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NGC 2660 AND ITS NEARBY CARBON STAR

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ABSTRACT

From photoelectric *UBV*, *uvby*, and Hβ, and photographic *B*, *V* photometry of stars in and near the open cluster NGC 2660 we find that:

1. The cluster is reddened by $E_{B-V} = 0.38 \pm 0.05$ mag.
2. The true distance modulus is $(m - M)_0 = 12.3 \pm 0.3$ mag.
3. There is a deficiency of stars on the evolved upper main sequence near $V = 15.9$ mag.
4. A cluster age of $\sim 1.2 \times 10^9$ years and a value of $[\mathrm{Fe/H}] \leq [\mathrm{Fe/H}]_{\mathrm{Hyades}}$ is obtained.
5. An N-type carbon star within 1′ of the cluster center has a high probability of membership; its absolute magnitude is therefore $M_V = -2.0 \pm 0.3$ and its mass is $\mathfrak{M} \sim 1.8\, \mathfrak{M}_\odot$.
6. The available data suggest that the carbon stars in NGC 2660 and NGC 7789 are in a post–helium-flash evolutionary stage.

Certain difficulties encountered when comparing theoretical tracks with the observations, both for NGC 2660 and NGC 2477, are briefly mentioned, and in an appendix we present the results of model calculations made for stars of composition $X = 0.69$, $Y = 0.30$, and $Z = 0.01$ for $\mathfrak{M} =$ 1.10, 1.20, 1.35, 1.50, and 1.70 $\mathfrak{M}_\odot$.

Subject headings: carbon stars — interiors, stellar — open clusters

I. INTRODUCTION

NGC 2660 [$\alpha(1950) = 8^{\mathrm{h}}41^{\mathrm{m}}.0$; $\delta(1950) = -47°02'$; $l^{\mathrm{II}} = 266°$; $b^{\mathrm{II}} = 3°$] is a relatively inconspicuous southern cluster of intermediate age (Hartwick and Hesser 1971, hereafter referred to as Paper I) with a color-magnitude (C-M) diagram similar to that of NGC 2477 (Eggen and Stoy 1961; Hartwick, Hesser, and McClure 1972, hereafter referred to as H^{2}M; Cannon 1970). In Paper I we made use of the preliminary photometry to estimate the absolute magnitude of a carbon star that falls within 1′ of the cluster center, assuming that it is a member of the cluster. In this paper we present the results of additional photometry of NGC 2660 and its nearby carbon star, with the goal of refining the distance-modulus estimate of Paper I and of determining the age of the cluster by comparison with new theoretical tracks.

In § II the observational data utilized in constructing the C-M diagram are presented; in § III various determinations of the reddening are presented prior to determining the distance modulus; in § IV the color-magnitude diagram is compared with theoretical tracks in order to derive a cluster age, and the deficiency of stars on the upper main sequence is discussed; while in § V the probability of membership of the carbon star is discussed and an absolute magnitude is determined. Finally, in an appendix, we present results of calculations made for stars of composition $X = 0.69$, $Y = 0.30$, and $Z = 0.01$ for $\mathfrak{M} = 1.10$, 1.20, 1.35, 1.50, and 1.70 $\mathfrak{M}_\odot$.

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II. OBSERVATIONAL DATA

a) *Photoelectric Sequence*

The principal photoelectric sequence used in reducing the photographic material consists of 35 stars ranging in *V* magnitude from 8.4 to 18.5. The *UBV* data for these stars are tabulated in table 1, and the stars are identified in figure 1 (plate 7). The photoelectric observations were made during the 1970 and 1971 seasons with the 152- and 91-cm telescopes of the Cerro Tololo Inter-American Observatory using conven-

TABLE 1

PHOTOELECTRIC UBV DATA FOR NGC 2660 SEQUENCE STARS

Number	Photoelectric V (mag)	Photoelectric B−V (mag)	Photoelectric U−B (mag)	$n_{p.e.}$	Photographic V (mag)	Photographic B−V (mag)
9001	16.37	0.89	0.38	2	16.27	0.90
9002	14.86	0.75	0.41	2	14.85	0.75
9003	15.83	0.84		1	15.87	0.76
9004	11.72	0.16	−0.45	4	11.67	0.24
9005	8.38	1.13	1.14	4		
9006	14.90	0.89	1.00*	2	14.92	0.87
9007	16.58	0.85	0.32*	2	16.58	0.83
9008	14.64	0.73	0.48	2	14.65	0.73
9009†	11.68V	4.29V	≥3.62::*	4	11.42	4.82
9010	17.64	0.95	0.40	1	17.62	0.97
9011	17.52	0.96		1	17.46	0.84
9012	17.02	0.75		1	17.00	0.74
9014	12.64	0.63	0.47	2	12.59	0.66
9015	15.12	0.54	0.45:	1	15.10	0.57
9016	13.98	1.36	1.01	1	14.00	1.33
9017	16.20	0.93		1		
9018	16.23	0.90	0.26	1	16.29	0.85
9019	14.79	1.44	1.27	1	14.79	1.46
9020	16.98	0.98	−0.20	1	17.08	0.85
9021	14.84	0.67	0.44	2	14.85	0.68
9022	15.66	1.29	1.18	1	15.65	1.32
9023	13.49	1.35	1.10	2	13.50	1.36
9024	13.28	0.46	0.33	2	13.29	0.47
9025	12.98	1.48	1.46	2	12.98	1.53
9026	16.23	1.47	0.91	2	16.23	1.45
9027	15.60	1.46	1.25	1	15.59	1.51
9031	18.48	1.61		2		
9032	17.83	1.16	1.18:	1	17.76	1.22
9033	17.10	1.06		1	17.06	1.14
9034	18.28	0.88		1	18.37	0.79
9035	17.78	1.56	0.97:	1	17.78	1.42
9036	17.86	0.82		1		
9037	17.76	1.02	0.64:	1	17.78	1.03
9038	18.25	0.92	0.10:	1	18.25	0.92
9039	17.36	0.94	0.41:	1	17.46	0.84

