but it does lie slightly above the main giant sequence in a position similar to that of the Ba II star found in the old open cluster NGC 2420 (McClure, Forrester, and Gibson 1974). One of the Melotte 66 strong CN stars, 4326, has been measured with DDO photometry by Dawson (1978), and he has shown that photometry also reveals a discrepant CN index relative to all the other giants observed in the cluster.

Hawarden (1976, 1978) has discussed the fact that the giant branch of Melotte 66 has a large intrinsic width in $B - V$, and he pointed out that the blue edge of the branch is preferentially populated by stars from the outer zones of the cluster. He suggests that these are highly evolved stars, a disk analog of the asymptotic branch of globular clusters, and that they have

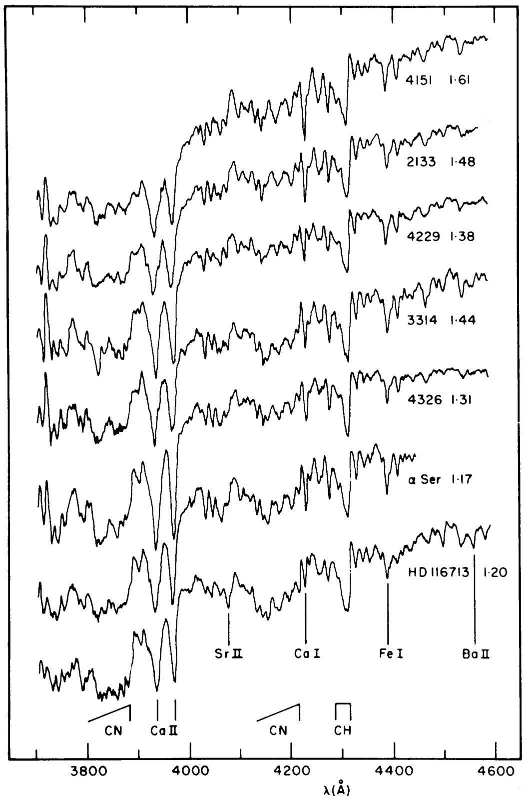

FIG. 8.—Intensity tracings of a sample of Melotte 66 giant stars, the strong CN star α Ser, and the Ba II star HD 116713. The star designations are followed by their $B - V$ values. The first three stars are located on the giant branch of the cluster. Stars numbered 3314 and 4326 which show stronger CN are located somewhat above the giant branch.

preferentially arrived in the outer parts of the cluster as a result of dynamical evolution due to mass loss on the initial giant branch. The stars that we found with strong CN also lie on the bright or blue side of the giant branch. It is possible that these stars are not cluster members, but it is highly unlikely that random field stars at the galactic latitude of Melotte 66 would have such strong CN bands. The most likely explanation for these stars is, as Hawarden (1976) has suggested, that they are highly evolved asymptotic branch stars. In this case, it is possible that they have mixed carbon-rich material to the surface. Hesser, Hartwick, and McClure (1976) suggested that disk clusters do not show the abundance anomalies on the giant branch which are exhibited by globular clusters such as ω Cen (see, for example, Bessell and Norris 1976; Dickens and Bell 1976). Indeed, the DDO photometry for Melotte 66 giants by Dawson (1978) indicates that, for the large majority of giants, the CN strengths are consistent. It appears now, however, that a few giants in disk clusters may be exhibiting these abundance anomalies (including those discussed here in Melotte 66 and two stars in NGC 2420 discussed by McClure *et al.*). In all cases these stars tend to lie above or blueward of the principal giant sequence. A more thorough examination of the Melotte 66 giant branch should be made to determine how widespread this phenomenon is for this cluster.

VI. SUMMARY

A new C-M diagram for the old open cluster Melotte 66 has been constructed from photographic photometry of seven B and six V plates calibrated with an improved photoelectric sequence. All of the features described by Hawarden (1976) have been reproduced. When the cluster is fitted to a metal-poor main sequence ($Z = 0.007$) appropriate to the observed metal abundance, the resulting giant branch clump luminosity is $M_v = +2.0$ mag, approximately 1 mag fainter than that in other open clusters and the horizontal branches of globular clusters. This difference possibly can be reconciled in terms of its old age and a lower helium abundance for the disk relative to the halo.

