THE COLOR-MAGNITUDE DIAGRAM FOR THE GALACTIC CLUSTER NGC 7789*

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ABSTRACT

Colors and magnitudes for nearly seven hundred stars are given for the cluster NGC 7789 The color-magnitude diagram and the absence of large numbers of faint stars show this to be a galactic cluster Photoelectric calibrations in three colors for forty-three stars were obtained with the 60-inch telescope Photographic plates taken with the 100-inch telescope were used for the photometry The cluster has a strong yellow giant branch which slopes blueward toward faint magnitudes until the Herzsprung gap is reached at $(B-V)_0 = 0\ 92$. The gap is $\Delta(B-V) = 0\ 45$ mag wide The main sequence is reached at $V \approx 14$ and has the characteristic steep slope due to evolution Blue stars exist brighter than the main-sequence break point, as in M67 and M3 This feature is unexplained by evolutionary theory The apparent distance modulus is $m - M = 12\ 20 \pm 0\ 2$, the reddening is $E(B-V) = 0\ 28$, the true modulus is $11\ 36 \pm 0\ 2$, and the distance is 1870 ± 170 parsecs The yellow giant stars reach $(B-V)_0 = 1\ 62$ This color would correspond to M2 III stars if our photometry is correct and if color is a good indicator of spectral type in this range. However, spectra obtained with the 60-inch telescope indicate a type K4 III for the stars at the top of the giant branch NGC 7789 fits into the systematic scheme of C-M diagrams for other galactic clusters in the expected way It is older than Praesepe or Hyades but younger than M67 The giant sequence of NGC 7789 crosses the giant sequence of M11 This again shows the non-unique mass-luminosity relation for luminosity class III giants

I. INTRODUCTION

NGC 7789 is a rich cluster of stars at $\alpha(1950) = 23^h54^m28^s$, $\delta(1950) = +56°26'.2$, $l = 83°$, $b = -5°.2$. It has the appearance of a galactic, rather than a globular, cluster because of the absence of large numbers of faint stars. Both Trumpler and Shapley list it as a galactic cluster. But in 1954, V. C. Reddish concluded, from data he had obtained on the color-magnitude (C-M) diagram and the luminosity function, that NGC 7789 was a globular cluster. Acting on this result, A. J. Deutsch placed the cluster on his program for spectroscopic studies of individual stars in globular clusters. Deutsch's spectrogram of one of the bright red stars in NGC 7789 showed that the cluster was indeed galactic rather than globular because the star was a normal luminosity class III giant. Because of this spectroscopic datum and Reddish's photometric results, the cluster appeared to be important because it is old. The slope of the red giant branch is similar to the galactic clusters NGC 752 and M67. Consequently, it was put on this observatory's program for evolutionary studies. The present paper gives the photometric data and C-M diagram for NGC 7789. The usual combination of photoelectric and photographic techniques was used.

II. THE PHOTOELECTRIC DATA

Colors and magnitudes for forty-three stars in the vicinity of NGC 7789 were measured in three colors with the 60-inch telescope on Mount Wilson. The measurements

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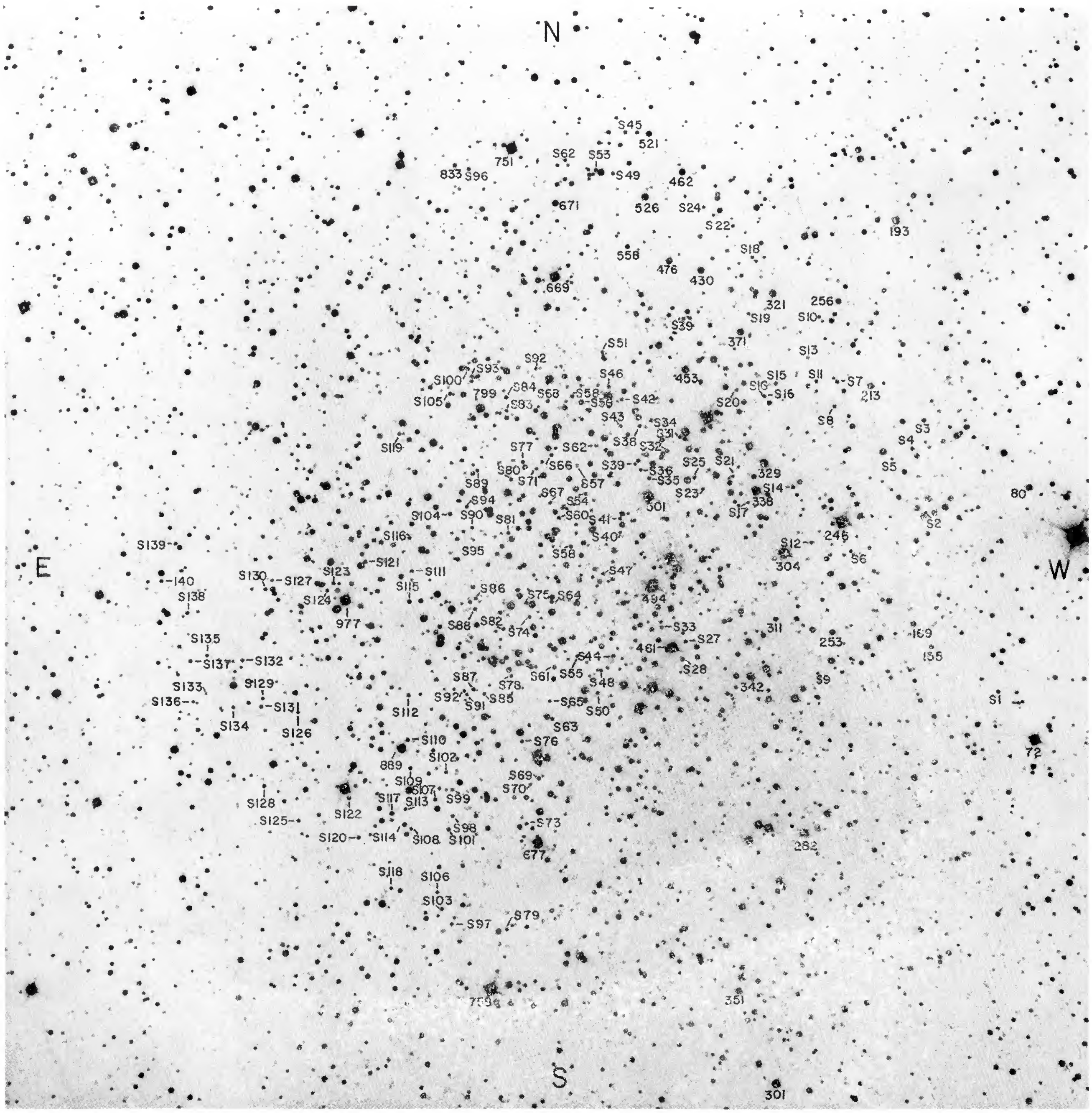