NOTES TO TABLE:
* One measure only
† See Table 6

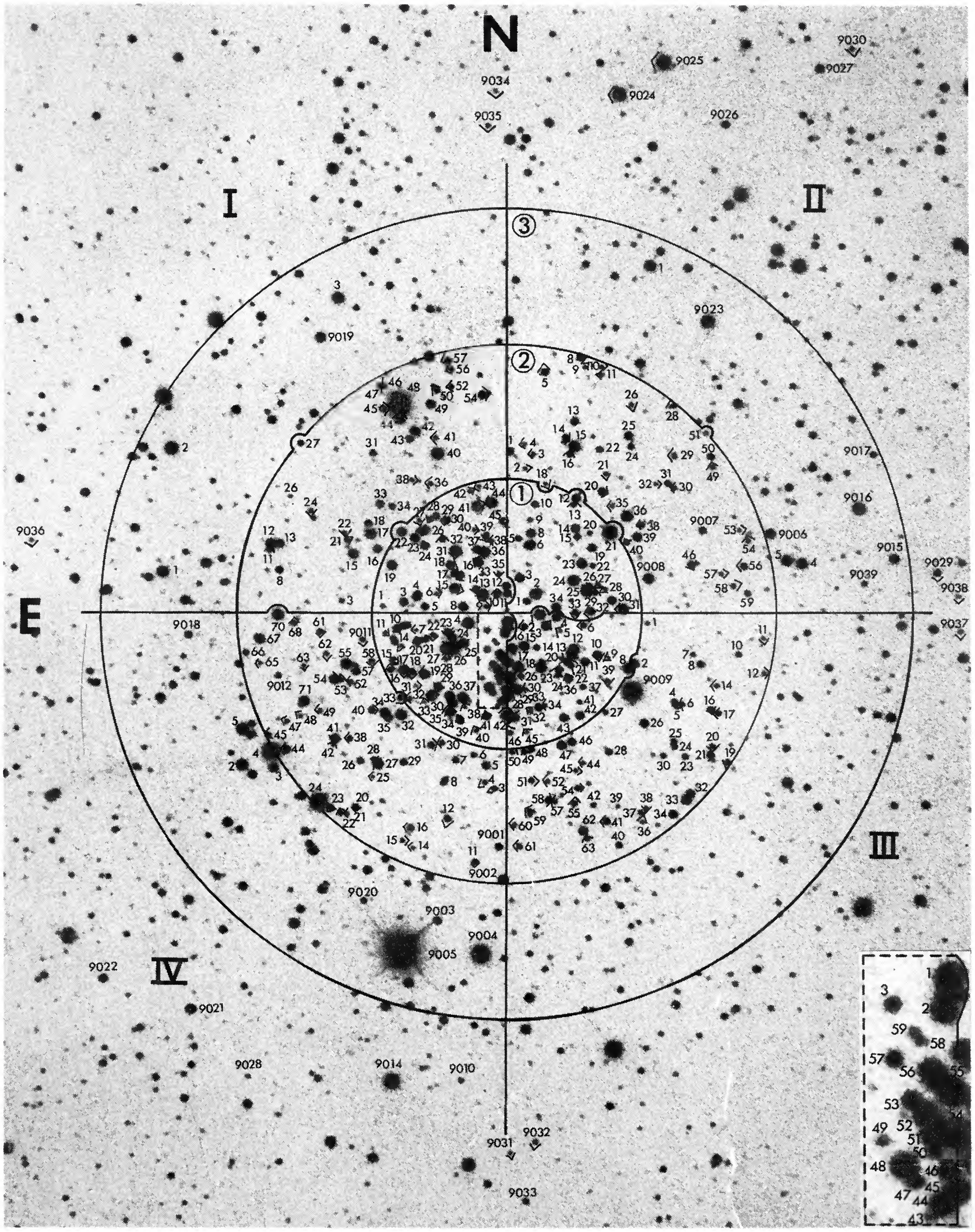

FIG. 1.—Finding chart for the faint photoelectric sequence stars, as well as the stars measured by iris photometry. The reproduction is from a 30-minute visual plate (103aD + GG14) taken with the 152-cm telescope on Cerro Tololo. The circles are of radii 1′, 2′, and 3′. The carbon star is number 9009.

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tional 1P21 single-channel photometers and *UBV* filters; the standards were those described by H^{2}M. Extinction was determined nightly, and the mean values were used in the reductions. Typical rms differences between published and transformed values of the magnitude and colors for the standard stars on a single night are ± 0.02 mag.

b) *Photographic Photometry*

The photographic material consists of plates taken in *V* (103aD + GG14) and *B* (103aO + GG13) at the f/7.5 Ritchey-Chrétien focus of the 152-cm telescope. Exposure times ranged from 15 to 45 minutes. Results of iris photometry of 349 stars (identified in fig. 1) are presented in table 2; the reduction procedures were identical to those used previously (H^{2}M; Hartwick and Hesser 1972). Stars brighter than $V \sim 17.5$ mag were measured on five *V* and five *B* plates, whereas most stars fainter than $V \sim 17.5$ mag were observed on only one plate in each color. The results presented in table 1 have been corrected for the following color equations:

$$B - V = 0.111 + 0.880(b - v)\,,$$

$$V = v - 0.088 + 0.094(B - V)\,,$$

where b and v represent the magnitudes determined directly from the iris photometry. Median internal standard errors for the multiply observed stars are ± 0.03 in *V* and ± 0.04 in $B - V$. No evidence for field errors in excess of 0.03 mag was found.

c) *Additional Photoelectric Work*

Apart from the principal photoelectric sequence of § II*a* that was used exclusively for the iris reductions of § II*b*, various less ambitious photoelectric observations have been made in connection with our investigation of NGC 2660.

i) *B, V Photometry of Giant Stars*

For eventual utilization with intermediate-band photometry on the DDO system (McClure and van den Bergh 1968), a program of *B*, *V* photometry of the giant stars was undertaken in the 1972 season. In table 3 we present results obtained with the same equipment used for the earlier observations of table 1; these results are consistent with those obtained earlier, but have been kept separate herein to emphasize that they were not utilized in the iris reductions.

ii) *uvby*–Hβ *Photometry of Early-Type Stars*

The utility of the *uvby*–Hβ systems (Crawford and Barnes 1970; Crawford and Mander 1966) for application to foreground reddening determinations has been pointed out by Crawford and Barnes (1969). Several early-type stars were identified for us by Dr. Jurgen Stock on an objective-prism plate taken with the Curtis Schmidt telescope on Cerro Tololo; in addition, several early-type stars were isolated in the *UBV* photometry (§ II*c* iii). Four-color–Hβ data obtained for seven of these stars using the 152-cm and 91-cm telescopes, 1P21 photocells, and CTIO filter set 3 in the 1972 season are presented in table 4, and the stars are identified in figure 2 (plate 8); the y magnitudes have been transformed to the *V* magnitude of the *UBV* system. Transformations were effected using the mean of slope and extinction coefficients determined on at least 9 nights. Typical rms errors in the transformations of the standard stars on a single night are 0.015, 0.013, 0.012, 0.015, 0.006 mag in y, $b - y$, m_1, c_1, and β, respectively.

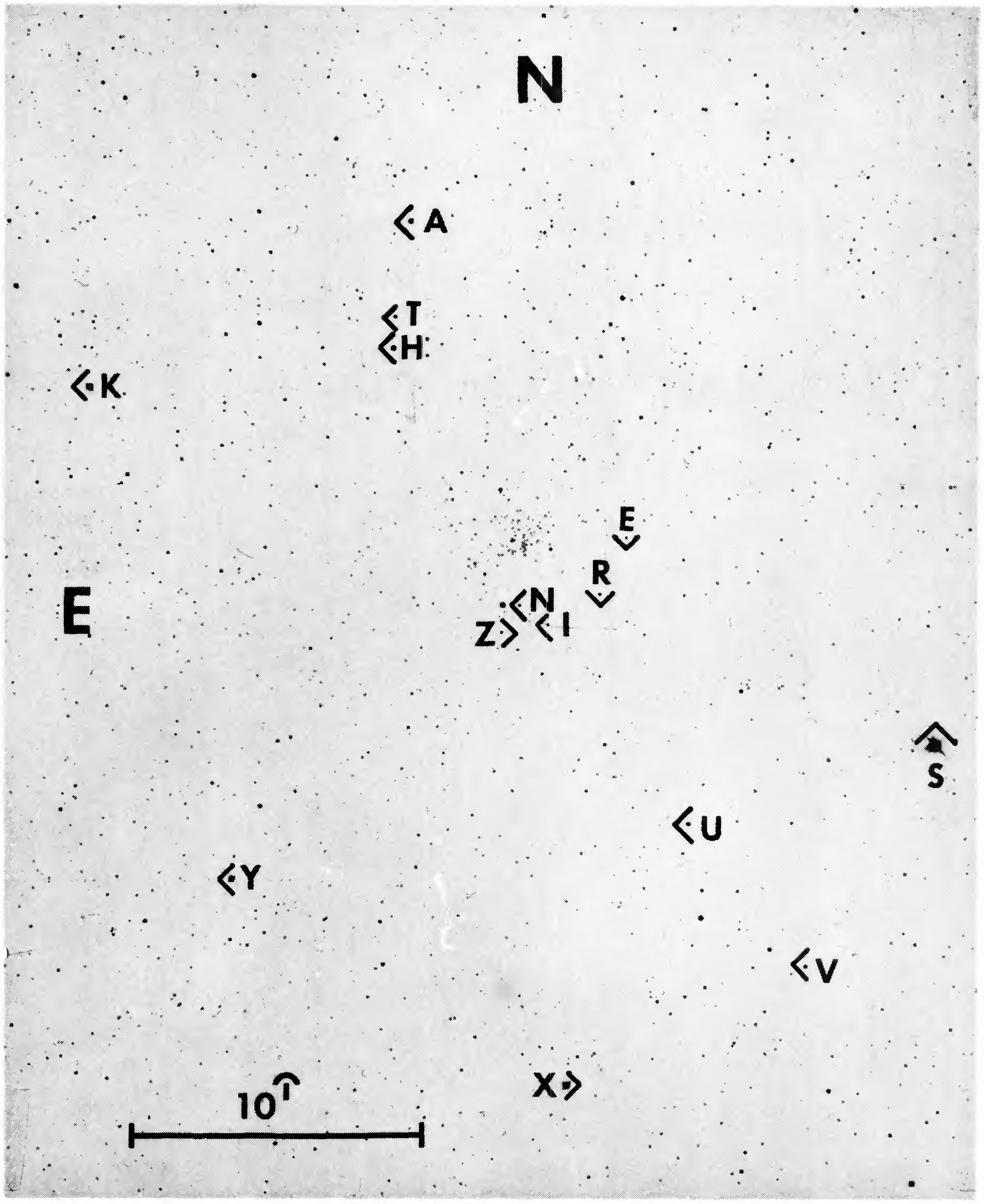

FIG. 2.—Finding chart for the bright stars measured in *UBV* and for the fainter, early-type stars used for reddening determinations via *uvby*–Hβ photometry. The reproduction is from a 5-minute visual plate (103aD + GG14) taken with the 152-cm telescope on Cerro Tololo.

