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THE AGE OF THE LARGE MAGELLANIC CLOUD CLUSTER NGC 2031[1]

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ABSTRACT

NGC 2031 is a globular cluster in the Large Magellanic Cloud. A color-magnitude diagram is fitted with appropriate isochrones which indicate that the age of the cluster is 140 ± 20 Myr. The cluster is similar to the well-known young cluster NGC 1866.
Subject headings: globular clusters: individual (NGC 2031) — Magellanic Clouds — stars: evolution

1. INTRODUCTION

NGC 2031 is a 10th mag star cluster located approximately 1 kpc SW of the neutral hydrogen peak in the Mathewson & Ford (1983) map of the Large Magellanic Cloud. The integrated colors in van den Bergh's (1981) compilation are $U-B = -0.05$, $B-V = 0.27$. According to Frenk & Fall (1982) it would be classified Searle, Wilkinson, & Bagnuolo (1980) class III. Magellanic Cloud star clusters remain an important laboratory for testing our ideas on stellar evolution, particularly on the late stages of stellar evolution (Mould 1991) and for learning more about the chemical evolution of dwarf galaxies (Da Costa 1990). A key datum for these purposes is the age of the cluster, and that is the subject of this investigation.

2. PHOTOMETRY

The 4 m telescope at CTIO was used to observe the cluster at prime focus. The scale of the instrument is 0″.6 pixel^{-1}. Exposures of the cluster were made through a Johnson B filter and a Kron-Cousins R imaging onto a 512 × 320 RCA CCD. Conditions were photometric, and the seeing was 1″.4 FWHM. Four 500 s blue exposures were taken on 1984 November 25, together with six 300 s red exposures. A 100 s blue and 30 s red exposure were also obtained. Details of the data processing and calibration are provided by Mould, Jensen, & Da Costa (1992).

Figure 1 (Plate 1) shows the co-added blue frame. Point-spread function photometry was carried out using the ALLSTAR routine of DAOPHOT II (Stetson 1987, 1991). Table 1 records the colors, magnitudes and coordinates of stars within a radius of 0′.8 of the cluster center. Figure 2 (Plate 2) is an enlargement of Figure 1 and serves to identify these stars.

Careful examination of star images with $R < 16$ reveals a number of images with saturated cores on the red frame. Photometry of these stars is given separately in Table 2. Since DAOPHOT rejects saturated pixels from point-spread function fitting, this will decrease the S/N ratio of bright star photometry, but should not significantly bias it. We have verified this by means of ALLSTAR photometry on the short exposure frames. Only two stars in Table 1 are measured more than 0.1 mag different in R on the short exposure frame. These are indicated with colons in Table 2.

3. STELLAR CONTENT

Figure 3a is the color-magnitude diagram of stars in Tables 1 and 2. It shows a bright main-sequence turnoff and a prominent blue loop. Cepheids have been found among these core helium-burning stars (Bertelli et al. 1992; Mateo, Olszewski, & Madore 1990).

The reddest star in the cluster (star J in Table 2) has $R \approx 15.5$ and $B-R > 3$. Spectroscopy of this star would be of great interest. If it is a cluster member, it might be one of the most massive carbon stars known in the LMC. Carbon stars seem to confine themselves to intermediate age clusters (Frogel, Mould, & Blanco 1990). Either mass loss (Mould 1991) or envelope burning (Blocker & Schonberner 1991; Sackman & Boothroyd 1992) is currently thought to prevent the onset of the thermal pulses that produce carbon stars for turnoff masses of ~ 4–$6\ M_\odot$.

The main-sequence turnoff in Figure 3a is located at $R \approx 16$. The cluster evidently is similar in age to NGC 1866 which has a turnoff at $V \approx 16$ (Robertson 1974). Becker & Matthews (1983) obtained an age of 86 Myr for NGC 1866.

4. THE COLOR-MAGNITUDE DIAGRAM

Table 3 contains photometry of the field stars in the top and bottom 0′.5 of the CCD frames. The resulting field color-magnitude diagram is shown in Figure 4. One can readily see from Figures 3 and 4 that the brightest main-sequence cluster stars are at $R = 16$ and that there is a distinct difference between the cluster and the field, both in the main-sequence region (the field turnoff is fainter and is an older population) and as regards the evolved stars (the cluster has a blue loop, but the field has a red horizontal branch).

Before we can fit isochrones, we must discuss the reddening and metallicity of N2031. According the Mathewson & Ford's (1983) map of the Magellanic Stream, the cluster lies in a region with between 150 and 400 × 10^{19} H I atoms cm^{-2} either in front of it, behind it, or both. According to Sauvage & Vigroux (1991) this corresponds to $E(B-V) = 0.06$–0.17. Foreground reddening for the LMC can be taken as $E(B-V) = 0.07$. We adopt a reddening of $E(B-V) = 0.18 \pm 0.05$.

[1] Based on data obtained at Cerro Tololo Inter-American Observatory. CTIO is part of N.O.A.O. which is operated by AURA Inc. for NSF.