There are numerous blue stragglers in the cluster, or the turnoff is rather spread out in luminosity. In addition, the turnoff is very bright relative to the base of the giant branch. These two effects, as well as the faintness of the clump resulting from main-sequence fitting, could be explained by a metal abundance spread in the cluster, although it is difficult to understand how this abundance spread could originate in a sparse cluster like Melotte 66.

Accepting the observed metal abundance determined from photoelectric UBV and DDO observations at face value, the age of Melotte 66 appears to be $6–7 \times 10^9$ years. This is significantly older than NGC 188, from fits to the same set of isochrones, making Melotte 66 the oldest known disk cluster.

Several stars with anomalously strong CN bands have been found on the giant branch of the cluster. These are probably mixed stars in an advanced stage of evolution, and they support Hawarden's (1978) suggestion of an asymptotic branch in the cluster.

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REFERENCES

Anthony-Twarog, B. J., and Demarque, P. 1977, *Astr. Ap.*, **57**, 471.
Bessell, M. S., and Norris, J. 1976, *Ap. J.*, **208**, 369.
Butler, D., Dickens, R. J., and Epps, E. 1978, *Ap. J.*, **225**, 148.
Cannon, R. D. 1970, *M.N.R.A.S.*, **150**, 111.
Ciardullo, R. D., and Demarque, P. 1977, *Trans. Yale University Obs.*, Vol. 33.
Dawson, D. W. 1978, *A.J.*, **83**, 1424.

Demarque, P., and McClure, R. D. 1977*a*, in *The Evolution of Galaxies and Stellar Populations*, ed. B. Tinsley and R. Larson (New Haven: Yale University Observatory), p. 199.
———. 1977*b*, *Ap. J.*, **213**, 716.
Dickens, R. J., and Bell, R. A. 1976, *Ap. J.*, **207**, 506.
Eggen, O. J., and Sandage, A. R. 1969, *Ap. J.*, **158**, 669.
Eggen, O. J., and Stoy, R. H. 1963, *Roy. Obs. Bull.*, No. 53.
Freeman, K. C., and Rogers, A. W. 1975, *Ap. J.* (*Letters*), **201**, L71.
Gross, P. G. 1973, *M.N.R.A.S.*, **164**, 65.
Hanson, R. B. 1975, *A.J.*, **80**, 379.
Hawarden, T. G. 1975, *M.N.R.A.S.*, **173**, 223.
———. 1976, *M.N.R.A.S.*, **174**, 471.
Hawarden, T. G. 1978, *M.N.R.A.S.*, **182**, 31P.
Herzog, A. D., and Illingworth, G. 1976, *Ap. J. Suppl.*, **33**, 55.
Hesser, J. E., Hartwick, F. D. A., and McClure, R. D. 1976, *Ap. J.* (*Letters*), **207**, L113.
Janes, K. A. 1975, *Ap. J. Suppl.*, **29**, 161.
———. 1977, *Pub. A.S.P.*, **89**, 576.
McClure, R. D., Forrester, W. T., and Gibson, J. 1974, *Ap. J.*, **189**, 409.
McClure, R. D., and Twarog, B. A. 1977, *Ap. J.*, **214**, 111.
Mengel, J. G., Sweigart, A. V., Demarque, P., and Gross, P. G. 1979, preprint.
Sandage, A. R. 1962, *Ap. J.*, **135**, 333.
Sweigart, A. V., and Gross, P. G. 1976, *Ap. J. Suppl.*, **32**, 367.
van Altena, W. F. 1974, *Pub. A.S.P.*, **86**, 217.