FIG. 1.—The identification chart for the photoelectric standards and the supplementary stars in NGC 7789. Küstner nu bers are used for the standards. Arbitrary numbers prefixed by S are used for the supplementary stars.

extended over two observing seasons. The photometer described by Walker (1954) was used in the 1956 season. This used an EMI 5659 end-on multiplier tube operating without refrigeration. The filters used were Corning 9863 for the ultraviolet, 1 mm of Schott BG12 plus 2 mm of Schott GG13 for the blue, and 1.7 mm of Schott GG11 for the yellow. A new photometer was used in the 1957 season which employed a refrigerated 1P21 photomultiplier and the same filters in the blue and visual bands. No ultraviolet measures in NGC 7789 were made in the 1957 season.

All measures were reduced in the usual manner to outside the atmosphere by the method of conditioned extinction coefficients. By special observations on seven nights, all data were transformed to the Johnson U, B, V photometric system, with probable errors of the order of ± 0.01 mag. The details of the photoelectric reductions are described more fully in a current paper (Sandage 1958).

Table 1 gives the photoelectric data for the forty-three stars. Where possible, numbers assigned by Küstner (1923) are used. Five stars fainter than Küstner's limit which were also measured are given supplementary numbers as explained in the next section. The Küstner numbered standards of Table 1 are marked on Figure 1. They are the stars with no S prefix.

III. THE PHOTOGRAPHIC DATA

Plates in the blue and visual wave-length regions were taken of NGC 7789 with the 100-inch telescope diaphragmed to 58 inches. The telescope so diaphragmed gives a circular field of 475 seconds of arc free from photometric errors larger than 0.01 mag.

TABLE 1

PHOTOELECTRIC STANDARDS IN NGC 7789

Küstner No	V	$B-V$	$U-B$	n	Küstner No	V	$B-V$	$U-B$	n
72	10 98	1 81	. .	4	501	11.17	1 74	.	2
80	13 16	1 25	+1 13	1	521	13 52	0.67	+0 11	1
155	15 07	0 91		3	526	12 80	1 28	+ 97	1
169	14 17	0 71		3	558	14 65	0 58		1
193	12 59	1 42	+1 64	1	669	11 44	1 66		2
213	13 62	1 51		1	671	13 32	0 68	+ 10	1
246	10 29	0 21	+0 11	10	677	11 11	0 15	− 05	1
253	13 75	0 74	+0 25	1	751	10 84	1 84		2
256	13 92	0 73	+0 26	1	758	10 46	0 72	+ .33	5
282	12 05	0 24	+0 17	2	799	11 78	0 33	+ 20	1
301	12 29	1.37		2	833	15 23	0 83		1
304	11.05	1 73		7	889	11.52	0 21	+0 18	1
311	14 85	0 60		2	977	11 01	1 77		1
321	12 92	1 26	+0 88	1					
329	12 29	1 42	+1 45	1		Supplementary Stars			
338	11 79	1 17	+0 86	1	S1	15 78	1 12		2
342	12 42	0 19	+0 05	1	S8	15.78	0 81		1
351	13 55	0 50	+0 21	2	S9	16 45	0 56		1
371	12 94	0 35	+0 20	1	S12	15 95	0.72		1
430	12 95	0 65	+0 14	1	S15	16 28	1 06		1
453	12 61	0.26	−0 01	1					
461	11 29	1 64	.	1					
462	12 97	0 52	+0 28	1					
476	13 14	1 26	+0.97	2					
494	10.70	1 74		1					

(due to off-axis aberrations). Because of the peculiar mounting of the 100-inch telescope and the high declination of NGC 7789, the plates had to be taken at the large hour angles of 3–4 hours. The plates were Eastman 103*a*-O behind 2 mm of Schott GG13 for the blue, and Eastman 103*a*-D behind 2 mm of Schott GG11 for the visual.

Two plates in each color were measured with the Eichner variable-iris diaphragm photometer at California Institute of Technology. Nearly seven hundred stars were chosen for measurement in a circular area with a radius of about 450″ centered on Küstner's co-ordinate system at $X = -50''$ and $Y = 0$. An attempt for completeness was made for stars within a circle of radius 230″. No attempt at completeness was made outside this area. The magnitude limits were $V = 10.2$ to $V = 16.3$.

All standard stars of Table 1 were read back through the photographic calibration-curves. They were treated as unknowns, to determine the color and magnitude equation between the photoelectric system of Table 1 and the photographic plates. A small color equation was detected. It was well determined from $B-V = 0.2$ to $B-V = 1.7$. In other investigations of this same type (Johnson and Sandage 1955; Sandage and Walker 1955; Johnson, Sandage, and Wahlquist 1956; Sandage 1958) no color equation had ever been found between similar photoelectric-photographic data. In the present case it probably arises from the large hour angle at which the plates were taken. The color equation was applied to the first reductions of the photographic data. The data so corrected are given for the standard stars in Table 2. The residuals of Table 2 from Table 1 in the

TABLE 2

MAGNITUDES FOR STANDARDS READ FROM THE PHOTOGRAPHIC CALIBRATION-CURVES

Küstner No	V	$B-V$	Küstner No	V	$B-V$
72	10 98	1 92	501	11 22	1 71
80	13 19	1 31	521	13 44	0 76
155	15 02	1 02	526	12 79	1 31
169	14 18	0 72	558	14 53	0 66
193	12 54	1 55	669	11 46	1 63
213	13 62	1 63	671	13 30	0 67
246	10 27	0 24	677	11 14	0 13
253	13 76	0 74	751	10 80	1 89
256	13 93	0 75	758	10 45	0 74
282	12 03	0 23	799	11 79	0 29
301	12 08	1 37	833	15 25	0 78
304	11 08	1 73	889	11 56	0 18
311	14 84	0 58	977	11 03	1 72
321	12 92	1 31			
329	12 25	1 47		Supplementary Stars	
338	11 83	1 15	S1	15 77	1 15
342	12 43	0 14	S8	15 96	0 65
351	13 48	0 53	S9	16 43	0 59
371	12 93	0 36	S12	15 99	0 62
430	12 94	0 68	S15	16 30	1 04
453	12 67	0 18			
461	11 27	1 66			
462	12 94	0 56			
476	13 14	1 28			
494	10 61	1 87			

sense photoelectric *minus* photographic are shown in Figures 2 and 3. These residuals define the color and magnitude equations of the *final* photographic data with respect to Johnson's U, B, V system. The residuals show no systematic trend with V or $B-V$. Consequently, all data reported in this paper are on the U, B, V system to within the accuracy of the determination.