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TABLE 2

NGC 2660 PHOTOGRAPHIC DATA

Star	V	B-V	Star	V	B-V	Star	V	B-V	Star	V	B-V
1101	18.01	0.84	1142	18.00	1.03	1254	15.37	0.61	2202	18.39	0.78
1103	15.57	0.62	1143	18.33	0.88	1256	17.73	0.92	2203	17.89	1.36
1104	15.02	0.67	1144	14.40	1.25	1257	16.61	0.80	2204	18.18	1.02
1105	16.27	0.71	1145	15.73	0.71	1301	14.38	1.25	2205	16.33	0.76
1106	18.23	0.85	1203	17.77	0.91	1302	13.47	0.55	2208	16.34	0.65
1108	15.27	0.68	1208	16.24	0.69	1303	14.06	1.87	2209	18.11	0.84
1109	17.72	0.75	1211	17.20	0.89	2101	16.36	0.72	2210	18.17	0.96
1110	15.86	0.72	1212	14.17	1.21	2102	14.43	1.20	2211	18.07	0.84
1111	16.60	0.67	1213	15.89	0.96	2103	15.31	0.62	2213	15.97	0.72
1112	15.65	0.68	1215	14.85	0.70	2105	17.00	0.69	2214	16.31	0.72
1113	14.16	1.25	1216	15.70	0.65	2106	14.99	0.54	2215	14.12	1.28
1114	17.14	0.91	1217	14.36	1.29	2108	15.42	0.62	2216	17.33	1.23
1115	14.64	1.29	1218	16.20	0.83	2109	17.81	0.86	2218	18.25	0.89
1116	15.72	0.84	1221	17.21	0.84	2110	16.60	0.73	2220	16.08	0.67
1117	16.28	0.62	1222	17.86	0.86	2112	15.64	0.63	2221	17.99	0.90
1118	15.38	0.59	1224	17.93	0.90	2113	17.28	0.83	2222	16.83	0.80
1119	15.09	0.66	1226	18.52	0.73	2114	15.55	0.61	2224	16.69	0.56
1122	15.12	0.70	1227	17.01	0.83	2115	16.58	0.70	2225	15.48	0.63
1123	15.09	0.64	1231	16.87	0.73	2119	15.89	1.00	2226	17.96	1.06
1124	16.28	0.67	1233	15.85	0.75	2120	17.75	0.86	2228	17.46	0.97
1126	15.05	0.71	1234	17.10	0.75	2121	12.93	1.35	2229	17.53	0.86
1127	18.05	0.90	1236	17.69	0.96	2122	17.58	0.81	2230	17.83	1.01
1128	17.56	0.69	1238	18.09	0.85	2123	14.76	0.74	2231	16.80	0.81
1129	16.05	0.67	1240	13.85	0.31	2124	14.35	1.26	2232	18.51	0.72
1130	16.30	0.79	1241	17.74	1.22	2125	14.03	1.28	2235	18.13	0.92
1131	16.78	0.69	1242	14.89	0.68	2126	16.68	1.04	2236	14.43	0.69
1132	14.12	1.25	1243	16.25	0.69	2127	17.52	0.83	2238	17.04	0.72
1133	15.12	0.65	1244	14.49	0.85	2128	17.95	0.99	2239	15.35	0.68
1135	18.35	0.78	1245	15.95	0.76	2129	17.42	0.86	2240	17.84	0.73
1136	14.49	0.56	1246	17.02	1.14	2130	15.66	0.64	2246	16.26	0.71
1137	15.58	0.62	1247	17.83	0.84	2131	14.55	0.63	2249	17.60	0.90
1138	18.33	0.85	1248	11.10	1.11	2132	15.49	0.59	2250	16.34	0.70
1139	16.36	0.70	1249	15.22	0.67	2133	16.55	0.69	2251	18.05	0.95
1140	18.32	0.81	1250	16.58	1.13	2134	15.21	0.64	2253	18.55	0.70
1141	14.53	1.26	1252	17.60	0.87	2201	16.49	0.78	2254	17.92	1.03

TABLE 2 (Continued)

Star	V	B-V	Star	V	B-V	Star	V	B-V	Star	V	B-V
2256	16.69	0.75	3132	17.90	0.77	3233	14.88	1.39	4115	15.84	0.84
2257	18.21	0.96	3133	15.74	0.67	3234	15.83	0.76	4116	16.61	0.71
2258	17.83	0.93	3134	18.29	0.75	3236	18.16	1.02	4117	14.72	0.75
2259	17.11	0.83	3136	16.34	0.68	3237	17.55	0.76	4118	16.30	0.70
2301	14.37	0.73	3137	17.38	0.81	3238	18.23	0.89	4119	15.08	0.63
2304	14.42	1.33	3139	17.57	0.99	3239	18.26	0.91	4120	16.03	0.66
2305	14.55	1.34	3141	17.85	1.09	3240	16.69	0.74	4121	16.96	0.68
2307	15.08	0.52	3142	15.56	0.63	3241	16.44	0.76	4122	17.02	0.80
3101	14.26	1.27	3143	15.75	0.72	3242	17.77	0.85	4123	15.72	0.71
3102	16.83	0.72	3145	18.40	0.77	3244	18.14	0.98	4124	15.13	0.68
3103	15.40	0.63	3146	17.24	0.82	3245	18.09	0.97	4125	15.06	0.65
3104	15.43	0.78	3201	18.05	1.02	3246	15.72	0.68	4126	12.65	1.72
3105	18.40	0.68	3202	16.20	0.67	3247	15.11	0.60	4127	13.70	1.05
3106	16.96	0.73	3204	16.87	0.76	3248	16.55	0.86	4128	18.00	0.88
3108	14.39	1.21	3205	17.54	0.94	3249	17.68	1.02	4129	15.49	0.57
3109	18.51	0.59	3206	17.66	1.10	3250	17.45	0.94	4130	14.39	0.45
3110	15.60	0.65	3207	17.80	1.01	3251	17.47	1.33	4131	18.62	0.63
3111	15.64	0.68	3208	16.52	0.83	3252	17.94	1.00	4132	17.76	1.13
3112	14.25	1.31	3210	17.28	0.99	3254	16.92	0.86	4133	18.60	0.50
3113	14.10	1.25	3211	18.29	0.89	3255	17.01	0.70	4134	14.84	0.68
3114	16.92	0.77	3212	18.32	0.87	3257	17.45	0.93	4135	15.01	0.62
3115	14.75	0.71	3214	17.74	1.04	3258	16.32	0.75	4136	14.83	0.65
3116	14.83	0.61	3216	16.95	0.75	3259	17.44	0.86	4137	14.32	1.22
3117	14.10	0.59	3217	17.05	0.91	3260	17.91	0.92	4138	18.39	0.66
3118	14.26	1.24	3219	16.82	0.87	3261	17.42	0.81	4139	16.19	0.69
3120	17.83	0.57	3220	17.56	0.79	3262	15.48	0.64	4140	18.14	0.76
3121	15.58	0.73	3221	16.28	0.86	3263	17.65	0.95	4141	15.79	0.62
3122	16.56	0.59	3223	16.97	0.76	4101	14.21	1.03	4142	13.67	0.52
3123	15.89	0.72	3224	16.95	0.80	4102	14.72	0.59	4143	17.89	0.67
3124	16.99	0.66	3225	16.76	0.64	4103	17.02	0.71	4144	14.83	0.67
3126	17.76	0.75	3226	15.46	0.72	4104	14.14	1.22	4145	14.62	0.72
3128	15.45	0.97	3227	17.61	0.84	4107	18.71	0.54	4146	15.35	0.53
3129	14.76	0.92	3228	16.63	0.70	4110	16.00	0.79	4147	16.59	0.90
3130	17.85	0.64	3230	17.35	0.82	4111	18.14	0.89	4148	14.63	0.63
3131	15.14	0.66	3232	15.71	0.73	4114	18.27	0.86	4149	18.21	0.70