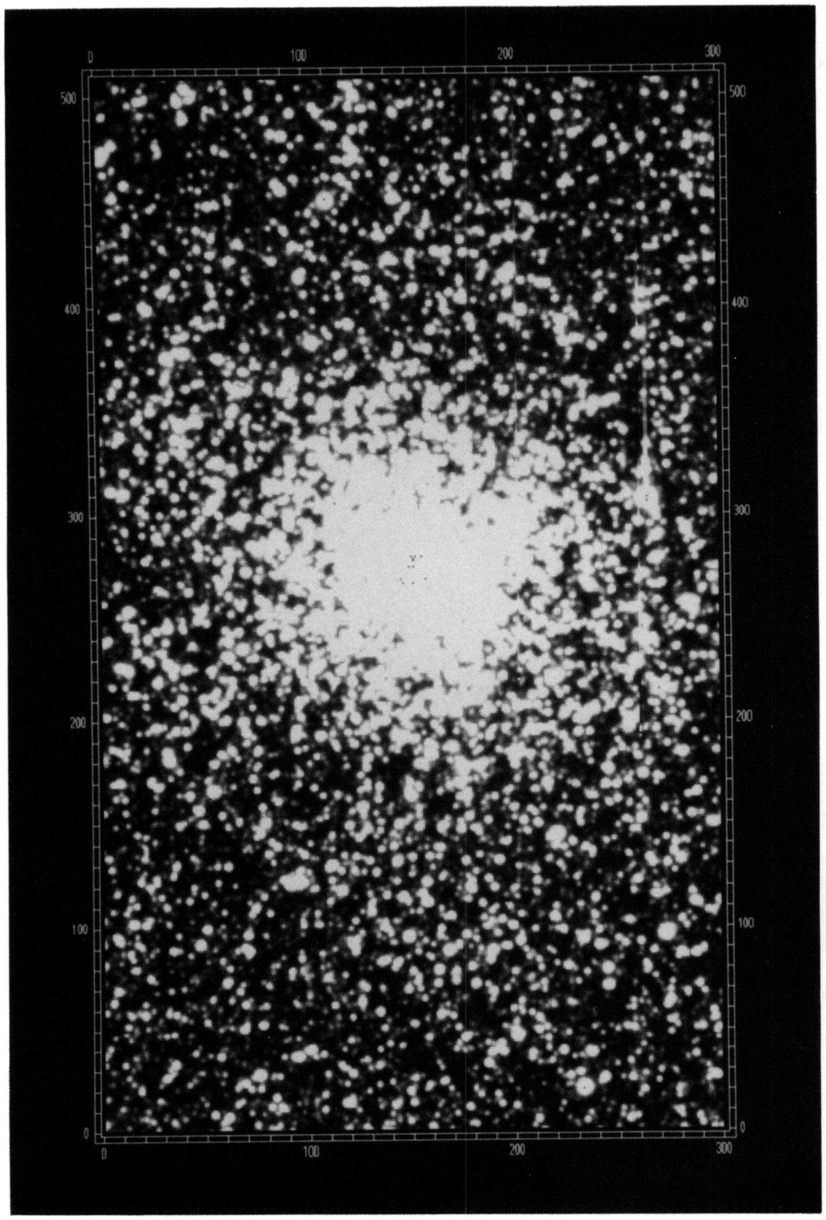

FIG. 1.—Full 3′ × 5′ image of the cluster. West is up, and north is to the left.

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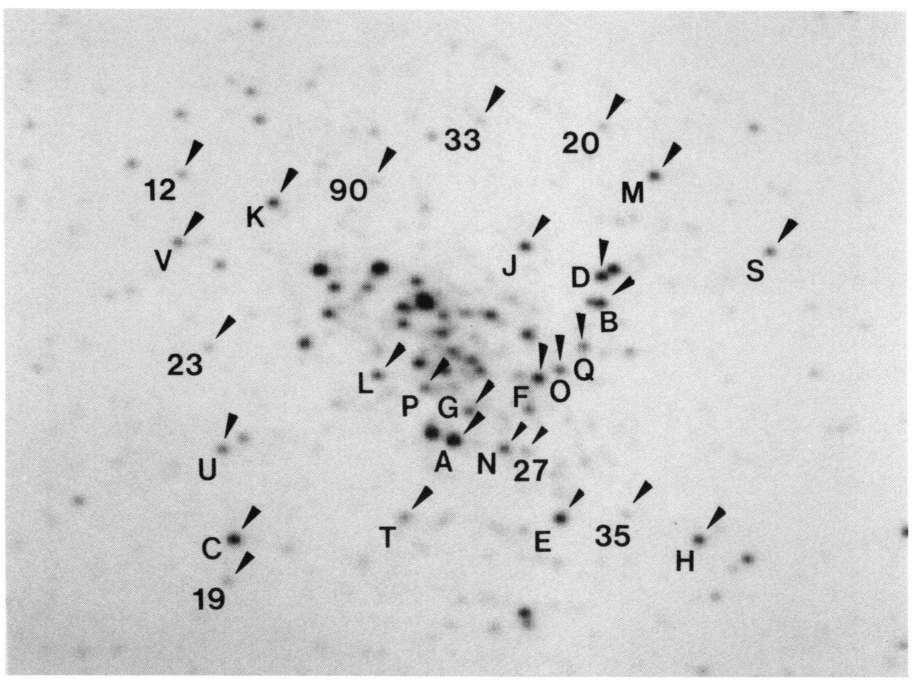

FIG. 2.—Central 2′ × 2′ of the cluster. Star numbers refer to Table 1. Orientation is the same as Fig. 1.

