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THE PRECISE COORDINATES OF THE SUPERGIANT AND GLOBULAR CLUSTER CANDIDATES OF THE GALAXY M81

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ABSTRACT. *The precise equatorial coordinates for 80 possible supergiants and 65 globular cluster candidates in the galaxy M81 are given. Five new globular cluster candidates found on the 2 m telescope plates to the south of M81 are added. The coordinate measurement was made using the plates of the 2 m and 1 m telescopes with a standard error of ≈ 1.2 arcsec.*

1. BRIGHTEST SUPERGIANT CANDIDATES OF M81

Although a great number of papers report on the stellar population of M81, there is still a great deal of unclear to us, even concerning its brightest stars. The first detailed study of M81 stellar population was made by Sandage (1984) using the plates of the 5 m telescope. Comparing the cepheids of NGC 2403 and M81, he has estimated the distance modulus for M81 $(m-M)_v=28^m.8$. The apparent magnitudes of the brightest blue and red supergiant candidates of M81 in Sandage's work were $19^m.0-19^m.5$ and $20^m.0-20^m.5$, respectively. The stellar photometry for M81 was performed by Freedman (1984, 1985), but the detailed results of this photometry were not published. Later, from IR observations of the two cepheids, Freedman and Madore (1988) estimated the distance modulus for M81 $(m-M)_I=27^m.6$. Consequently, at the light absorption value in the direction of M81 $A_v=0^m.2$, its brightest stars, according to Sandage (1984), should have the absolute magnitudes $-8^m.6$ – $-8^m.0$ for blue and $-7^m.6$ – $-7^m.0$ for red supergiants. In such a large galaxy as M81 one should expect the supergiants whose brightness is about one magnitude higher than that of the stars selected by Sandage (1984).

When attempting to select bright supergiants we have selected the candidates on the basis of the plates of the 6 m and 2 m telescopes around M81 (Georgiev et al., 1992a; Bilkina et al., 1991) and inside of the galactic disc (Georgiev et al., 1992b). The absolute magnitudes of our blue and red supergiant candidates are $-9\overset{m}{.}6$ - $-9\overset{m}{.}2$ and $-8\overset{m}{.}8$ - $-8\overset{m}{.}4$, respectively. The brightest blue and red supergiants of M31 and M33 have the similar absolute magnitudes (van den Bergh, 1991a,b).

Recently, Zickgraf and Humphreys (1991) published the results of their survey of M81 brightest stars from the plates of the Kitt Peak 4 m telescope. Note that these authors take the value of colour excess $E(B-V)=0\overset{m}{.}3$ in the direction of M81. Nevertheless, in their list, as well as in all other relevant papers, there are present rather blue stars. At the same time, in contrast to all other authors, Zikcgraf and Humphreys' lists have no red stars with $(B-V)>1\overset{m}{.}6$. The faint end of the stellar magnitude scale in their paper appears to be brighter than in other investigations. The difference between their and our data at $B=22\overset{m}{.}5$ and $V=21\overset{m}{.}5$ reaches approximately $1\overset{m}{.}0$ and $0\overset{m}{.}5$, respectively. Colour indices for "red" stars in Zickgraf and Humphreys (1991) list are $(B-V)=1\overset{m}{.}3-1\overset{m}{.}6$, so they should not enter into the list of red supergiants where the values $(B-V)=1\overset{m}{.}8-2\overset{m}{.}0$ and even greater are normal.

These discrepancies in the photometry of faint stars are, probably, caused by the difference in the methods of allowing for the background in the bright regions of M81. We also do not exclude the possibility of systematic error in our stellar magnitude scale. For the final solution of this problem, it is necessary to establish photometric standards not only outside the bright region of M81, as Zickgraf et al. (1990) did, but also in its disc.