TABLE 2 (Continued)

Star	V	B-V	Star	V	B-V
4150	17.01	1.19	4234	14.65	0.73
4151	13.98	1.09	4235	15.48	0.68
4152	14.82	0.64	4238	17.37	1.60
4153	16.05	0.66	4240	16.11	0.80
4154	13.75	1.20	4241	15.11	0.72
4155	14.17	0.60	4242	18.25	0.77
4156	14.63	0.54	4244	15.67	0.74
4157	16.85	0.67	4245	17.18	0.85
4158	18.10	0.77	4247	17.86	1.01
4159	17.68	1.34	4248	18.09	1.05
4203	17.14	0.85	4249	17.92	1.03
4204	17.81	1.01	4252	17.66	0.88
4205	16.03	0.78	4253	16.84	0.69
4206	17.43	0.82	4254	15.51	0.59
4207	16.82	0.79	4255	14.45	0.70
4208	17.08	1.29	4257	16.04	0.74
4211	16.90	0.77	4258	17.39	0.97
4212	16.46	0.75	4261	17.24	0.90
4214	18.03	1.04	4262	17.91	0.98
4215	17.96	0.91	4263	18.18	0.92
4216	16.44	0.78	4265	18.53	0.56
4220	16.55	0.79	4266	17.08	0.78
4221	17.90	0.86	4267	15.06	1.36
4222	17.11	0.87	4268	16.95	0.73
4223	16.94	0.76	4270	14.31	0.48
4224	11.93	1.53	4271	14.70	0.81
4225	18.37	0.87	4302	14.29	1.28
4226	16.60	0.81	4303	14.86	0.76
4227	14.64	0.70	4304	11.83	1.86
4228	17.36	0.94	4305	13.78	1.04
4229	16.46	1.59	9025	12.98	1.53
4230	17.22	0.76	9028	18.15	0.94
4231	16.52	0.79	9029	16.24	0.85
4232	14.27	1.29	9030	17.78	1.01
4233	16.40	0.65			

TABLE 3

B, *V* PHOTOELECTRIC PHOTOMETRY OF GIANTS IN NGC 2660

Star	*V* (mag)	*B* − *V* (mag)	*n*
1115.........	14.68	1.33	1
1132.........	14.12	1.31	1
1301.........	14.37	1.29	1
1302.........	13.45	0.54	1
2121.........	12.99	1.31	3
3101.........	12.45	1.26	1
4104.........	14.15	1.25	2
4224.........	11.99*	1.82*	1
4302.........	14.27	1.30	1
9023.........	13.47	1.38	2
9025.........	12.98	1.48	2

* Variable?

TABLE 4

uvby–Hβ PHOTOMETRY OF BRIGHT STARS NEAR NGC 2660

	Y (mag)	$b - y$ (mag)	m_1 (mag)	c_1 (mag)	β (mag)	n	E_{B-V} (mag)
A.........	9.00	0.000	0.111	0.540	2.750	2	0.09
E.........	12.77	0.343	0.003	0.493	2.654	3	0.60
I..........	12.06	0.380	0.008	0.471	2.682	3	0.65
N.........	11.73	0.165	0.028	0.342	2.696	3	0.36
R.........	11.85	0.317	0.015	0.325	2.654	2	0.58
U.........	10.23	0.051	0.164	0.924	2.898	2	0.11
Z.........	12.61	0.416	0.135	1.044	2.803	2	0.42

iii) UBV *Photometry of Bright Field Stars*

UBV photometry of nine bright stars in the vicinity of NGC 2660 was obtained on 2 nights in 1970 June with a 41-cm telescope and equipment as described above. The data are presented in table 5 and the stars are identified in figure 2; typical rms errors in the transformation to the *UBV* system on a single night were 0.02 mag for V, $B - V$, and $U - B$. Agreement between the four-color and *UBV* data for those stars in common is satisfactory. The *UBV* data, originally intended to be the precursors of a set of reliable photoelectric secondary standards of intermediate brightness, have found application in the reddening determinations to be discussed in the next section.

III. REDDENING AND DISTANCE-MODULUS DETERMINATIONS

At the galactic coordinates of NGC 2660 we expect the reddening to be appreciable and possibly nonuniform; indeed, inspection of long-exposure photographs suggests the presence of an absorbing lane several minutes from the western edge of the cluster. Consequently we have attempted to estimate the reddening by a variety of methods. From *UBV* measurements alone we are able to make several determinations. From the position of star 9004 in the two-color plane, assuming it to be a main-sequence object, we find $E_{B-V} = 0.37$ mag. The six blue stars of table 5, if they are all assumed to be main-sequence stars and if their individual reddenings are averaged without respect to distance, yield $E_{B-V} = 0.27$ mag; but star T, the faintest star close to the cluster, yields a value in closer accord with that of star 9004. For three Cepheids lying within 1° of the cluster, SW, SX, and T Vel, Fernie (1967) gives reddenings of 0.34, 0.33, and 0.34 mag, respectively. (It is interesting to note that SW Vel shares the distance modulus of the cluster, while being spatially coincident with it.) Adjusting the Cepheid

TABLE 5

PHOTOELECTRIC *UBV* DATA FOR BRIGHT FIELD STARS

Name	V (mag)	$B - V$ (mag)	$U - B$ (mag)	n	E_{B-V} (mag)
A...........	8.95	−0.03	−0.42	2	0.14
H...........	8.64	1.01	0.78	2	...
K...........	7.21	−0.12	−0.61	2	0.36
S*...........	4.76	0.12	0.19	2	...
T...........	10.82	0.28	−0.14	2	0.43
U...........	10.20	0.09	−0.03	1	0.16
V...........	10.16	0.13	0.07	1	0.23
X...........	6.71	0.24	0.09	2	0.30
Y...........	7.82	1.14	0.90	2	...

* HR 3452 (A5 II).

reddenings to obtain equivalent B-star reddenings (Fernie 1963), we find $E_{B-V} = 0.38$, 0.37, and 0.38 mag. Finally, to determine reddenings from the *uvby*–Hβ data of table 4 for those stars judged from their photometry to be A stars, the relation $(b - y)_0 = 2.943 - 1.000\beta - 0.100\delta c_1 - 0.100\delta m_1$ was used in conjunction with the preliminary calibration of the c_1 and m_1 relations (Crawford 1970); while for B stars the relation $(b - y)_0 = -0.116 + 0.097c_0$ was applied. Stars N and Z, lying in close proximity to the southern edge of NGC 2660, yield $E_{B-V} = 0.39$ mag, while stars E, I, and R, lying in the absorption lane to the west of the cluster, yield $E_{B-V} = 0.61$ mag. Clearly the absorption is nonuniform in the vicinity of NGC 2660, but an average of $E_{B-V} = 0.38 \pm 0.05$ mag formed from those distant stars with least angular separation from the cluster is assumed to represent fairly the actual situation in the immediate vicinity of the cluster. As will be seen later, the behavior of the giants in the two-color diagram provides additional support for the adopted reddening.