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TABLE 1

Photometry of Stars in NGC 2031

#	x	y	B–R	R
1	134	269	0.51	16.01
2	151	260	0.69	16.03
3	146	251	0.37	16.07
4	144	266	0.33	16.08
5	98	290	1.93	16.14
6	105	331	1.96	16.21
7	103	249	0.06	16.27
8	174	240	0.84	16.27
9	166	263	0.44	16.31
10	192	269	0.31	16.33
11	146	320	0.01	16.45
12	89	311	2.25	16.55
13	169	279	0.90	16.60
14	129	281	0.14	16.60
15	124	274	1.25	16.62
16	147	250	-0.25	16.63
17	145	303	0.04	16.66
18	160	204	0.06	16.70
19	99	215	1.85	16.74
20	186	322	0.05	16.76
21	124	283	-0.09	16.77
22	125	256	0.81	16.78
23	96	270	0.08	16.78
24	180	274	0.33	16.79
25	133	321	0.06	16.80
26	181	243	0.38	16.83
27	167	246	0.29	16.86
28	184	262	0.44	16.92
29	119	332	0.16	16.92
30	133	309	-0.05	16.94
31	167	227	1.84	16.99
32	125	292	0.48	17.02
33	157	324	-0.13	17.05
34	200	299	0.41	17.05
35	191	231	1.82	17.07
36	189	300	0.07	17.08
37	175	337	0.08	17.09
38	113	223	1.90	17.10
39	175	236	-0.04	17.11
40	144	223	0.36	17.11
41	206	298	0.28	17.11
42	137	260	-0.05	17.12
43	73	282	0.05	17.13
44	162	253	0.17	17.13
45	78	284	0.08	17.16
46	182	252	0.11	17.17
47	176	243	0.02	17.21
48	186	268	0.08	17.22
49	190	276	-0.12	17.23
50	144	294	0.32	17.24
51	194	291	-0.03	17.26
52	179	234	0.20	17.27
53	121	313	0.10	17.27
54	147	241	0.24	17.28
55	163	339	-0.05	17.29
56	116	276	0.27	17.33
57	152	341	0.11	17.35
58	162	227	0.15	17.37
59	153	210	2.42	17.39
60	201	285	0.12	17.41
61	193	301	0.06	17.42
62	160	228	-0.01	17.42
63	182	316	1.44	17.43
64	170	327	0.09	17.43
65	121	268	0.67	17.44
66	156	272	-0.18	17.44
67	215	305	0.11	17.45
68	150	205	0.03	17.45
69	215	279	0.03	17.45
70	159	286	0.05	17.45
71	185	300	0.12	17.48
72	166	300	1.14	17.49
73	155	327	0.67	17.50
74	159	211	0.04	17.51
75	95	295	1.80	17.53
76	177	253	0.52	17.55
77	212	227	1.76	17.56
78	120	247	0.07	17.60
79	139	247	1.60	17.61
80	106	278	0.10	17.61
81	130	297	0.76	17.62
82	126	299	0.14	17.62
83	144	191	0.06	17.62
84	142	324	0.14	17.62
85	88	243	0.58	17.64
86	113	301	0.04	17.65
87	120	200	0.71	17.65
88	91	277	1.21	17.68
89	215	286	0.22	17.68
90	134	335	0.10	17.70
91	132	256	0.21	17.70
92	179	261	0.06	17.71
93	174	209	0.17	17.73
94	199	328	1.47	17.73
95	214	262	-0.03	17.74
96	153	293	0.07	17.75
97	129	321	-0.08	17.75
98	82	288	0.19	17.75
99	211	247	0.10	17.78
100	169	298	0.17	17.78
101	113	285	0.14	17.79
102	123	251	0.01	17.80
103	129	233	0.34	17.80
104	136	255	0.40	17.80
105	216	244	1.07	17.81
106	113	291	0.15	17.81
107	174	309	0.12	17.85
108	198	273	0.54	17.87
109	155	291	-0.07	17.89
110	78	251	0.06	17.92
111	122	323	0.42	17.92
112	151	239	0.24	17.92
113	209	256	0.07	17.92
114	162	298	0.05	17.92
115	151	319	0.14	17.92
116	179	278	-0.06	17.93
117	203	278	0.06	17.93
118	186	245	0.77	17.95
119	189	250	0.12	17.96
120	210	268	0.60	17.96
121	79	301	0.06	17.96
122	138	226	0.03	17.96
123	185	220	0.07	17.97
124	162	269	-0.05	17.97
125	109	293	0.05	17.98
126	139	269	-0.44	17.99
127	205	324	0.03	17.99
128	114	320	0.11	18.00
129	131	198	0.18	18.00
130	192	247	0.18	18.00
131	134	250	0.89	18.02
132	99	265	0.56	18.04
133	100	326	0.14	18.04
134	167	221	-0.22	18.05
135	166	236	0.21	18.06
136	159	341	-0.10	18.07
137	157	247	0.17	18.08
138	90	319	0.00	18.08
139	157	289	-0.05	18.08
140	90	228	0.11	18.09
141	74	258	0.15	18.11
142	183	202	1.54	18.11
143	152	297	0.05	18.12
144	107	257	0.08	18.14
145	213	234	0.01	18.15
146	86	240	0.06	18.15
147	87	306	1.39	18.15
148	186	333	0.13	18.17
149	211	267	0.37	18.17
150	138	211	0.24	18.19
151	194	290	-1.05	18.19
152	90	249	0.15	18.20
153	193	282	0.05	18.21
154	169	238	0.03	18.21
155	141	335	0.70	18.22
156	204	238	0.06	18.23
157	108	300	0.10	18.23
158	185	215	0.02	18.24
159	88	273	0.01	18.26
160	158	340	-0.31	18.27
161	124	316	0.02	18.27
162	206	270	0.15	18.29
163	146	202	0.19	18.29
164	172	290	-0.06	18.29
165	125	261	0.83	18.30
166	120	309	0.22	18.31
167	176	325	0.07	18.32
168	140	192	0.12	18.33
169	220	243	0.14	18.33
170	211	320	0.08	18.34
171	204	272	0.11	18.35
172	230	286	0.05	18.36
173	94	310	1.04	18.38
174	139	345	0.69	18.38
175	119	218	0.05	18.38
176	160	307	0.52	18.40
177	197	323	1.63	18.42
178	181	217	0.07	18.45
179	196	254	0.42	18.45
180	135	198	0.13	18.46
181	120	234	0.07	18.46
182	158	221	0.01	18.46
183	115	248	0.19	18.48
184	93	253	0.67	18.48
185	134	237	0.02	18.49
186	121	298	2.29	18.49
187	178	289	0.08	18.49
188	217	273	0.77	18.52
189	108	239	0.05	18.53
190	98	310	0.16	18.53
191	119	255	0.01	18.54
192	166	331	1.62	18.54
193	137	241	0.04	18.54
194	193	252	0.13	18.56
195	113	237	-0.04	18.57
196	192	220	0.00	18.58
197	134	212	1.14	18.59
198	118	238	0.09	18.60
199	161	315	-0.06	18.61
200	110	285	0.11	18.62
201	127	237	0.12	18.63
202	98	284	1.17	18.63
203	165	308	0.21	18.63
204	90	263	0.26	18.64
205	94	223	0.10	18.64
206	157	318	1.00	18.65
207	82	269	0.13	18.67
208	132	344	0.04	18.68
209	184	240	0.10	18.70
210	140	317	0.15	18.71
211	135	215	0.16	18.72
212	187	273	-0.70	18.74
213	205	312	-0.58	18.76