Table 3 gives the photometric data for each of the program stars which were bright enough to have Küstner numbers. These stars are not identified on the photographic chart, since their positions and identifications can be recovered from Küstner's catalogue (1923). Table 4 gives the B and V magnitudes, together with $B-V$ for one hun-

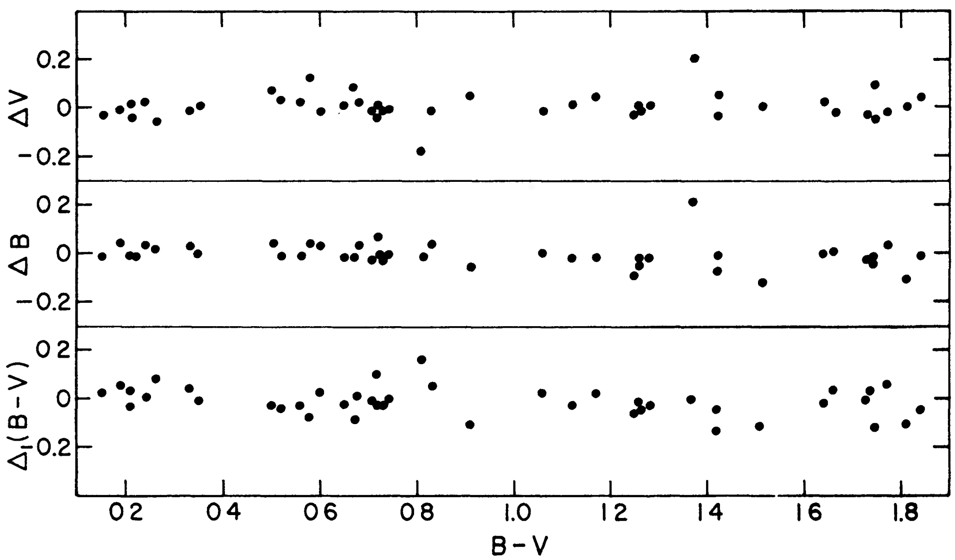

FIG. 2.—The color equation between the photoelectric values of Table 1 and the final photographic values of Table 2 The residuals are taken in the sense photoelectric *minus* photographic.

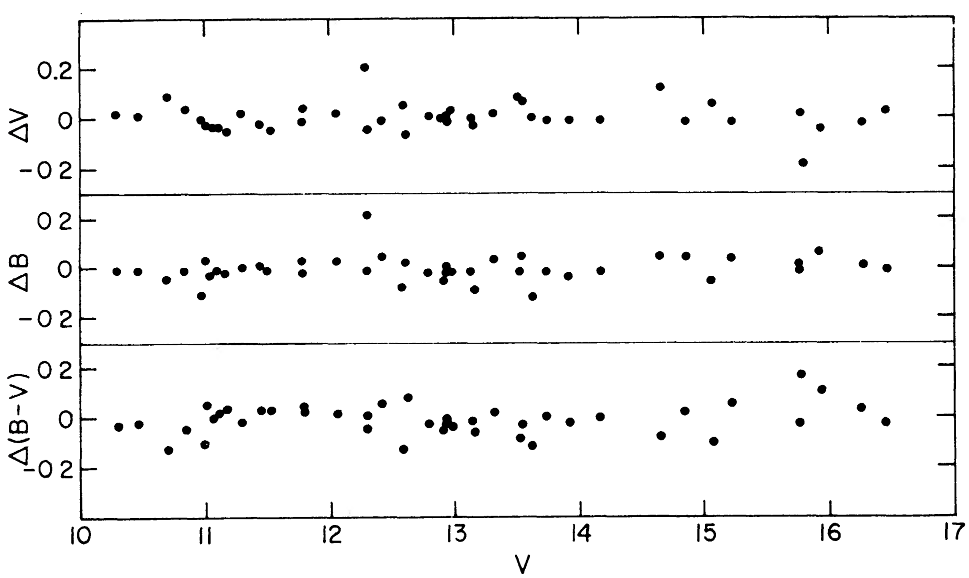

FIG. 3 —The magnitude equation between the photoelectric values and the final photographic values. The residuals are taken in the sense photoelectric *minus* photographic.