The C-M diagram of NGC 2660 based on the data of tables 1–3 is presented in figure 3; only those stars from table 1 whose proximities, spatially, with respect to the cluster as well as to the principal loci of figure 3, suggest that they are cluster members have been included in the diagram. In the preparation on the C-M diagram, data from table 1 or table 3 have been preferred to those of table 2. From the above discussion of reddening, it seems likely that some of the scatter in figure 3 might have its origin in nonuniform absorption in the vicinity of the cluster, but area 2 and 3 stars (those on the western side) show no systematic separation from the area 1 and 4 stars. The line drawn through the fainter stars shows the locus adopted by us for determining the distance modulus. Superposing this locus upon the zero-age main sequence tabulated

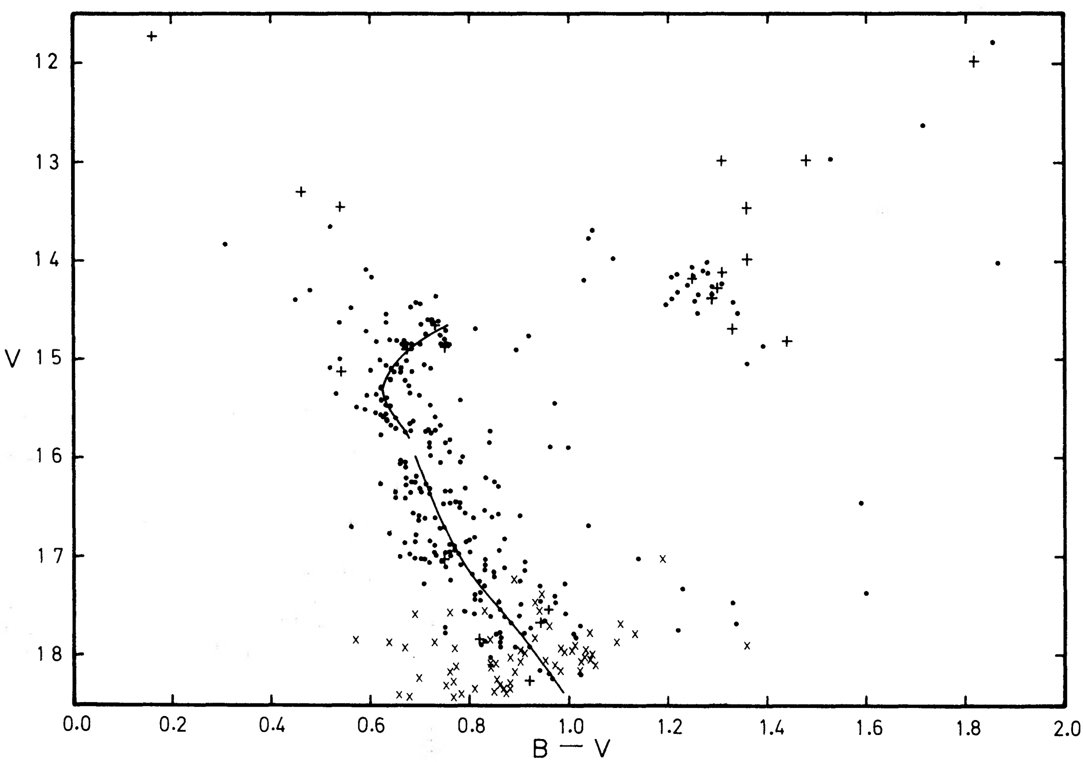

FIG. 3.—C-M diagram for more than 350 stars measured near NGC 2660. The photographically derived values (dots for stars measured on more than one plate pair and crosses for those measured on only one plate pair) have been corrected for a small color equation (see text); the vertical crosses are photoelectric data from tables 1 and 3 for stars judged to be cluster members. The carbon star falls off the diagram at $V_{\max} = 11.53$ mag and $\langle B - V\rangle \simeq 4.3$ mag.

by Eggen (1965), and correcting for a reddening of 0.38 ± 0.05 mag with a ratio of total-to-selective absorption of 3.3 ± 0.6 (Martin 1971), yields $(m - M)_0 = 12.3 \pm 0.3$ as the true distance modulus of NGC 2660. This corresponds to a distance of 2.9 kpc.

IV. COMPARISON WITH THEORETICAL TRACKS

The age and turnoff mass for NGC 2660 can be estimated from a comparison of the C-M diagram in figure 3 with theoretical isochrones computed with the same composition as the cluster stars. Isochrones computed for the composition $Y = 0.3$, $Z = 0.01$ are shown in figure 4. The tracks, which are tabulated in the Appendix, were computed with the program and input physics described by Hartwick and Vanden Berg (1973). The theoretical results predict a deficiency of stars, or gap, about 0.25 mag wide, at a point on the locus in figure 3 just below the maximum extension to the blue. To investigate the question of the existence and location of a gap in our observations we applied the method of Aizenman, Demarque, and Miller (1969) and the statistical test of Hawarden (1971) to the data in figure 3, including only those stars lying within ±0.1 mag of the locus shown in the diagram. The results indicate that a gap does exist at $V \simeq 15.9$ (the χ^2 test gives a probability of 99.8 percent that the gap is real). Assuming that the large scatter in the C-M diagram has not biased the formal analysis, we note that this gap lies approximately 0.4 mag below the position predicted by the theoretical results. A similar result was found by H^{2}M in NGC 2477.

The two-color diagram plotted in figure 5 shows that the three photoelectrically observed stars which are located near the turnoff in figure 3 lie below the Hyades locus after a reddening of $E_{B-V} = 0.38$ mag has been applied. Stars occupying the same (low-gravity) region of the two-color diagram were found in NGC 2477. H^{2}M suggested that these stars may form a separate group above the turnoff point, as hinted at in the diagrams of other clusters, such as NGC 188 (Eggen and Sandage 1969). Unfortunately the large observational scatter does not allow an unambiguous interpretation of the status of these "low-gravity" stars in either cluster, but it should be noted that in M67 evidence has been presented supporting the view that the somewhat

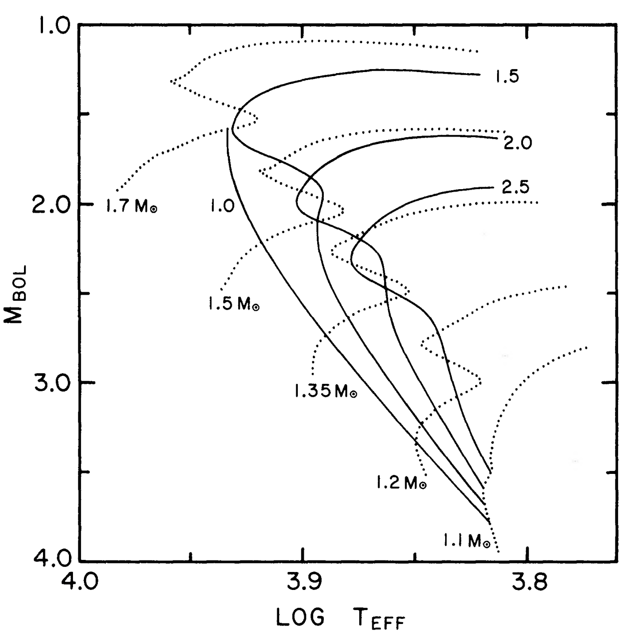

FIG. 4.—Theoretical tracks (*dotted lines*) and isochrones (*solid lines*) for stellar models with $Y = 0.3$ and $Z = 0.01$; the numbers adjacent to the isochrones are ages in 10^9 years.

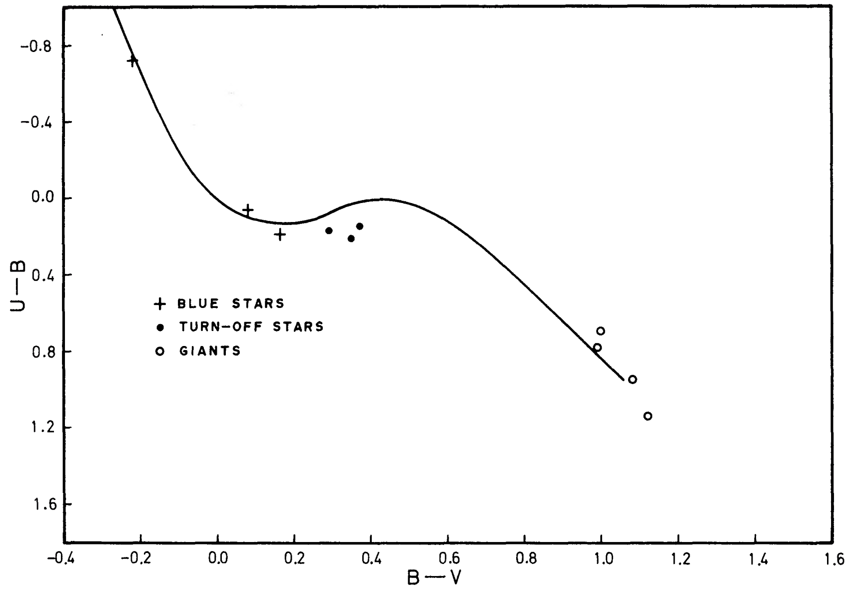

FIG. 5.—The two-color diagram corrected for reddening for photoelectrically measured stars in the vicinity of NGC 2660. The blue star is seen to be in excellent agreement with the giants of NGC 2660, while the three stars thought to lie above and redward of the turnoff in fig. 3 fall in the low-gravity region of the present diagram. The solid line is the Hyades locus.

more luminous "blue stragglers" have normal rather than low gravities and masses higher than those of the turnoff stars (Bond and Perry 1971; Strom, Strom, and Bregman 1971).