TABLE 1—*Continued*

#	x	y	B–R	R	#	x	y	B–R	R	#	x	y	B–R	R
214	118	212	1.55	18.79	265	168	308	0.27	19.28	316	79	278	0.10	19.91
215	173	255	-0.62	18.79	266	105	302	-0.48	19.28	317	142	202	-0.22	19.92
216	124	307	0.15	18.79	267	162	292	-0.36	19.28	318	104	269	1.28	19.93
217	177	283	-0.32	18.80	268	219	260	0.19	19.28	319	161	216	0.75	19.94
218	199	293	0.15	18.80	269	86	283	0.11	19.29	320	226	259	0.28	19.99
219	138	217	1.21	18.80	270	176	332	0.05	19.30	321	151	333	0.71	19.99
220	90	269	-0.01	18.81	271	220	274	0.07	19.30	322	107	221	0.42	20.05
221	94	307	0.17	18.84	272	112	233	0.23	19.31	323	85	259	0.20	20.05
222	202	242	0.25	18.85	273	79	238	0.09	19.33	324	74	272	0.63	20.06
223	84	254	-0.01	18.86	274	200	255	0.36	19.36	325	122	239	0.22	20.11
224	211	308	0.08	18.86	275	105	210	0.01	19.36	326	95	242	-0.18	20.12
225	144	328	0.05	18.87	276	204	291	0.49	19.37	327	162	330	0.73	20.15
226	204	319	0.04	18.89	277	206	249	0.18	19.40	328	92	235	0.94	20.16
227	90	231	0.14	18.89	278	110	218	-0.08	19.41	329	182	197	0.15	20.20
228	188	255	0.58	18.91	279	125	210	0.53	19.42	330	199	263	0.91	20.21
229	208	293	0.02	18.94	280	130	331	0.20	19.44	331	146	215	2.21	20.22
230	103	318	1.12	18.94	281	127	336	0.09	19.45	332	173	305	0.24	20.22
231	114	263	0.46	18.95	282	129	326	0.49	19.46	333	85	278	0.62	20.26
232	188	329	0.14	18.96	283	210	217	0.06	19.47	334	119	223	-0.12	20.31
233	116	323	0.30	18.98	284	93	281	0.18	19.49	335	170	314	-1.06	20.34
234	199	319	0.09	19.01	285	194	204	0.10	19.50	336	169	193	0.29	20.35
235	218	270	0.42	19.01	286	73	268	0.16	19.51	337	122	230	0.66	20.36
236	142	314	0.08	19.02	287	142	201	0.22	19.51	338	176	345	1.72	20.40
237	220	285	0.10	19.02	288	169	335	0.11	19.52	339	154	201	-0.22	20.45
238	193	313	0.18	19.04	289	103	238	2.37	19.53	340	153	224	0.06	20.47
239	193	241	-0.05	19.05	290	113	201	0.15	19.54	341	225	266	0.81	20.53
240	178	224	1.69	19.06	291	154	235	-0.52	19.55	342	96	319	-0.13	20.55
241	160	311	0.65	19.08	292	159	197	0.27	19.55	343	201	228	-0.73	20.58
242	99	258	1.93	19.08	293	231	267	0.55	19.56	344	187	204	-0.02	20.60
243	134	205	0.18	19.08	294	99	318	0.20	19.57	345	143	208	0.47	20.61
244	156	227	-0.03	19.11	295	109	266	0.11	19.58	346	108	235	0.42	20.61
245	115	241	0.31	19.12	296	119	262	1.27	19.59	347	122	225	0.61	20.62
246	144	197	0.52	19.13	297	110	278	-0.11	19.60	348	226	255	1.18	20.65
247	106	290	-0.18	19.15	298	220	231	0.28	19.61	349	93	301	0.13	20.67
248	214	309	0.07	19.15	299	157	346	0.37	19.64	350	201	222	0.51	20.76
249	156	310	0.46	19.15	300	79	239	-0.26	19.65	351	164	346	-0.21	20.80
250	109	243	0.25	19.18	301	95	218	-0.02	19.68	352	149	221	-0.35	20.89
251	169	313	0.21	19.19	302	219	251	0.57	19.68	353	208	315	0.19	20.96
252	84	250	0.08	19.20	303	198	237	0.34	19.69	354	98	277	0.37	21.00
253	112	334	0.17	19.21	304	174	296	1.34	19.70	355	171	344	0.06	21.00
254	105	243	-0.01	19.21	305	131	244	1.36	19.72	356	191	211	1.97	21.04
255	95	283	-0.06	19.22	306	153	235	-0.78	19.78	357	188	337	0.66	21.10
256	187	228	-0.02	19.22	307	155	331	0.27	19.79	358	185	233	0.81	21.26
257	223	255	0.90	19.23	308	133	230	0.11	19.80	359	195	337	1.63	21.49
258	110	317	0.30	19.24	309	205	230	-0.20	19.81	360	125	247	-0.12	21.50
259	127	213	0.22	19.24	310	111	339	0.24	19.84	361	181	336	1.27	21.63
260	112	310	-0.16	19.25	311	155	230	0.01	19.84	362	177	202	0.12	21.71
261	115	259	-0.04	19.25	312	161	194	0.71	19.84	363	197	226	1.51	21.71
262	146	234	0.29	19.25	313	137	222	0.23	19.86	364	153	192	0.42	22.08
263	178	318	-0.11	19.25	314	211	303	0.32	19.88	365	106	312	-0.24	22.24
264	179	296	0.29	19.28	315	185	206	0.35	19.88					