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TABLE 3

COLORS AND MAGNITUDES OF KÜSTNER STARS IN NGC 7789

Küstner No.	V	B−V	Küstner No.	V	B−V	Küstner No.	V	B−V	Küstner No.	V	B−V
72	10.98	1.92	312	11.96	1.37	426	13.49	0.64	549	12.29	1.44
80	13.19	1.31	313	14.02	0.74	428	14.11	(1.00)cr	551	15.69	0.67
82	13.47	0.71	316	13.77	0.33	429	14.59	0.64	553	14.01	0.66
88	13.04	0.40	319	12 82	1.16	430	12.94	0.68	555	13.03	1 27
106	14.72	0.62	321	12.92	1.31	432	15.04	0.67	556	14.09	0.72
124	14.65	0.65	322	14.70	0 63	433	14.79	0.66	558	14.53	0.66
144	13.42	0.37	323	14.54	0.66	434	13.57	0.59	559	14.50	0 83
155	15 02	1 02	326	14.42	0.55	436	14.32	0.57	560	14.20	0.68
156	(Variable?)		327	12.39	1.02	443	13.55	0.86	561	14.94	0.58
159	14 93	0.65	329	12.25	1.47	444	12.90	1.26	562	14.22	0.66
160	13.01	1.27	332	15.49	0.68	446	15.68	0.72	563	14.81	0.51
161	13.71	0.83	337	12.26	1.32	450	12.33	1.37	566	14.16	0.55
167	13.98	0.78	338	11.83	1 15	451	14.61	0.65	567	15.77	0.66
168	13.77	0.37	339	15 01	0.67	453	12.67	0.18	569	15.10	0.58
169	14.18	0 72	341	15.01	0.89	461	11.27	1.66	573	13.76	0.64
170	14.33	0.70	342	12.43	0.14	462	12.94	0.56	574	14.22	0.62
171	15 54	0.59	343	14.45	0.63	463	14.16	0.62	575	12.07	1.48
179	14.38	1.17	347	12.97	1 27	464	13.93	0.61	576	13.59	0.64
181	14 19	0.67	348	12.92	1.23	466	12.17	1.47	578	14.59	0.63
184	14.41	0.63	349	13 33	0.45	467	13.53	0.62	582	14.00	0.71
192	13.58	0.35	351	13 48	0 53	468	11.10	1.65	583	14.62	0.54
193	12.54	1.55	352	15.78	0.69	470	15.56	0.66	585	13.78	0.71
197	13.28	0 45	353	12.58	1.46	471	15 48	0 73	586	15 34	0.62
200	13.15	1 28	354	14.55	1 38	472	15.04	0 67	589	15.21	0.61
212	13.24	1.24	355	14.71	0.67	475	15.19	0.69	590	14.04	0.67
213	13 62	1.63	356	15.79	0.72	476	13.14	1.28	592	15.77	0.65
215	14.81	0 77	359	14.21	0.60	479	15.07	0.67	593	12.91	1.31
224	15.66	0.71	360	14.29	0.74	480	14.51	0.60	594	14.30	0.66
227	14.34	0.56	362	14.84	0.64	483	14.81	0.66	599	14.54	0.66
231	15.01	0 73	364	(16.11)	(0.66)	485	14.41	0.55	602	13.89	0.68
232	13.04	1.33	365	14 03	0.76	486	13.71	1.19	603	14.08	0 58
233	14.51	0.63	368	14 88	0.75	489	11 19	1.39	604	14.37	1.18
234	13.43	0.48	369	14 47	2.12	490	15.68	0.69	605	12.79	1.23
235	14.15	0.72	370	15.88	0.69	491	12.89	1.29	609	14.17	0.72
237	14.53	0 73	371	12.93	0.36	493	15.38	0.64	610	14.79	0.59
241	(16.04)	(0.66)	372	13 96	0.63	494	10.61	1.87	611	14.98	0.60
244	13.13	1.26	373	(15.93)	0.73	496	13.91	(0.82)	614	15.39	0.63
246	10.27	0.24	375	14.74	1.38	501	11.22	1.71	615	14.47	0.55
247	15.12	0.81	377	13.60	0.64	503	14.71	0 53	616	15.64	0.80
248	14.88	0.66	378	14.79	0.94	504	15.32	0.65	620	14.52	0.66
253	13.76	0.74	379	15.78	0.66	505	15.71	0.69	623	15.56	0.71
254	13.21	1.25	381	14.50	0.57	506	15.28	0.68	624	14.81	0.62
255	12.89	1.35	382	14.04	0.72	508	14.79	0.55	625	14.40	0.66
256	13.93	0.75	388	13.73	1 31	510	14.67	0.69	626	12.86	1.26
257	15.48	0.56	389	14.87	0.62	515	14.47	1.45	627	13.98	0.67
259	15.18	0.62	392	(15.90)	0.71	516	14.02	0.67	632	13 97	0.71
260	15.50	0.70	393	15.39	0.61	517	14.68	0.52	633	14.05	0.57
262	14 09	0.67	394	15.36	0 64	518	14.34	0 62	635	12.83	0.48
265	14.59	1.20	402	14.03cr	(0.72)cr	521	13.44	0.76	637	12.39	1.44
268	13.64	0.67	404	15.63	0.67	526	12.79	1.31	638	14.24	0.68
269	14.77	0.62	405	13.99	0.63	527	15.05	0.67	640	15.20	0.69
273	14.30	0.58	406	13.98	(0.61)cr	528	14.27	0.61	641	14.34	0.63
278	13.84	0.71	409	12.95	0.31	529	15.74	0 69	642	14.29	0.69
282	12.03	0.23	410	13 82	(0.55)cr	531	15.70	0.68	644	15.44	0.62
286	14.11	0.96	412	14.83cr	(0 57)cr	533	15.35	0.68	645	15.31	0.67
288	15.24	0.67	413	15.43	0.72	534	14.20	0.73	646	14.55	0.60
293	15.05	0.66	414	14 96	0.66	536	13 97	0.90	648	15.20	0.54
294	14 65	0.65	415	10.63	1.90	541	15.31	0.73	650	14.90	0.56
296	12.43	0.57	416	13.06	1.26	545	15.42	0.73	651	13.51	0.57
297	12.66	1.17	418	14.34	0.60	546	15.54	0.72	654	14.42	0.54
301	12.08	1.37	419	14.27	0.68						
304	11.08	1.73	420	14.82	0.63						
308	13.46	0.68	421	14.10	0.58						
310	14.97	0.69	422	14.40	0.59						
311	14 84	0.58	424	14.85	0.68						

TABLE 3 (Continued)