Age determination from the theoretical tracks requires knowledge of the helium abundance Y and the heavy-element abundance Z of the cluster stars. The latter quantity may be estimated from the ultraviolet excess (deficiency) of the giant stars (Wallerstein and Helfer 1966). The positions in the two-color diagram of four stars falling near the giant sequence are shown in figure 5. The giants have had their reddening removed following the procedures described by Hartwick and McClure (1972). Based upon the four stars, we deduce from the figure that $[\mathrm{Fe/H}]_{2660} \leq [\mathrm{Fe/H}]_{\mathrm{Hyades}}$. From figure 3, $V_{\mathrm{T.O.}} = 15.35$, hence $m_{\mathrm{bol(T.O.)}} = 15.40$ and $M_{\mathrm{bol(T.O.)}} = 1.55$. From the isochrones for $Y = 0.3$ and $Z = 0.01$, the age of NGC 2660 is $\sim 1.5 \times 10^9$ years and the turnoff mass is $\sim 1.7\,\mathfrak{M}_\odot$. For $Y = 0.29$ and $Z = 0.03$ we find from the tracks of Hallgren and Demarque (1966) and Hallgren (1967) an age of 0.9×10^9 years and turnoff mass $\sim 1.9\,\mathfrak{M}_\odot$.

V. THE CARBON STAR

In Paper I we pointed out the proximity of an N-type carbon star to the cluster NGC 2660. In view of the meager and conflicting evidence for luminosities, masses, and ages of carbon stars (Blanco 1965; Gordon 1968), and the difficulties of significantly improving the situation observationally, the coincidence of the carbon star and NGC 2660 deserves the fullest exploitation. Whether or not this star is a member of the cluster will be very difficult to ascertain spectroscopically, thereby forcing us to rely on other arguments. Both the statistical improbability of a chance spatial coincidence between the cluster and the carbon star and the position the star occupies in the C-M diagram lead us to conclude that the star is probably a member. If we make use of Westerlund's (1971) catalog, we find approximately three carbon stars per square degree in the vicinity of NGC 2660; the probability of finding a carbon star within a circle of 2′ radius is, conservatively, 0.01. On this basis the chances seem excellent that the star is a member of the cluster.

Photoelectric observations obtained at Cerro Tololo on 7 nights spaced over 2 years reveal a range in V of 0.21 mag; the data are presented in table 6, and we caution the reader that these magnitudes and colors must be uncertain in view of the need to extrapolate far beyond the range of values encountered in the standard stars. Eggen (1972) has tentatively suggested, on the basis of six points with a range of $11.53 \leq V \leq 11.90$ mag, that the NGC 2660 carbon star may be a quasi-periodic ($P \sim 100$ days) variable. Combining our data with those of Eggen appears to rule out a period of 100 days, and many more data will evidently be required to discern convincingly any periodicity within the V-magnitude fluctuations. The data in table 6 yield $\langle V \rangle = 11.64$ mag, while the mean from Eggen's data is $\langle V \rangle = 11.70$. The mean $B - V$ found from our 152-cm telescope data and Eggen's data is 4.26 mag. Adopting $V_{\max} = 11.53$ as the maximum apparent magnitude and combining $V_{\max}$ with the reddening and distance modulus determined for the cluster, yields $M_V = -2.0$ mag for the carbon star on the assumption of cluster membership.

For the present results, Gordon's (1968) recent summary of the data available on absolute-magnitude determinations for carbon stars provides a good basis for comparison. Gordon concludes that the absolute magnitude of N-type stars ranges from $-1.5 > M_v > -3.5$ depending on spectral type, while Richer (1971), from a galactic-rotation analysis, derived $M_v = -2.7 \pm 0.7$ for 33 N-type stars of different spectral types. Gaustad and Conti (1971) have pointed out that if the carbon star MSB 75 is a member of the open cluster NGC 7789, then its absolute magnitude is $M_v = -2.1$. The similarity between this value and the one found above for NGC 2660 is especially interesting in view of the similarity of C-M diagrams and hence ages of NGC 7789 and NGC 2660. Recently Walker (1972) has found $M_v = -1.9$ for star 135, a probable carbon star near NGC 419 in the Small Magellanic Cloud. Without a knowledge of the spectral type it is not possible to determine the bolometric correction and hence the bolometric magnitude of these carbon stars. However, according to both Gordon and Richer the bolometric correction is greater than 2.5 mag for N-type stars. This being the case, $M_{\text{bol}} < -4.5$ for the above carbon stars.

Iben (1967) concluded that the mass below which stars will undergo the helium flash is $2.25 < \mathfrak{M}_\odot < 3.0$. The mass deduced above for the carbon star in NGC 2660 is well below this limit. Recent theoretical evolutionary calculations to the helium flash lead to the following values of M_{bol} at the tip of the giant branch: $M_{\text{bol}} = -3.5$ for a star of $(M, X, Z) = $ (1.2, 0.69, 0.06, Demarque and Heasley 1971); $M_{\text{bol}} = -3.2$ for a star with (0.85, 0.75, 0.001, Demarque and Mengel 1971); $M_{\text{bol}} = -3.8$ for (1.4, 0.602, 0.044, Refsdal and Weigert 1970); while Eggleton (1968) finds $M_{\text{bol}} \simeq -3.7$ for a large range in chemical composition. As these values of M_{bol} represent the maximum luminosity a star attains during its pre–helium-flash evolution, and as these values are significantly lower than the lower limit found above for the carbon stars, we conclude that the carbon stars in NGC 2660 and NGC 7789 are in a post–helium-flash stage. This stage could very likely be the second ascent of the giant branch, where the thermal instability which occurs in these double-shell models (Schwarzschild and Härm 1967)

TABLE 6

B, *V* PHOTOELECTRIC DATA FOR THE CARBON STAR

JD 2,440,000+	V (mag)	$B - V$ (mag)	Aperture (cm)
741.5	11.66	4.38	152
983.5	11.66	4.23	152
984.5	11.71	4.25	152
985.5	11.69	4.27	152
1449.5	11.50	4.17	152
1488.5	11.63	4.98	91

may be responsible for allowing carbon-rich material to reach the surface convection zone.

VI. CONCLUSIONS

Based on photoelectric and photographic observations of stars in the open cluster NGC 2660 we can make the following conclusions: (1) The cluster is reddened by $E_{B-V} = 0.38 \pm 0.05$ mag. (2) The true distance modulus is $(m - M)_0 = 12.3 \pm 0.3$ mag. (3) A deficiency or gap of stars apparently exists at $V = 15.9$ mag on the evolved main sequence. (4) The cluster is $\sim 1.2 \times 10^9$ years old and has an [Fe/H] value comparable to, or slightly less than, that of the Hyades. (5) A nearby carbon star, with a significant probability of being a cluster member, has an absolute magnitude of $M_V = -2.0 \pm 0.3$ and a mass of $\mathfrak{M} \simeq 1.8\, \mathfrak{M}_\odot$. (6) Evidence is presented suggesting that the carbon stars in NGC 2660 and NGC 7789 are in a post–helium-flash evolutionary stage.

Finally, attention has been called to some specific and interesting difficulties encountered in matching observations with theory for both NGC 2477 and NGC 2660, and new theoretical tracks have been prepared for interpretation of these observations.

We are grateful to the night assistants at Cerro Tololo for their continued, excellent help; to Mrs. M. Reeves for her patient and careful photographic photometry; to Mrs. J. V. Barnes and Srta. L. Vega G. for their aid in the photometric reductions; and to Don Vanden Berg for his excellent assistance in computing the models.