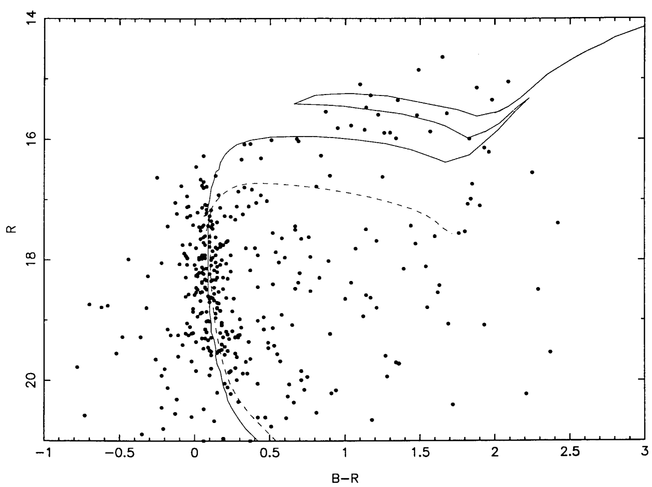

FIG. 3*a*

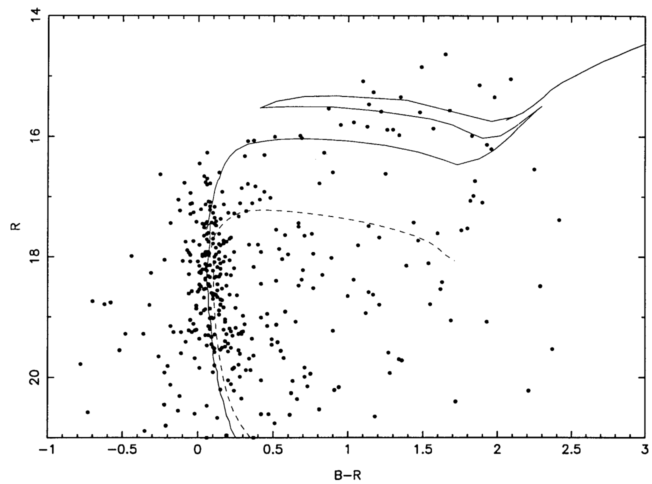

FIG. 3*b*

FIG. 3.—Color-magnitude diagram of the cluster NGC 2031 within 80 pixels of the cluster center. The superposed isochrones are (*dashed curve*) 150 Myr, $Z = 0.01$ (Revised Yale Isochrones), and (*solid curve*) 126 Myr, $Z = 0.008$ (Padua isochrones). Fig. 3*a* employs a short modulus for the LMC (18.2); a long modulus (18.7) is used in Fig. 3*b*

There is no available information on the metallicity of NGC 2031. We might suppose that the age-abundance relation for the LMC could provide guidelines. Da Costa (1990) shows $-0.6 < [Fe/H] < 0$ for clusters younger than 500 Myr. Feast (1990) adopts $[Fe/H] = -0.2$. We shall examine isochrone fits with $Z = 0.008$, corresponding to $[Fe/H] = -0.4$ for scaled solar abundances.