COLORS AND MAGNITUDES OF KÜSTNER STARS IN NGC 7789

Küstner No.	V	B-V
655	14.65	0 55
658	13.05	1.20
659	14.40	0.56
663	14.59	0.61
665	12.77	1.20
666	13.95	0.63
669	11.46	1 63
670	14.21	0.59
671	13.30	0.67
674	13.88	1 59
675	(12.25)cr	(1.22)cr
676	12.80	1.23
677	11.14	0.13
682	13.70	0 66
684	12.92	1 28
685	15.86	0.64
686	15.20	0.64
687	15.69	0.67
688	14.78	0.60
689	13.54	0 93
690	15.57	0 67
691	15 01	0.99
692	12 92	1.26
694	14.65	0.60
695	14 96	0.65
696	13.66	0.32
697	14.75	0.67
698	13 80	0.60
699	14 90	0.58
703	14.04	0.63
704	13.60	0.65
705	14.66	0.59
707	12.93	1 25
708	14.48	0.57
709	12.37	1.30
710	14.72	0.62
711	12.60	1.04
712	14.37	0.63
713	15.02	0.63
714	14.13	0.68
715	13 85	0.69
716	12.83	1.24
717	14.75	0.40
718	15.37	0 67
721	15.63	0.71
723	15.46	0.62
724	13.07	1 19
725	14.66	0.60
726	14.81	0.57
728	13.82	0.74
730	14.85	0.62
732	12.68	1.22
733	14.50	0.56
734	13 79	0.68
737	13.30	1.20
738	15.07	0.57
742	14.04	0 67
743	15.10	0.60
745	15.61	0.67
746	12.51	0.39
747	14.36	0.56
750	15.24	0.68
751	10.80	1.89
752	13.04	1.28
753	14 02	0.54
755	15.02	0.68
756	15.50	0.71
757	15.73	0.69
758	10.45	0.74
760	13.53	0.70
761	14.63	0.58
762	15.56	0.66
763	15.61	0.64
765	11.58	1.44
766	15.00	0.63
769	14.34	0.58
777	15.54	0.64
778	12.99	1.24
782	15.31	0.70
784	15.28	0.43
786	14 96	0.60
787	14.20	0.62
789	13.70	0.57
790	14.31	0.59
792	15.17	0.61
794	13.80	0.65
798	14 69	0.58
799	11.79	0.29
802	15.54	0 67
804	15.29	0.90
805	15.72	0 65
806	15.24	0.60
807	13.96	0.62
808	14.74	0.56
810	14.31	0.63
811	15.42	0.64
814	12.88	1 20
815	14.14	0.60
816	13.57	0.67
817	14.92	0.65
818	13.98	0.70
819	15.04	0.61
820	14.01	0.66
821	13.85	0.65
822	15 73	0 70
824	15.20	0.64
826	15.48	0.46
827	12.79	1.22
833	15.25	0.78
834	13.76	0.75
836	15.06	0.74
838	14.14	0.66
840	13.80	0.69
843	15.37	0 64
844	14.02	0 61
845	15.31	0.62
847	15.46	0.67
849	13 02	1.15
850	14.98	0.63
851	15.56	0.78
854	14.20	0 58
855	14.39	0.57
856	15.43	0.63
857	13.87	0.67
859	12.65	1.39
861	13.84	0.55
862	15.09	0.60
863	(14 94)cr	(0.67)
864	15.20	0.56
865	12.60	1.08
866	12.81	1 22
870	12.83	1 27
871	14 57	0.60
874	14.64	0.58
875	12.86	1 25
880	14.78	0.60
882	15 08	0.59
885	14 42	0.60
886	14.98	0.65
887	14.71	0.62
889	11.56	0.18
890	14.11	0.73
894	14 58	0.85
897	12 84	1 23
900	15 63	0.73
901	14.92	0.65
902	13 00	1.27
904	15.48	0.63
906	12.62	0 52
908	12 96	1.22
909	14.58	0.60
910	14.64	0.54
912	14.24	0.58
914	14 12	0.60
916	13 25	1.22
920	14.79	0.59
922	14.93	1.01
924	13.54	0.64
925	14.57	0.62
928	15.00	0.65
929	15.37	0.66
930	15.22	0.60
931	14.87	0.64
933	15.21	0.59
935	14.43	0.58
938	14 50	0.59
939	15.73	0.71
943	14 76	0.56
945	15.43	0.75
947	15.30	0.70
948	14.32	0.63
949	(14.05)cr	(0.69)
950	12.80	1.24
953	15.91	0 80
955	15.77	0.65
957	12 97	1.27
958	15.20	0.65
965	13.97	0.67
967	14.93	0.63
970	11.82	1.55
971	10.98	1.89
977	11 03	1.72
987	15.35	0.69
988	14.00	0.66
991	11 49	1.55
993	14.38	0.61
1002	14.12	0.90
1005	12.62	1.11
1007	15 10	0.79
1011	15.73	0.90
1014	15 23	0 66
1021	14 91	0.67
1022	14.32	1.53
1027	13.79	0.69
1029	13.83	0.75
1030	14 06	0.70
1033	15.81	0.91
1034	14.48	0 59
1036	12.91	1.17
1040	14 83	0 60
1047	12 31	0.47
1049	13 99	1.43
1051	13.31	0 65
1057	14.26	0.73
1059	14 18	0 68
1063	15.55	0.73
1066	11.92	1.51
1070	15.49	0.66
1071	12 53	1.28
1074	(14.33)cr	(1 22)
1075	(14.22)cr	(0 73)
1077	(14.49)cr	(0.62)
1079	15.26	0.80
1081	(13 76)cr	(0.75)
1083	14.77	0.62
1084	12.80	1 35
1086	14.68	0.56
1090	15.48	0.82
1091	12.97	1.38
1092	12.26	1 40
1094	15 39	0.77
1096	13.53	1.33
1097	13.81	0 36
1098	14.07	0 64
1101	12 89	1.27
1103	13.36	0.68
1106	15.32	0.79
1107	12.71	1.25
1108	14.92	0 65
1114	13.16	1 18
1119	12.65	0.25
1141	13.96	0.72
1145	15.48	0.68
1146	15.71	0.70
1148	14.58	0.96
1149	12.07	1.04
1156	13.83	0.72
1163	13.15	0 57
1196	11 85	1.56
1198	14.76	0.62
1208	11.63	0.56
1209	14.30	0.71
1211	11.50	0.05
1225	12.56	1.25
1230	14.12	0.67
1234	14.09	0.69
1238	13 54	0.80
1244	12.81	1.85
1259	13.83	0.72
1298	13.61	(0.69)
1309	11.15	0.38
1349	14.33	0.63