Humphreys et al. (1986) and Humphreys and Aaronson (1987) carried out spectral observations of blue and red stars in M81. Sandage's list (1984) was taken as a basis, so the supergiants, whose relation to M81 has been already proved, appear to be about one magnitude fainter than those supergiant candidates which were detected later by Zickgraf and Humphreys (1991) and Georgiev et al. (1992 b). The nature of the brightest new supergiant candidates in M81 can be studied on the basis of spectral observations only. Therefore, we represent their precise coordinates (Tables 1 and 2). The finding charts can be found in our early papers (Georgiev, 1992 a,b).

Fig. 1 shows the colour-magnitude diagram for the blue and red supergiant candidates in M81, brighter than $19\overset{m}{.}4$. It is seen, that at $(B-V)=-0\overset{m}{.}4-0\overset{m}{.}5$, within $V=18\overset{m}{.}0-18\overset{m}{.}4$ there stand out six blue objects. Two of them coincide with the compact HII regions noted by Petit et al.(1988). Lower, within $18\overset{m}{.}7-19\overset{m}{.}4$, there are 13 blue objects five of which also coincide with HII regions. There is the brightest blue object from Sandage's list (1984), it is S75, which is also the brightest of the proved supergiants in M81. Two other proved members of M81 from this list (S12 and S124) are fainter than $19\overset{m}{.}5$. The survey of Zickgraf and Humphreys has added to this part of the colour-magnitude diagram two blue stars, three HII objects and three stars with (B - V)=$0^m_.5 - 0^m_.6$.

Table 1. Blue supergiant candidates.

N	N	α(1950)	δ(1950)	V	(B-V)	type*
SI1	ZH244	9 51 6.60	69 13 55.4	19.94	0.19	
SI2	ZH364	9 51 14.13	69 16 7.5	19.72	0.10	sg
SI3		9 52 1.74	69 18 25.8	20.13	-0.27	
SI4		9 51 4.40	69 22 31.5	20.22	0.20	
SI7		9 51 32.37	69 14 45.3	21.30	-0.26	
SI8		9 52 8.94	69 19 33.8	19.89	0.07	sg
SIB		9 51 31.70	69 14 10.9	19.51	0.27	
S15	ZH784	9 51 34.48	69 25 18.8	19.75	0.12	
S51	ZH479	9 52 15.14	69 17 1.9	19.80	0.*51*	
S75	ZH1143	9 52 3.89	69 10 58.4	19.15	0.13	sg
S91	ZH228	9 51 36.71	69 12 35.5	20.19	-0.26	
S100	ZH372	9 50 50.27	69 15 14.0	19.71	0.22	
S124	ZH502	9 50 30.73	69 20 44.8	19.64	-0.08	mult
S134		9 50 46.95	69 24 30.7	19.75	0.01	
BGG263		9 52 36.45	69 11 43.2	18.06	0.27	
A26		9 51 1.69	69 21 10.3	18.16	0.19	
A90		9 52 31.36	69 14 43.4	18.34	0.07	
W67		9 50 9.47	69 16 41.7	19.23	-0.14	
BGG160		9 50 56.18	69 29 45.7	19.35	0.14	
A88		9 52 15.68	69 16 15.7	19.37	0.06	
ZH486		9 51 3.44	69 18 17.7	18.13	0.51	
ZH224		9 51 28.97	69 10 1.3	18.76	0.10	
ZH628	J	9 51 45.58	69 21 51.0	18.86	0.59	
ZH642		9 51 27.16	69 22 16.3	19.10	-0.02	
ZH344		9 52 28.01	69 12 45.2	19.24	0.59	
ZH633		9 51 30.85	69 20 46.4	19.58	0.59	
ZH494		9 50 54.60	69 21 14.8	19.68	0.15	
ZH483		9 52 1.61	69 15 15.7	19.81	0.09	
ZH607		9 52 2.95	69 20 7.8	19.88	0.51	
ZH348	A84	9 52 19.30	69 12 56.0	18.94	-0.09	H II
P		9 50 43.08	69 21 4.1	19.03	-0.01	H II
Q	ZH501	9 50 27.74	69 20 2.3	18.80	-0.18	H II
T		9 50 35.81	69 17 46.7	18.09	-0.15	H II
V		9 50 41.29	69 17 30.8	18.35	-0.35	H II
ZH394		9 50 34.18	69 19 10.0	18.97	-0.24	H II
ZH1256		9 51 38.84	69 22 10.4	18.90	--	H II

*The type of the object by Humphreys et al. (1986), Humphreys & Aaronson (1987) and Petit et al. (1988):
d - dwarf; sg - supergiant; mult - multiple star;
HII - HII source.