We fitted isochrones at two distance moduli that bracket the likely distance of the LMC (Feast 1990; Mould 1990): $(m - M)_0 = 18.2$ and 18.7 mag. The redder of the two isochrones in Figure 3*a* is a Green, Demarque, & King (1987) 150 Myr isochrone interpolated to $Y = 0.25$ and $Z = 0.008$, reddened by 0.27 in $B - R$. If we neglect convective overshooting, which causes stars to remain longer on the main sequence than the Yale tracks would predict, we conclude that 150 Myr is an upper limit to the age of NGC 2031. Bertelli et al. (1990) have recently published a fairly comprehensive set of isochrones implementing convective overshooting and mass loss. These were kindly provided by C. Chiosi for $Y = 0.25$, $Z = 0.008$, and the Reimers (1975) mass-loss parameter $\eta = 0.35$. In Figure 3*a* for a distance modulus of 18.2 mag, we compare their 158 Myr isochrone with the color-magnitude diagram of NGC 2031. It is an acceptable fit to the data. In Figure 3*b* we assume a true distance modulus of 18.7 in overlaying these isochrones and adopt the same reddening. An acceptable fit is obtained for an age of 126 Myr.

This range of parameters brackets the likely parameters of NGC 2031. The uncertainty in age is dominated by the uncertainty in distance modulus. The age of NGC 2031 is 140 ± 20 Myr.

TABLE 2

PHOTOMETRY OF BRIGHT STARS IN NGC 2031

Number	x	y	$B - R$	R
A	151	247	1.65	14.64
B	184	280	1.49	14.85:
C	101	224	2.09	15.05
D	185	286	1.10	15.09:
E	175	229	1.88	15.15
F	170	262	1.17	15.27
G	154	255	1.35	15.35
H	207	224	1.98	15.35
I	156	264	1.14	15.47
J	167	293	3.11	15.49
K	110	304	0.87	15.54
L	133	263	1.68	15.57
M	197	310	1.22	15.59
N	162	246	1.48	15.60
O	175	264	1.04	15.77
P	145	260	0.95	15.81
Q	180	270	1.13	15.84
R	136	275	1.57	15.87
S	224	292	1.26	15.89
T	139	229	1.30	15.89
U	98	246	1.34	15.98
V	88	295	1.83	15.99
W	154	278	0.68	15.99

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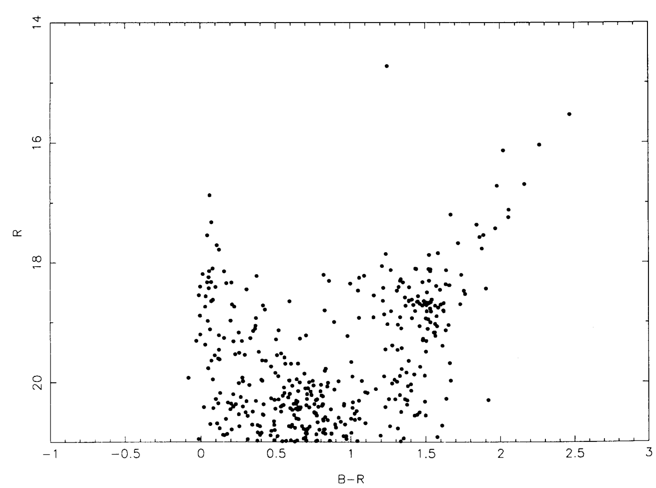