TABLE 4

COLORS AND MAGNITUDES FOR SUPPLEMENTARY STARS IN NGC 7789

Star	B	V	B-V
S 1	16.92	15.77	1.15
2	16.89	16.17	0.72
3	16.26	14.90	1.36
4	16 55	15.66	0.89
5	16.94	-	-
S 6	17.07	-	-
7	16.95	16.30	0.65
8	16.61	15.96	0.65
9	17.02	16.43	0.59
10	16.87	16.10	0.77
S 11	17.30	-	-
12	16 61	15.99	0.62
13	17.39	-	-
14	16.59	15.83	0.76
15	17.34	16.30	1 04
S 16	16.64	15.78	0.86
17	17.18	-	-
18	16 96	16.31	0.65
19	17.28	16.33	0.95
20	16.97	16 25	0.72
S 21	17.11	-	-
22	16.63	15.96	0 67
23	16.95	16.29	0.66
24	17.22	-	-
25	16.79	16.12	0.67
S 26	16.63	16.06	0.57
27	16.56	15.90	0.66
28	16.51	15.81	0.70
29	Discordant		
30	16.37	15.60	0.77
S 31	17.15	-	-
32	16.76	16.09	0 67
33	16.78	16.04	0.74
34	16.83	16.18	0.65
35	17.17	-	-
S 36	17.36	-	-
37	17.10	15 89	1.21
38	17.08	-	-
39	17.42	-	-
40	16.98	-	-
S 41	17.34	-	-
42	16.94	16.20	0.74
43	16.92	-	-
44	16.81	16.15	0.66
45	16.80	15.60	1.20
S 46	17.21	-	-
47	17.39	-	-
48	16.74	-	-
49	16 72	16.11	0 61
50	16.44	15.78	0.66
S 51	17.00	-	-
52	16.96	-	-
53	16.66	-	-
54	16 78	-	-
55	16.94	-	-
S 56	17.36	-	-
57	17.27	-	-
58	17.36	-	-
59	Discordant		
60	16.82	16.17	0.65
S 61	16.53	15.83	0.70
62	17.31	-	-
63	16.87	16.03	0 84
64	16.76	16.03	0.73
65	16.84	16.13	0.71
S 66	16 81	-	-
67	16.73	16.06	0 67
68	16.65	15.87	0.78
69	16.82	15.72	1.10
70	17.00	-	-
S 71	17.16	-	-
72	17.09	-	-
73	16.63	15 94	0.69
74	17.23	-	-
75	16.74	-	-
S 76	16.78	16.06	0.72
77	17.27	-	-
78	16.88	16.04	0.84
79	17 10	-	-
80	16.71	16 05	0.66
S 81	17.42	15.99	1.43
82	16.81	16.09	0 72
83	16.93	-	-
84	16.90	15.82	1.08
85	16.95	16.13	0.82
S 86	16.56	15.86	0.70
87	16.45	15.80	0.65
88	16.68	15.96	0.72
89	16.85	-	-
90	16.93	15.99	0.94
S 91	17.34	-	-
92	17.05	-	-
93	16.43	15.75	0.68
94	16.95	-	-
95	16 87	16 11	0.76
S 96	16.63	15.93	0.70
97	17.01	-	-
98	16.92	16.14	0.78
99	16.88	16.12	0 76
100	16 43	15.73	0.70
S 101	17.08	15.71	1.37
102	16.72	15.94	0.78
103	17.43	-	-
104	16.60	15.76	0.84
105	16.59	15.79	0.80
S 106	17.33	-	-
107	16.71	16.01	0.70
108	17.42	-	-
109	16.68	15.88	0.80
110	16.36	15.67	0.69
S 111	16.73	15.98	0.75
112	16.43	15.69	0.74
113	17.18	-	-
114	16.53	14.95	1.58
115	16 50	15.24	1 26
S 116	17.20	-	-
117	16.37	14.86	1.51
118	17.48	-	-
119	16.48	16.15	0.69
120	Discordant		
S 121	16.57	15.81	0.76
122	16.58	15.83	0.75
123	16.51	15.68	0.83
124	16.64	15.91	0.73
125	16 91	16.09	0.82
S 126	16.97	-	-
127	17.21	16.12	1.09
128	16.47	15.75	0.72
129	16.86	16.16	0.70
130	16.73	-	-
S 131	Discordant		
132	16.70	15.98	0.72
133	16.86	16.15	0.71
134	16.50	15.90	0.60
135	Discordant		
S 136	17.37	-	-
137	16.35	15.56	0.79
138	16 78	15.73	1.05
139	17.28	16.02	1 26
140	16.57	15.80	0.77

dred and forty supplementary stars which are fainter than Küstner's limit. These stars are numbered in order of increasing R.A. and are identified on Figure 1. The prefix *S* indicates "supplementary." The probable errors for the entries of Tables 3 and 4 are p.e.$(V) = \pm 0.021$ mag., p.e.$(B) = 0.021$ mag., and p e.$(B-V) = 0.031$ mag.

IV. THE COLOR-MAGNITUDE DIAGRAM

The data of Tables 1, 3, and 4 give the reddening, the C-M diagram, and the distance of the cluster. Figure 4 is the $U-B$, $B-V$ relation with the photoelectric data of Table 1 plotted. The normal relation of Johnson and Morgan (1953) is shown shifted by $\Delta(B-V) = 0.28$, $\Delta(U-B) = 0.20$. A reddening line of slope 0.73 has been assumed. The fit to the observed points is good. In the following we shall assume the reddening

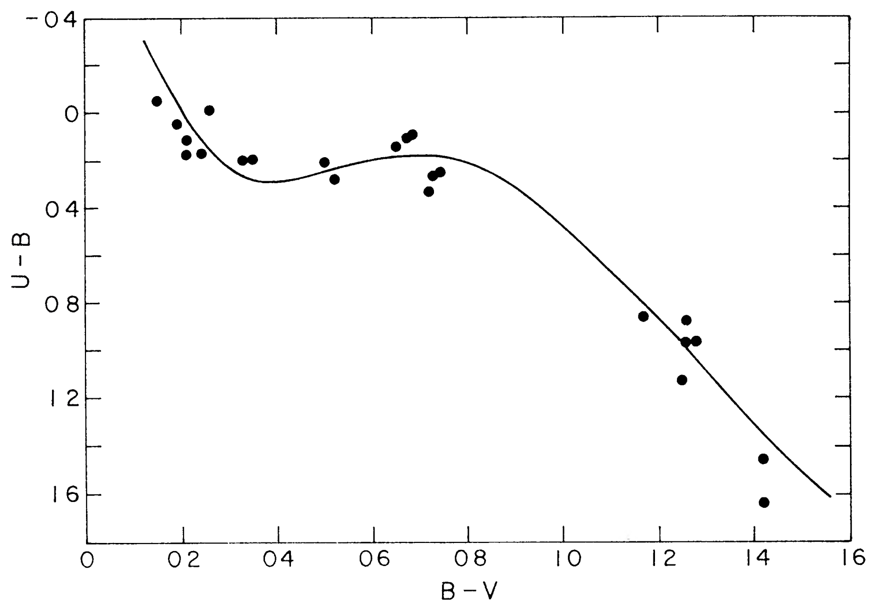

FIG 4 —The two-color diagram for the photoelectric stars of Table 1 The solid line is the standard Johnson and Morgan relation shifted by $E(B - V) = 0$ 28 along a reddening line with a slope of 0 73.

to be $E(B-V) = 0.28$. There is no evidence for differential reddening across the cluster.