On the colour-magnitude diagrams (Freedman, 1984; Georgiev et al., 1992a,b; Bilkina et al., 1991; Zickgraf and Humphreys, 1991) one can distinctly see the high red star concentration region within V=$19^m_.0$-$19^m_.4$ above which there are practically no red stars. Among the red stars of this group red dwarfs from our Galaxy seem to be present. However, at the Galactic latitude of M81 the dwarf density is low (Georgiev et al., 1992b), so the existence of this stellar group can hardly be explained by them only. Another high concentration red star region, which has no strict upper limit, begins at V=$20^m_.5$. It is precisely where S48 is, the brightest of the proved red supergiants in M81 with V=20^{m}.53 (Sandage, 1984).

Table 2. Red supergiant candidates.

N	N	α(1950)	δ(1950)	V	(B-V)	type*
S14	ZH786	9 51 33.76	69 25 10.4	20.79	1.78	
S26	ZH632	9 51 50.74	69 22 58.8	21.43	1.78	
S36		9 52 6.80	69 21 22.0	21.19	1.92	
S44	ZH1241	9 52 3.65	69 19 31.4	19.84	1.70	d
S45		9 52 4.67	69 19 25.8	19.89	2.27	d
S48	ZH587	9 52 27.67	69 19 30.9	20.53	1.91	sg
S52		9 52 12.51	69 17 17.4	20.29	1.74	d
S70		9 51 58.93	69 11 51.5	20.88	1.78	
S74	ZH341	9 52 19.00	69 10 52.8	21.11	1.59	
S84	ZH220	9 51 35.24	69 9 29.8	20.13	1.98	d
S85	ZH215	9 51 35.63	69 8 52.4	20.72	1.96	
S96		9 50 59.09	69 13 35.5	19.99	1.94	d
S103	ZH379	9 50 43.53	69 15 45.6	20.70	2.14	sg
S132	ZH673	9 50 43.82	69 23 31.0	21.30	1.67	
S142		9 51 21.30	69 22 49.0	20.96	2.31	
S152		9 50 57.67	69 21 46.2	20.43	1.78	
S155	ZH669	9 50 57.70	69 24 10.5	20.93	2.13	
S156	ZH1261	9 51 0.09	69 23 30.1	21.09	2.41	sg
A1		9 50 49.01	69 13 26.3	19.63	1.60	
A2		9 50 50.48	69 13 26.5	19.31	1.61	
A6		9 51 30.59	69 14 51.0	19.34	1.70	
A14		9 51 5.38	69 16 29.7	19.58	2.28	
A16	ZH491	9 50 50.28	69 19 6.0	19.13	1.94	
A23		9 50 42.01	69 21 26.0	19.22	1.91	
A89		9 52 30.34	69 16 19.4	19.32	1.65	
E34		9 53 5.55	69 15 54.4	19.80	1.93	
E43		9 53 54.87	69 19 46.5	19.55	1.90	
E44		9 54 0.21	69 15 13.1	18.95	1.99	
E45		9 53 53.61	69 17 29.5	19.81	1.79	
E46		9 53 49.87	69 17 42.5	20.08	1.97	
E49		9 53 42.20	69 16 30.1	19.99	2.01	
E60		9 53 15.01	69 13 15.9	20.05	1.96	
E62		9 53 18.77	69 12 31.0	19.67	2.10	
E107		9 54 0.89	69 18 5.8	19.61	2.19	
NE48		9 52 24.31	69 33 18.0	19.31	2.01	
NE51		9 52 49.16	69 36 48.0	19.52	1.92	
NE56		9 53 9.04	69 36 2.6	19.37	1.66	
NW39		9 50 9.61	69 26 22.3	19.27	1.81	
NW40		9 50 20.11	69 26 23.3	19.27	1.76	
W7		9 48 57.58	69 10 31.8	19.14	1.81	
W15		9 49 18.80	69 13 4.7	18.53	1.71	
W44		9 49 4.33	69 9 25.6	19.18	1.86	
W57		9 50 23.76	69 8 3.2	19.09	1.91	
W74		9 49 40.61	69 17 8.7	19.57	2.06	
BGG61		9 51 14.85	69 8 37.2	19.35	1.75	
ZH759		9 52 22.62	69 22 12.0	19.21	1.32	
ZH753		9 51 52.94	69 24 34.4	19.63	1.12	
ZH1284		9 51 58.48	69 23 33.2	19.94	--	
ZH1172		9 51 55.34	69 12 11.5	20.02	--	
ZH1207		9 52 8.89	69 15 43.3	20.38	--	
ZH1264		9 51 5.33	69 25 9.8	20.46	--	
ZH1258		9 51 13.98	69 22 49.2	20.66	--	
ZH1179		9 50 37.31	69 17 37.9	20.90	--	