APPENDIX

Tabulated below are the tracks used to construct the isochrones shown in figure 4. The tracks were computed with the same assumptions and input physics described by Hartwick and Vanden Berg (1973).

TABLE A1

EVOLUTIONARY TRACK FOR A STAR WITH MASS = 1.100 SOLAR MASSES

X = 0.690 Y = 0.300 Z = 0.010

No.	Time	M_{bol}	Log T_e	$L/L_\odot$	Log g	Log P_c	Log T_c	Log ρ_c	X_c	Center
1	0.0	3.94779	3.81271	2.0365	4.3676	17.3309	7.2002	2.0023	0.67474	Conv
2	0.0750	3.93589	3.81331	2.0589	4.3653	17.3376	7.2030	2.0099	0.66395	Conv
3	0.1750	3.92074	3.81371	2.0879	4.3608	17.3437	7.2059	2.0181	0.64954	Conv
4	0.5750	3.85139	3.81541	2.2256	4.3399	17.3742	7.2181	2.0604	0.58087	Conv
5	0.9750	3.78029	3.81713	2.3762	4.3183	17.4085	7.2321	2.1103	0.50251	Conv
6	1.3750	3.70369	3.81915	2.5499	4.2957	17.4493	7.2492	2.1716	0.41147	Conv
7	1.6750	3.64670	3.81979	2.6873	4.2755	17.4805	7.2634	2.2224	0.33717	Conv
8	1.9750	3.58986	3.81959	2.8318	4.2520	17.5126	7.2797	2.2711	0.27096	Conv
9	2.2750	3.53935	3.81802	2.9666	4.2255	17.5451	7.2968	2.3295	0.18929	Conv
10	2.5000	3.49510	3.81662	3.0900	4.2022	17.5801	7.3140	2.3878	0.11525	Conv
11	2.7250	3.43399	3.81657	3.2689	4.1776	17.6438	7.3246	2.4929	0.03080	Rad
12	2.9500	3.37398	3.81606	3.4547	4.1515	17.7032	7.3187	2.5703	0.00827	Rad
13	3.1500	3.31169	3.81540	3.6587	4.1239	17.7707	7.3145	2.6456	0.00234	Rad
14	3.3500	3.24638	3.81385	3.8855	4.0916	17.8406	7.3151	2.7141	0.00057	Rad
15	3.5500	3.17478	3.81168	4.1504	4.0543	17.9216	7.3176	2.7901	0.00011	Rad
16	3.7000	3.11073	3.80934	4.4026	4.0193	18.0033	7.3203	2.8658	0.00002	Rad
17	3.8500	3.04489	3.80564	4.6778	3.9782	18.0980	7.3231	2.9530	0.00000	Rad
18	4.0000	2.97313	3.79999	4.9974	3.9269	18.2107	7.3276	3.0548	0.00000	Rad
19	4.1000	2.91561	3.79400	5.2693	3.8799	18.3222	7.3321	3.1541	0.00000	Rad
20	4.1600	2.87651	3.78916	5.4626	3.8449	18.4163	7.3359	3.2368	0.00000	Rad
21	4.2050	2.84733	3.78433	5.6114	3.8139	18.5020	7.3394	3.3112	0.00000	Rad
22	4.2500	2.82245	3.77802	5.7414	3.7787	18.6014	7.3436	3.3960	0.00000	Rad
23	4.2800	2.80502	3.77282	5.8343	3.7510	18.6842	7.3489	3.4644	0.00000	Rad

TABLE A2

EVOLUTIONARY TRACK FOR A STAR WITH MASS = 1.200 SOLAR MASSES

X = 0.690 Y = 0.300 Z = 0.010

No.	Time	M_{bol}	Log T_e	$L/L_{\odot}$	Log g	Log P_c	Log T_c	Log ρ_c	X_c	Center
1	0.0	3.51269	3.84525	3.0404	4.3615	17.3540	7.2275	1.9978	0.67764	Conv
3	0.3750	3.44742	3.84773	3.2287	4.3454	17.3813	7.2423	2.0333	0.61220	Conv
5	1.0250	3.31592	3.85008	3.6444	4.3021	17.4323	7.2695	2.1064	0.48684	Conv
7	1.6250	3.20782	3.84575	4.0260	4.2416	17.4616	7.2941	2.1590	0.37457	Conv
9	2.1250	3.11901	3.83778	4.3691	4.1742	17.4883	7.3169	2.2128	0.26602	Conv
11	2.5250	3.06618	3.83006	4.5870	4.1221	17.5163	7.3374	2.2698	0.18072	Conv
13	2.8450	3.01647	3.82296	4.8019	4.0739	17.5556	7.3593	2.3343	0.09127	Conv
15	3.0550	2.95711	3.82342	5.0717	4.0520	17.6285	7.3850	2.4188	0.03444	Conv
17	3.0825	2.93651	3.82639	5.1688	4.0556	17.6582	7.3921	2.4482	0.02291	Conv
19	3.0970	2.91607	3.82943	5.2671	4.0596	17.6870	7.3982	2.4753	0.01628	Conv
21	3.1110	2.88536	3.83436	5.4182	4.0670	17.7306	7.4056	2.5155	0.00988	Conv
23	3.1230	2.83527	3.84204	5.6740	4.0777	17.8066	7.4121	2.5878	0.00458	Conv
25	3.1330	2.78293	3.84755	5.9542	4.0788	17.9382	7.3822	2.7466	0.00107	Rad
27	3.1980	2.73666	3.84270	6.2135	4.0409	18.0642	7.3317	2.9136	0.00013	Rad
29	3.2780	2.69810	3.83729	6.4382	4.0039	18.1252	7.3263	2.9759	0.00001	Rad
31	3.3480	2.66166	3.83265	6.6578	3.9707	18.1795	7.3280	3.0254	0.00000	Rad
33	3.4280	2.61501	3.82650	6.9502	3.9275	18.2597	7.3325	3.0963	0.00000	Rad
35	3.5030	2.56424	3.81860	7.2829	3.8755	18.3643	7.3384	3.1877	0.00000	Rad
37	3.5530	2.52659	3.81127	7.5399	3.8312	18.4648	7.3437	3.2746	0.00000	Rad
39	3.5980	2.49454	3.80172	7.7657	3.7802	18.5812	7.3499	3.3739	0.00000	Rad
41	3.6330	2.47059	3.79173	7.9390	3.7306	18.6994	7.3582	3.4715	0.00000	Rad
43	3.6600	2.45575	3.78249	8.0482	3.6877	18.8146	7.3687	3.5634	0.00000	Rad

TABLE A3

EVOLUTIONARY TRACK FOR A STAR WITH MASS = 1.350 SOLAR MASSES

X = 0.690 Y = 0.300 Z = 0.010

No.	Time	M_{bol}	Log T_e	$L/L_{\odot}$	Log g	Log P_c	Log T_c	Log ρ_c	X_c	Center
1	0.0	2.95341	3.89596	5.0890	4.3918	17.3752	7.2645	1.9838	0.67468	Conv
3	0.5000	2.83966	3.89517	5.6511	4.3432	17.3994	7.2854	2.0281	0.56766	Conv
5	1.0000	2.73166	3.89027	6.2421	4.2804	17.4167	7.3056	2.0706	0.46163	Conv
7	1.5000	2.63607	3.88040	6.8167	4.2026	17.4292	7.3258	2.1151	0.33840	Conv
9	1.8000	2.58060	3.87133	7.1739	4.1441	17.4448	7.3421	2.1576	0.24088	Conv
11	2.0400	2.53498	3.86079	7.4818	4.0837	17.4689	7.3612	2.2117	0.14902	Conv
13	2.2200	2.49767	3.85344	7.7434	4.0394	17.5079	7.3819	2.2743	0.07597	Conv
15	2.3200	2.46063	3.85483	8.0121	4.0302	17.5658	7.4018	2.3399	0.03404	Conv
17	2.3400	2.43786	3.85826	8.1820	4.0348	17.5995	7.4110	2.3723	0.02209	Conv
19	2.3540	2.41031	3.86341	8.3922	4.0444	17.6398	7.4207	2.4086	0.01360	Conv
21	2.3640	2.37430	3.87051	8.6752	4.0583	17.6922	7.4312	2.4545	0.00754	Conv
23	2.3720	2.30854	3.88221	9.2169	4.0788	17.7938	7.4425	2.5473	0.00267	Conv
25	2.3900	2.23759	3.88579	9.8393	4.0648	18.0251	7.3749	2.8379	0.00014	Rad
27	2.4500	2.18376	3.87756	10.3394	4.0103	18.1643	7.3481	2.9942	0.00001	Rad
29	2.5100	2.13390	3.86944	10.8253	3.9579	18.2681	7.3483	3.0911	0.00000	Rad
31	2.5600	2.09057	3.86069	11.2661	3.9056	18.3755	7.3523	3.1870	0.00000	Rad
33	2.6000	2.05272	3.85085	11.6657	3.8511	18.4906	7.3583	3.2869	0.00000	Rad
35	2.6400	2.01526	3.83566	12.0752	3.7753	18.6543	7.3695	3.4245	0.00000	Rad
37	2.6600	1.99879	3.82361	12.2599	3.7206	18.7772	7.3821	3.5229	0.00000	Rad
39	2.6720	1.99161	3.81357	12.3411	3.6775	18.8692	7.3938	3.5942	0.00000	Rad
41	2.6800	1.98910	3.80573	12.3698	3.6451	18.9361	7.4028	3.6453	0.00000	Rad
43	2.6860	1.98917	3.79867	12.3689	3.6170	18.9935	7.4119	3.6880	0.0	Rad