The C-M diagram for the cluster is shown in Figure 5 from the data of Tables 3 and 4. The most striking feature is the sloping giant branch going from $V = 10.52$, $B-V = 1.9$, to $V = 13$ 2, $B-V = 1.2$. The branch is heavily populated. A pronounced Hertzsprung gap is present, extending from a normal $(B-V)_0$ of 0.47 to $(B-V)_0 = 0.92$. Finally, the main sequence with its characteristic turnoff is present from $V \approx 14.0$ to the limit of the data at $V = 16.3$. The effects of evolution are evident because the slope of the main sequence is steeper than the age-zero unevolved sequence, and the turnoff into the giant region is abrupt.

There are a number of stars which do not fall on the sequences in Figure 5. The most striking concentration of these stars is above the turnoff point at blue color indices. There are thirty-two stars in a band between $B-V \approx 0.10$ and $B-V \approx 0$ 35 at $V \approx 11.5$ to between $B-V \approx 0.3$ and $B-V \approx 0.6$ at $V \approx 13$ 5 Because of the low galactic latitude of NGC 7789, the possibility that these points are due to a concentration of bright main-sequence stars, belonging to the general field of the Perseus spiral arm, has not been ruled out. However, we feel that there are probably too many of these blue stars to be accounted for in this way. Furthermore, the recent proper-motion study of the vicinity of NGC 7789 by Meures, Bähr, and Thomas (1956) shows that at least ten of these outriding stars are probable cluster members. They are Küstner numbers 88, 144, 168, 197, 234, 349, 371, 409, 635, and 799. In view of the rather low resolving power of the proper-motion data, radial velocities would provide important additional data for deciding what proportion of the stars in this region of the C-M diagram are cluster members.

This feature of blue cluster members brighter than the main-sequence turnoff point occurs in a number of other clusters. Most notable is M67 (Johnson and Sandage 1955), where the bright blue stars were first interpreted as a possible horizontal branch (Sandage 1957). On the basis of our present results in NGC 7789, we now conclude that this interpretation is probably not correct. M3 also has many blue stars brighter than the main-sequence turnoff point (Sandage 1953; Johnson and Sandage 1956). Additional bright blue "stragglers" are known in the Coma Berenices cluster (17 Comae: Weaver 1952; Johnson and Knuckles 1955), and in Praesepe (Klein Wassink No. 265: Eggen 1951; Johnson 1952) and possibly in h and χ Persei (Masevich 1957, using Johnson and Hiltner's data of 1956). The point is of interest because these bright blue stragglers are not understood on current ideas of stellar evolution.

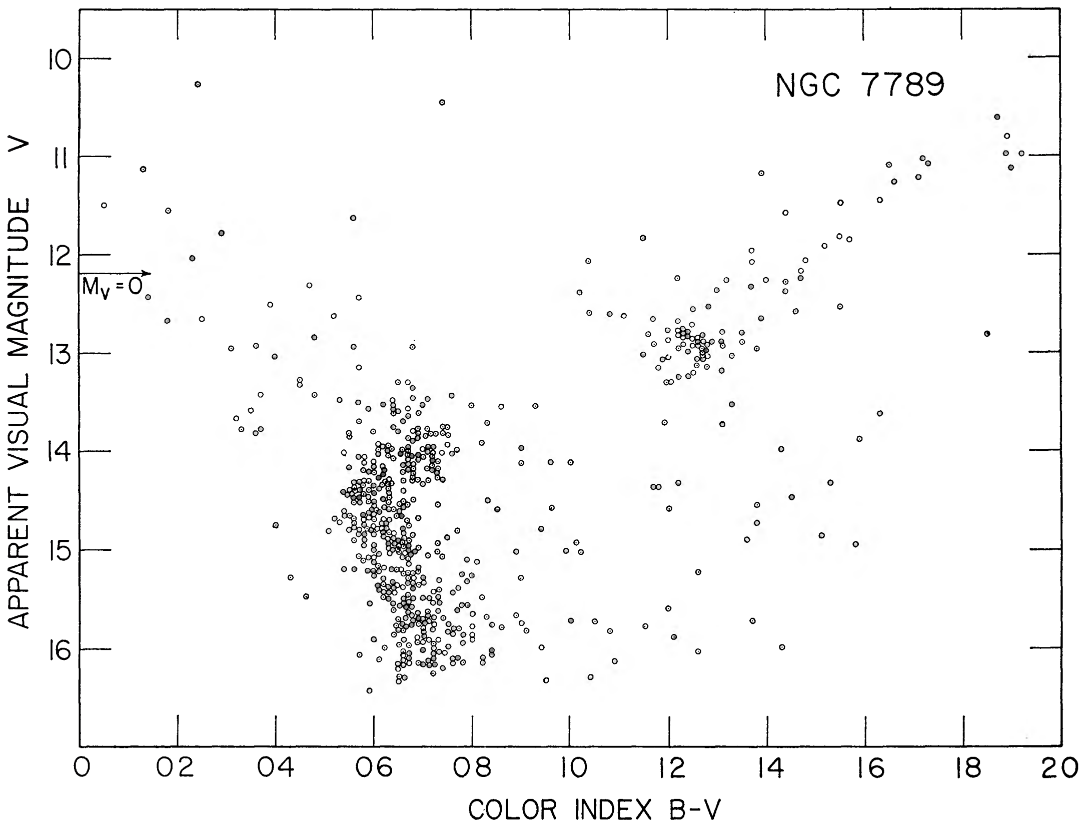

FIG. 5.—The color-magnitude diagram for NGC 7789 from the data of Tables 3 and 4

V. THE CLUSTER DISTANCE AND EVOLUTIONARY CONSIDERATIONS

The fit of the C-M diagram of Figure 5 with the age-zero main sequence (Johnson and Hiltner 1956; Sandage 1957) gives an apparent modulus of $m-M = 12.20 \pm 0.2$

mag. if $E(B-V) = 0.28$. This fit is difficult because we have not carried the photometry in NGC 7789 to the unevolved main sequence. Because the break point is at $V \approx 14.0$, we should not reach the unevolved main sequence until $V \approx 17.0$. However, if evolutionary corrections are applied, we can use the observed segment of the main sequence. Because the age of NGC 7789 is very close to NGC 752, we have used the evolved part of the NGC 752 sequence with help from the evolved M67 main sequence on the faint end and the evolved Praesepe main sequence on the bright end to interpolate the evolutionary effects. This gives the quoted value of $m-M = 12.20 \pm 0.2$. If $A_V/E(B-V) = 3.0$, then the true modulus is $(m-M)_0 = 11.36 \pm 0.2$. This corresponds to a distance of 1870 ± 170 parsecs.