*See the remarks after Table 1.

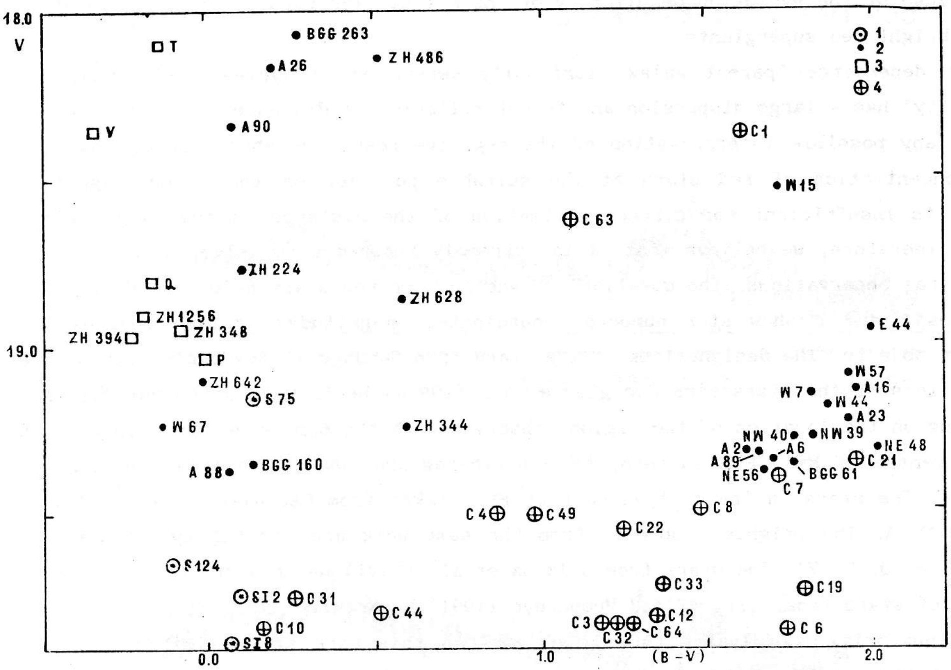

Fig. 1. *Color-magnitude diagram for the brightest objects:*
1 - confirmed blue supergiants; 2 - blue and red supergiant candidates;
3 - HII-sources; 4 - globular cluster candidates.

It should be noted that the advanced theoretical and observational data evidence that there is a certain upper limit to the absolute magnitude of red supergiants located within $-8^{m}.0$ - $-9^{m}.0$. So, in case of a large galaxy, such as M81, one can expect that on the colour-magnitude diagram there is a certain limiting magnitude, below which the high red star concentration should be observable. In this sense, the aforementioned group of 14 red stars is the only one possible of the brightest red supergiant candidates in M81.