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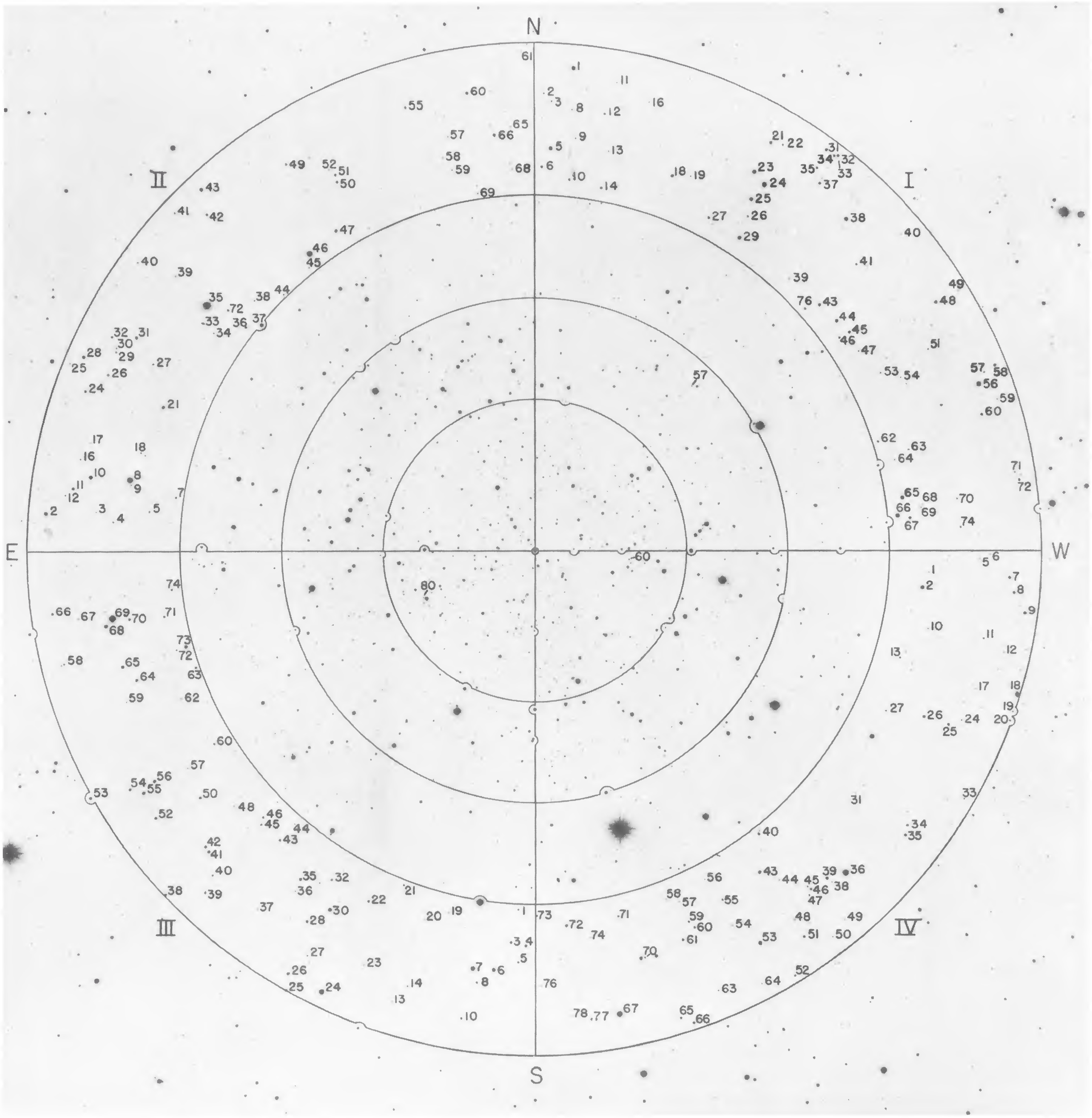

FIG. 1.—Identification chart (30 minute *V* exposure) for stars in Melotte 66 that are not identified by Hawarden (1976)

ANTHONY-TWAROG *et al.* (*see* page 189)