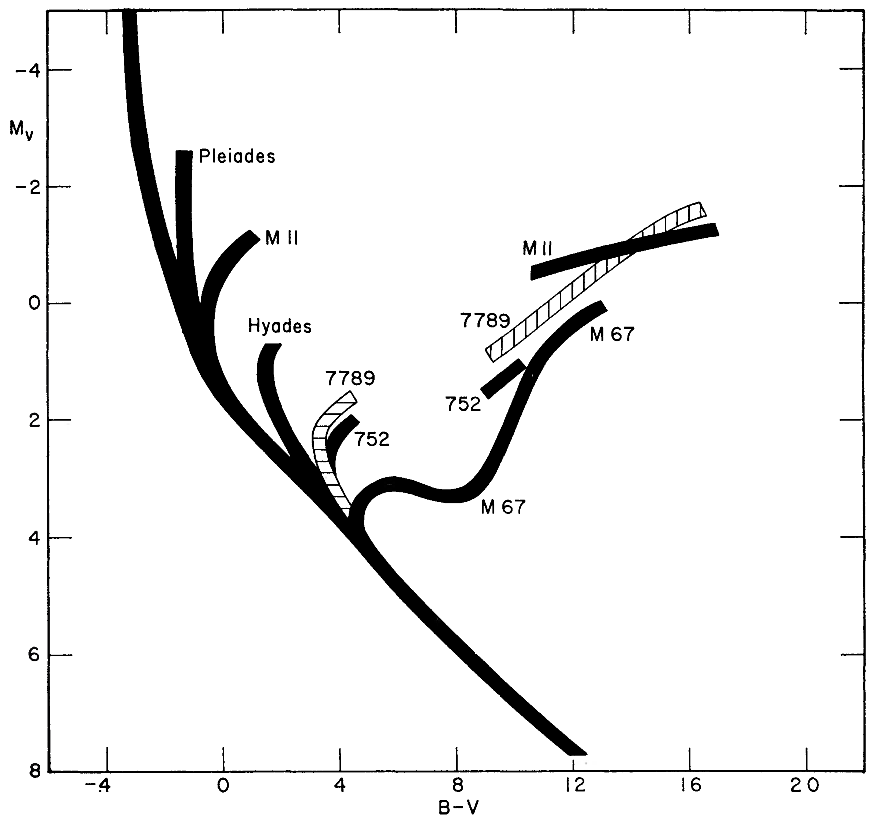

FIG 6 —The composite cluster diagram showing the relation of NGC 7789 to other known clusters The sequences of NGC 7789 are shown as a striped area

The relation of NGC 7789 to the systematics of other galactic clusters is shown in the composite diagram given in Figure 6. The main-sequence break point in 7789 is fainter than that of the Hyades and Praesepe but brighter than that of NGC 752 and M67. The Hertzsprung gap follows the systematics of the other clusters. It is $\Delta(B-V) = 0.45$ mag. wide, which is quite similar to the value in NGC 752.

The most interesting feature of Figure 6 is the long extension of the giant branch to red colors and the intersection of this branch with that of M11. The giants in NGC 7789 reach $M_V = -2.3$ at $(B-V)_0 = 1.62$. According to the $(B-V)_0 = f$ (spectral type) relation of Johnson and Morgan (1953), these stars should be M2 III stars, if the color is a unique indication of spectral type in this range. This is a point of some importance because, if true, this would be the only cluster besides NGC 6940 (Vasilevskis and Rach

1957) with normal M giants. However, spectrograms of four stars at the top of the giant branch were obtained by E. M. Burbidge with the help of G. R. Burbidge with the grating spectrograph on the 60-inch telescope (dispersion 80 A/mm). These stars do not have such a late spectral type as the photometry would indicate, which again shows the well-known fact that $B-V$ color is not a sensitive discriminant of spectral type for late-type stars. The types of Küstner numbers 751, 415, 494, and 977 are K3–4 III, K4 III, K4 III, and K3 III, respectively. In view of the richness of NGC 7789, it would seem worthwhile to survey the region around the cluster with an objective-prism instrument to search the region for M III stars If enough rich clusters can be found with M stars, there may be a chance to determine the ratio of K to M giants in clusters and to compare this with the ratio of $\sim$30 to 1 observed in the general field (Oort 1932).

The final point we wish to make is the crossing of the giant branch of NGC 7789 with the giant branch of M11. This again illustrates the funnel effect into the region of luminosity class III stars. There is apparently no unique mass for normal giants because Fig. 6 shows that any point in the composite C-M diagram from $B-V = 0.8$ to $B-V = 1.7$, $M_V = +2$ to $M_V = -2$, can be reached by a variety of evolutionary tracks, starting at the main sequence between $M_V = -1$ and $M_V = +3$.

Since this paper was prepared, Weber (1958) has announced the discovery of a variable star in NGC 7789. The star is Küstner 468, for which our measures (uncorrected for reddening and absorption) give $V = 11.10$ and $B-V = +1.65$. Weber found an amplitude of about 1 mag. (pg) and considered the star to be a cepheid, although he was not able to determine a period. His discovery was confirmed by Romano, who also believed the star to be a cepheid but mentioned rapid variations in brightness.

The absolute magnitude of only -1.10 and the large value of $B-V$ make it unlikely that this star, if a cluster member, is a classical cepheid; furthermore, it falls right on the giant branch. It is not red enough to be a typical long-period variable. It is at a considerably lower absolute magnitude than the red variables found occasionally on the giant branches of globular clusters Variation was not found on our plates. Possibly the star is a semiregular or irregular variable. A check on its cluster membership and observations leading to a light-curve would be very valuable.

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