If real supergiants of M81 are found among these stars, then it will be an important confirmation of the fact that the red supergiant candidates can be used as distance indicators for the large spiral galaxies, since the data on M101 are apparently less reliable. But if it appears that none of the stars of this group belong to M81, then there are several possible explanations to this fact:

1) In the direction of M81 or in the galaxy itself there is light absorption with $A_v \approx 1^{m}.0$. However the stellar photometry results of some papers give no confirmation to this presumption.

2) M81 is located farther than it is believed to be today, but this is inconsistent with the distance to the galaxy estimated from cepheids (Freedman and Madore, 1988) and from planetary nebulae (Jakoby et al., 1989).

3) Because of the evolution peculiarity of the M81 stellar population. at present it has no bright red supergiants.

4) The dependence "parent galaxy luminosity versus its brightest red supergiant luminosity" has a large dispersion and is not reliable for distance determination.

With any possible interpretation of the negative result we should infer that the high concentration of red stars at the suitable position on the colour-magnitude diagram is insufficient for correct estimation of the distance to the large spiral galaxy. Therefore, we believe that it is extremely important to solve, with the help of spectral observations, the question, of whether our red stars belong to M81.

Tables 1 and 2 show star numbers, coordinates, magnitudes, colour indices and types of objects. The designations of the stars from Sandage (1984) begin with S. The designations of the stars from Georgiev et al. (1992a) begin with different letters, depending on the location of the regions observed with the 6 m telescope with respect to the centre of M81 (E - eastern, NE - north-eastern, NW - north-western and W - western). The stars in the central part of M81, taken from Georgiev et al. (1992b), begin with A. The brightest objects from the same work are denoted by the letters only (J, P, Q, T, V). The stars from Bilkina et al. (1991) begin with BGG. The designations of stars from Zickgraf and Humphreys (1991) begin with ZH.

The equatorial coordinates for all objects in this work are estimated from the plates of the 2 m RC telescope of Bulgarian National Observatory (Rozhen) and 1 m RC telescope of the Special Astrophysical Observatory of Russian AS. The astrometry is based on the five stars from the Smithsonian Catalogue (SAO). The root-mean-square error in estimating the star coordinates is $1\overset{''}{.}2$. The standard error obtained by comparing the coordinates of twelve stars measured from the plates of the 2 m and 1 m telescopes is $\approx 1''$.

The photometry of Sandage's stars (1984) and our supergiant candidates was carried out in the above-mentioned papers. The M81 brightest star candidates selected by Zickgraf and Humphreys (1991), which are not available in the other papers, are added with their magnitudes. Furthermore, at the end of Table 1, there are several blue starlike objects which are identified with compact HII-sources (Petit et al., 1988).

2. GLOBULAR CLUSTER CANDIDATES OF M81

Together with the investigation of the M81 brightest supergiant candidates we have found and made the photometry of its globular cluster candidates (GCC). When their relation to globular clusters is proved, they can be used for estimating the mass of M81 and also for calibrating the globular cluster absolute magnitudes as distance indicators.

The major results on the M81 globular cluster candidates are presented in Georgiev et al. (1991 a, b), where are presented the magnitudes and colours for 60 such objects. In this paper five more globular cluster candidates (C61 - C65) located in the southern periphery of M81 are added. They have been found and investigated photometrically on the plates of the 2 m telescope, beyond the fields of the 6 m telescope, the plates of which have been used earlier for search for globular cluster candidates. The location of globular cluster candidates of M81 is shown in Georgiev et al. (1991, 1992 a,b).

On the colour-magnitude diagram (Fig. 1) there are the M81 brightest globular cluster candidates with $V<20^m$. Taking into account the distance modulus and the light absorption value in the direction of M81 the mean absolute magnitude of its two brightest globular cluster candidates (C1 and C63) is estimated to be $-9\overset{m}{.}3$. These two objects stand out in brightness among other globular cluster candidates. The similar thing is observed in M33, where the group of six brightest globular clusters is noticeably brighter than other globular clusters. No analogues to the brightest globular clusters (such as ω Cen in the Milky Way) with $M_v<-10^m$ are found in M81. One of the possible explanations of this fact is the extreme compactness of bright clusters. With such a great distance to M81 and the scale 16″/pc they are not distinguished against background stars.