FIG. 4.—Color-magnitude diagram of the field of the cluster NGC 2031

TABLE 3

PHOTOMETRY OF FIELD STARS

#	x	y	B–R	R
1	222	4	0.85	20.63
2	231	2	0.08	19.95
3	233	6	1.31	19.46
4	145	3	1.60	18.46
5	158	5	0.53	20.41
6	50	6	0.00	19.20
7	44	6	1.46	20.50
8	46	11	0.62	20.55
9	78	10	0.22	19.32
10	218	7	0.65	20.62
11	220	11	0.75	20.05
12	282	9	1.92	20.30
13	174	9	1.97	17.43
14	197	10	0.07	19.64
15	168	15	0.79	20.79
16	80	14	0.36	19.11
17	7	15	1.36	20.28
18	104	16	1.42	18.71
19	291	17	0.96	20.39
20	125	17	0.65	20.15
21	197	18	1.03	20.53
22	8	24	0.11	20.69
23	55	26	0.64	20.31
24	51	26	1.03	20.63
25	266	22	1.57	19.03
26	105	26	1.54	18.66
27	218	26	0.54	20.39
28	214	32	1.57	18.90
29	159	31	0.63	20.44
30	64	31	0.71	20.78
31	252	32	1.50	18.70
32	44	33	1.10	20.68
33	48	35	0.78	20.41
34	41	36	1.76	18.48
35	284	35	1.33	18.31
36	53	35	0.36	19.06
37	113	38	0.13	20.77
38	164	40	1.44	20.54
39	141	40	0.25	20.02
40	154	44	1.53	18.12
41	116	42	1.54	18.62
42	9	43	1.42	19.87
43	172	44	0.08	18.63
44	30	46	1.41	18.93
45	239	46	1.33	19.90
46	222	46	0.69	19.86
47	272	46	1.62	18.80
48	169	49	1.27	18.82
49	107	49	1.30	20.29
50	130	461	0.13	20.18
51	166	464	0.03	19.38
52	43	461	1.66	19.69
53	248	462	0.93	20.66
54	49	463	0.31	20.56
55	232	463	0.08	20.44
56	291	466	-0.08	19.93
57	88	469	0.12	19.61
58	137	467	2.16	16.69
59	218	468	0.74	20.21
60	260	468	0.49	20.80
61	74	471	0.22	20.41
62	253	473	0.17	18.34
63	91	475	1.53	19.00
64	183	477	0.61	20.06
65	16	483	1.33	20.21
66	87	480	0.12	17.79
67	69	480	0.75	19.98
68	66	483	1.22	19.90
69	228	480	0.07	18.33
70	241	486	1.26	20.74
71	121	483	0.03	18.74
72	21	483	1.49	19.89
73	79	487	1.84	17.37
74	252	492	0.87	20.45
75	165	494	1.50	18.94
76	208	502	0.30	20.32
77	197	496	0.56	20.18
78	86	498	1.51	18.72
79	140	498	1.40	20.04
80	59	501	0.32	20.05
81	95	502	0.18	20.34
82	131	503	1.56	19.17
83	137	6	1.50	19.49
84	26	4	0.82	20.62
85	18	8	1.29	19.96
86	249	8	0.49	20.30
87	35	4	1.11	20.18
88	182	6	0.81	20.39
89	68	7	0.52	20.29
90	5	9	0.71	20.28
91	131	10	0.70	20.38
92	130	13	1.67	19.97
93	190	11	1.66	18.38
94	188	15	0.56	19.59
95	147	12	0.33	19.27
96	23	13	0.22	20.20
97	180	15	1.62	18.68
98	145	17	1.72	17.68
99	259	17	1.36	18.59
100	130	20	0.02	20.42
101	24	21	0.96	20.36
102	38	21	0.72	20.00
103	40	23	0.76	20.50
104	136	22	1.58	19.07
105	126	29	0.41	20.54
106	135	35	1.43	20.56
107	124	33	1.52	18.69
108	148	24	0.66	19.27
109	117	26	2.05	17.24
110	267	27	1.59	18.76
111	205	36	0.27	19.31
112	84	34	0.40	19.96
113	220	37	-0.01	18.55
114	131	38	0.64	19.95
115	213	38	1.57	19.23
116	135	41	1.37	18.72
117	91	43	1.61	19.39
118	2	44	0.61	20.71
119	7	46	0.60	20.75
120	8	50	0.41	19.98
121	73	50	1.67	17.20
122	212	49	1.24	19.03
123	251	49	1.48	18.33
124	243	49	0.77	20.56
125	53	48	0.42	20.55
126	64	48	0.03	18.57
127	133	49	1.15	18.92
128	235	49	1.48	19.30
129	258	52	1.27	20.02
130	83	50	1.34	19.43
131	147	51	1.32	18.41
132	46	52	1.64	18.37
133	196	464	0.04	17.54
134	123	461	1.05	18.47
135	176	461	0.26	19.51
136	185	467	0.42	20.37
137	286	468	0.76	20.37
138	172	470	0.05	19.77
139	200	471	1.06	20.61
140	42	471	0.25	20.54
141	292	477	0.22	18.74
142	275	474	0.23	20.37
143	207	475	0.28	20.41
144	202	477	1.17	20.11
145	199	479	1.34	20.49
146	205	480	0.47	19.74
147	195	481	1.34	19.10
148	82	480	0.00	18.89
149	4	475	0.30	18.45
150	167	477	0.23	19.53
151	248	483	1.62	18.82
152	96	479	1.53	18.77
153	273	480	1.52	18.95
154	150	486	1.38	20.30
155	269	485	0.51	19.55
156	91	490	0.06	18.14
157	186	488	0.70	20.10
158	231	489	1.45	18.57
159	13	494	1.54	18.82
160	221	498	1.31	18.47
161	37	496	2.26	16.03
162	19	501	1.48	19.28
163	234	503	1.22	18.43
164	238	502	0.67	20.42
165	282	497	0.43	19.64
166	7	502	1.49	18.65
167	11	502	0.65	20.42
168	263	499	0.35	19.15
169	53	502	0.55	20.09
170	156	503	1.51	19.31
171	182	504	0.77	20.52
172	186	2	0.82	20.64
173	168	6	0.47	20.27
174	163	7	1.61	20.72
175	20	3	0.70	20.10
176	208	3	0.37	18.93
177	192	4	1.01	20.43
178	57	5	0.04	18.33
179	74	6	1.50	20.33
180	276	7	0.16	19.26
181	243	11	1.38	20.37
182	104	8	1.39	18.65
183	33	9	1.31	20.77
184	61	11	1.52	18.68
185	94	12	0.82	20.79
186	100	13	1.39	19.65
187	165	18	0.06	20.70
188	223	25	1.35	18.33
189	68	18	1.48	18.72
190	65	21	0.43	18.79
191	249	23	0.34	20.71
192	253	23	1.33	18.28
193	240	23	0.08	18.10
194	10	28	0.92	20.59
195	7	31	0.50	19.84
196	161	29	0.71	20.20
197	246	30	1.01	19.91
198	112	30	1.57	18.40
199	262	32	0.34	20.49
200	280	33	1.37	19.84
201	103	36	1.53	18.67
202	256	36	0.17	20.61
203	259	40	0.83	19.77
204	183	41	1.23	19.45
205	184	46	0.96	20.71
206	168	38	1.65	19.05
207	154	40	0.90	20.70
208	38	46	0.83	20.58
209	213	43	1.51	18.50
210	295	43	0.55	20.38
211	27	45	0.59	19.97
212	18	49	0.26	20.74
213	94	49	1.25	20.28