TABLE A4

EVOLUTIONARY TRACK FOR A STAR WITH MASS = 1.500 SOLAR MASSES

X = 0.690 Y = 0.300 Z = 0.010

No.	Time	M_{bol}	Log TE	$L/L_\odot$	Log g	Log P_c	Log T_c	Log ρ_c	X_c	Center
1	0.0	2.47742	3.93655	7.8892	4.4095	17.3709	7.2897	1.9538	0.67763	Conv
3	0.3500	2.38968	3.93231	8.5532	4.3575	17.3699	7.3022	1.9718	0.58990	Conv
5	0.7250	2.28618	3.92604	9.4086	4.2910	17.3746	7.3181	2.0008	0.48422	Conv
7	1.1250	2.18548	3.91381	10.3231	4.2018	17.3799	7.3377	2.0433	0.35143	Conv
9	1.3300	2.13505	3.90544	10.8139	4.1481	17.3953	7.3532	2.0855	0.26288	Conv
11	1.4700	2.10102	3.89609	11.1581	4.0971	17.4073	7.3663	2.1224	0.18968	Conv
13	1.5550	2.07889	3.88921	11.3879	4.0608	17.4229	7.3778	2.1561	0.13764	Conv
15	1.6450	2.05459	3.88309	11.6456	4.0266	17.4514	7.3930	2.2031	0.08280	Conv
17	1.7100	2.02522	3.88239	11.9649	4.0120	17.4961	7.4099	2.2566	0.04265	Conv
19	1.7520	1.98147	3.88904	12.4570	4.0211	17.5639	7.4297	2.3215	0.01812	Conv
21	1.7600	1.95534	3.89435	12.7604	4.0319	17.6026	7.4389	2.3554	0.01139	Conv
23	1.7680	1.90651	3.90483	13.3474	4.0543	17.6760	7.4534	2.4185	0.00516	Conv
25	1.7740	1.81690	3.91873	14.4957	4.0740	17.8746	7.4440	2.6268	0.00049	Rad
27	1.7980	1.77063	3.91110	15.1268	4.0250	18.0780	7.3711	2.8921	0.00003	Rad
29	1.8280	1.72745	3.90591	15.7406	3.9870	18.1922	7.3653	3.0057	0.00000	Rad
31	1.8525	1.69109	3.90087	16.2766	3.9523	18.2910	7.3672	3.0968	0.00000	Rad
33	1.8775	1.65314	3.89361	16.8556	3.9081	18.4137	7.3721	3.2064	0.00000	Rad
35	1.9025	1.61758	3.88190	17.4167	3.8470	18.5785	7.3816	3.3486	0.00000	Rad
37	1.9205	1.59382	3.86772	17.8022	3.7808	18.7473	7.3973	3.4869	0.00000	Rad
39	1.9305	1.58481	3.85604	17.9504	3.7305	18.8679	7.4130	3.5810	0.00000	Rad
41	1.9365	1.58233	3.84695	17.9914	3.6931	18.9521	7.4261	3.6446	0.00000	Rad
43	1.9410	1.58233	3.83887	17.9914	3.6608	19.0208	7.4376	3.6957	0.0	Rad
45	1.9440	1.58409	3.83274	17.9624	3.6370	19.0696	7.4463	3.7315	0.0	Rad
47	1.9470	1.58661	3.82600	17.9208	3.6110	19.1206	7.4558	3.7685	0.0	Rad
49	1.9500	1.59080	3.81845	17.8516	3.5825	19.1736	7.4659	3.8067	0.0	Rad
51	1.9530	1.59675	3.81029	17.7541	3.5522	19.2283	7.4765	3.8458	0.0	Rad

TABLE A5

EVOLUTIONARY TRACK FOR A STAR WITH MASS = 1.700 SOLAR MASSES

X = 0.690 Y = 0.300 Z = 0.010

No.	Time	M_{bol}	Log T_e	$L/L_\odot$	Log g	Log P_c	Log T_c	Log ρ_c	X_c	Center
1	0.0	1.92329	3.98292	13.1426	4.4277	17.3592	7.3163	1.9146	0.68160	Conv
4	0.2400	1.84727	3.97679	14.0959	4.3728	17.3484	7.3265	1.9250	0.59742	Conv
7	0.4700	1.76437	3.96952	15.2143	4.3106	17.3417	7.3373	1.9421	0.50459	Conv
10	0.6600	1.70807	3.96081	16.0240	4.2532	17.3389	7.3483	1.9662	0.40982	Conv
13	0.8200	1.64959	3.94998	16.9108	4.1865	17.3397	7.3614	1.9971	0.31452	Conv
16	0.9500	1.60274	3.93922	17.6564	4.1247	17.3476	7.3761	2.0364	0.22129	Conv
19	1.0400	1.57154	3.92880	18.1712	4.0705	17.3635	7.3909	2.0799	0.14482	Conv
22	1.1300	1.53538	3.92045	18.7866	4.0227	17.4079	7.4136	2.1503	0.06634	Conv
25	1.1840	1.48353	3.92625	19.7054	4.0251	17.4935	7.4411	2.2381	0.02070	Conv
28	1.1970	1.42841	3.93876	20.7317	4.0531	17.5810	7.4620	2.3139	0.00775	Conv
31	1.2010	1.36856	3.95063	21.9066	4.0767	17.6733	7.4759	2.3951	0.00274	Conv
34	1.2065	1.30535	3.95511	23.2199	4.0693	17.9306	7.4116	2.7126	0.00013	Rad
37	1.2305	1.24115	3.94858	24.6343	4.0175	18.1182	7.3822	2.9208	0.00000	Rad
40	1.2605	1.17397	3.94011	26.2066	3.9568	18.3278	7.3877	3.1141	0.00000	Rad
43	1.2875	1.11202	3.92073	27.7454	3.8545	18.6468	7.4102	3.3887	0.00000	Rad
46	1.2960	1.09772	3.90730	28.1134	3.7950	18.8160	7.4326	3.5228	0.00000	Rad
49	1.3015	1.09241	3.89471	28.2510	3.7425	18.9512	7.4544	3.6258	0.0	Rad
52	1.3055	1.09409	3.88282	28.2074	3.6956	19.0621	7.4749	3.7078	0.0	Rad
55	1.3085	1.09859	3.87204	28.0907	3.6543	19.1516	7.4926	3.7728	0.0	Rad
58	1.3111	1.10554	3.86132	27.9116	3.6142	19.2327	7.5093	3.8310	0.0	Rad
61	1.3135	1.11584	3.85001	27.6481	3.5731	19.3096	7.5255	3.8856	0.0	Rad
64	1.3157	1.12778	3.83850	27.3457	3.5319	19.3816	7.5410	3.9364	0.0	Rad
67	1.3178	1.14296	3.82629	26.9660	3.4891	19.4511	7.5561	3.9852	0.0	Rad

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