TABLE 3—*Continued*

#	x	y	B–R	R	#	x	y	B–R	R	#	x	y	B–R	R
214	191	49	0.84	20.07	266	229	42	1.04	20.48	318	24	490	1.31	19.99
215	275	50	0.55	20.23	267	58	49	0.61	20.46	319	156	492	0.39	20.74
216	197	51	1.73	18.70	268	255	52	1.46	19.75	320	160	494	1.46	19.07
217	158	462	0.78	20.29	269	141	460	1.23	17.86	321	126	492	1.09	18.22
218	161	464	0.53	20.49	270	108	460	1.22	18.87	322	232	496	0.12	20.35
219	154	464	0.60	19.69	271	224	469	1.90	18.44	323	226	1	0.76	20.51
220	273	460	1.01	20.33	272	196	470	1.60	18.71	324	120	8	0.81	20.24
221	214	461	1.34	19.78	273	191	472	0.70	20.79	325	114	21	1.52	19.11
222	294	464	1.50	20.55	274	160	476	0.73	20.74	326	162	22	1.15	18.55
223	122	469	0.05	18.98	275	27	474	1.41	18.62	327	82	25	0.65	19.69
224	125	468	1.56	19.17	276	250	478	0.20	20.36	328	17	36	1.40	20.14
225	123	473	1.86	17.58	277	152	483	0.72	20.10	329	284	41	0.60	20.43
226	119	474	0.00	18.40	278	295	484	1.10	20.17	330	198	45	0.06	16.87
227	184	471	0.72	20.42	279	158	485	0.25	19.17	331	208	47	-0.03	19.31
228	59	472	1.39	18.64	280	39	487	0.16	18.15	332	288	49	1.89	17.54
229	283	474	0.21	18.70	281	60	494	0.27	20.25	333	277	461	0.56	19.69
230	140	475	0.63	20.76	282	281	490	0.50	19.29	334	266	468	1.44	18.11
231	17	479	1.06	20.31	283	102	493	0.07	18.65	335	224	474	0.59	20.19
232	200	487	0.49	20.45	284	149	495	1.06	18.93	336	141	490	0.82	18.20
233	195	491	1.45	18.65	285	204	495	1.50	18.67	337	131	494	0.29	19.55
234	221	489	2.02	16.13	286	223	495	1.43	18.81	338	145	494	1.53	18.15
235	170	489	0.82	20.79	287	191	496	0.10	20.28	339	21	498	1.51	18.82
236	66	490	0.92	19.98	288	288	502	0.52	19.90	340	273	497	0.52	19.13
237	156	497	1.64	20.28	289	40	502	0.02	18.19	341	122	498	0.11	17.71
238	119	493	1.27	18.13	290	17	4	0.80	20.04	342	228	26	0.89	19.00
239	212	500	1.64	19.14	291	138	11	0.06	19.12	343	274	27	0.73	20.16
240	171	499	0.64	20.60	292	160	11	0.38	20.72	344	263	465	0.20	20.45
241	163	500	1.39	18.42	293	72	19	1.77	18.53	345	261	478	2.06	17.12
242	120	503	0.10	18.41	294	230	19	1.25	14.72	346	290	484	0.66	20.45
243	200	503	1.21	18.64	295	222	20	0.49	20.65	347	127	485	0.70	19.22
244	144	504	0.21	20.79	296	44	27	0.58	20.25	348	209	487	1.53	18.31
245	133	1	0.37	20.32	297	290	29	0.62	20.36	349	104	491	0.86	18.31
246	136	1	0.64	20.36	298	12	34	1.07	19.98	350	71	492	0.83	18.80
247	30	2	0.28	19.93	299	99	34	0.85	20.01	351	14	18	0.54	19.52
248	252	3	1.58	17.85	300	191	36	1.88	17.77	352	155	20	0.41	19.64
249	248	5	0.64	20.32	301	190	40	0.41	18.72	353	79	24	0.59	20.74
250	286	4	0.38	19.49	302	139	47	0.90	20.76	354	91	34	2.47	15.53
251	253	8	0.67	20.73	303	295	47	1.43	18.10	355	86	43	0.65	20.46
252	83	9	1.00	18.36	304	246	48	0.66	20.00	356	12	48	0.78	20.67
253	276	14	1.28	19.39	305	272	52	0.09	19.55	357	48	472	0.81	20.37
254	11	21	0.89	20.12	306	190	460	1.23	20.41	358	243	476	1.98	16.72
255	61	19	1.57	18.73	307	92	460	0.12	19.46	359	111	484	1.06	18.26
256	260	25	0.83	19.81	308	268	460	1.31	19.04	360	293	2	1.38	20.06
257	182	23	0.80	20.15	309	119	468	0.05	18.25	361	176	473	0.98	19.23
258	31	31	1.21	18.06	310	113	468	1.74	18.21	362	27	24	0.59	18.65
259	188	26	0.69	20.78	311	246	470	1.46	18.70	363	19	489	1.00	19.66
260	183	31	0.21	18.34	312	55	474	1.64	18.13	364	18	496	1.53	17.88
261	130	30	1.44	18.66	313	284	479	0.20	18.97	365	294	25	0.37	18.23
262	208	31	0.81	20.22	314	220	480	0.49	20.71	366	97	38	0.06	18.43
263	204	33	1.33	18.92	315	223	481	0.30	20.50	367	42	497	1.52	18.11
264	225	34	0.77	20.30	316	49	484	1.00	20.61	368	72	25	0.07	17.33
265	185	36	0.12	19.22	317	194	488	0.28	19.99	369	196	460	0.13	19.62

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