The M81 system of globular cluster candidates looks, on the whole, fainter and redder than it was expected. It can be explained (partially) by systematic errors in the stellar magnitude scale and in the iris photometry, as diffuse objects are compared with stellar ones (Georgiev et al., 1991b). Other possible explanations, such as the high absorption in the direction of M81 or large distance to M81 do not agree with observational data (see Section 1). It is also possible that the system of globular (i.e. old) clusters of M81 differs considerably from the systems of globular clusters of the Milky Way and M31, but this is less probable.

To find real globular clusters in M81 and also to clarify their nature, systematic spectral observations are needed. Brodie and Huchra (1991) report on the observations of some globular cluster candidates in M81, however they present neither coordinates nor finding charts of these objects. To help the obervers in future, in this paper we present the coordinates, magnitudes and colour indices and morphological classes of M81 globular cluster candidates (Table 3) (Georgiev et al., 1991a,b). The finding charts are given in our earlier papers (Georgiev et al., 1992a,b). The globular cluster candidates (GCC) are denoted by C. The coordinates were estimated together with the coordinates of stars presented in Tables 1 and 2. The brightest globular cluster candidates are also designated on the colour-magnitude diagram (Fig. 1).

Table 3. Globular cluster candidates.

N		α(1950)	δ(1950)	V	(B-V)	class*
C1		9 52 45.00	69 12 3.8	18.36	1.60	A
C2		9 53 0.51	69 16 36.9	20.42	1.19	B
C3		9 52 31.81	69 15 59.8	19.82	1.16	A
C4		9 53 24.38	69 19 21.4	19.50	0.85	A
C5		9 53 12.84	69 18 49.8	20.71	0.83	B
C6		9 52 56.62	69 18 3.1	19.85	1.74	A
C7		9 52 51.83	69 18 56.8	19.39	1.70	B
C8		9 52 59.09	69 21 38.6	19.49	1.47	A
C9		9 53 30.08	69 21 47.3	20.97	0.46	B
C10	ZH600	9 52 20.00	69 21 40.1	19.84	0.16	A
C11		9 53 30.31	69 26 10.1	19.98	1.18	A
C12		9 53 46.05	69 27 50.5	19.80	1.34	A
C13		9 53 36.48	69 34 13.2	20.41	0.97	A
C14		9 53 0.19	69 28 25.4	20.89	0.81	B
C15		9 52 56.98	69 27 36.9	20.47	0.91	B
C16		9 52 42.90	69 26 57.3	20.40	0.92	B
C17		9 52 27.96	69 25 43.1	19.92	0.97	A
C18		9 52 13.65	69 25 55.6	19.97	1.38	A:
C19		9 52 3.03	69 26 58.6	19.78	1.73	B:
C20		9 50 43.93	69 29 58.3	20.22	0.86	A
C21		9 50 44.17	69 33 55.3	19.34	1.94	A
C22		9 50 24.33	69 32 59.2	19.55	1.24	A
C23		9 50 5.55	69 35 47.7	--	--	A
C24		9 49 6.99	69 30 46.5	20.57	0.15	A
C25		9 49 26.73	69 29 28.0	19.92	0.83	B
C26		9 48 24.84	69 26 6.4	--	--	A:
C27		9 47 51.92	69 23 58.3	--	--	A:
C28		9 49 40.43	69 21 30.1	20.28	1.17	B
C29		9 50 9.10	69 24 59.3	20.60	1.19	B
C30		9 49 45.58	69 19 24.6	20.18	1.40	B
C31		9 50 11.99	69 16 54.9	19.75	0.25	A
C32		9 50 19.71	69 16 33.1	19.83	1.21	A
C33		9 50 4.28	69 16 16.2	19.72	1.35	A
C34		9 49 32.91	69 14 52.8	20.24	1.24	B
C35		9 49 28.14	69 12 31.4	20.76	0.86	B
C36		9 50 21.90	69 12 12.3	20.21	0.45	A
C37		9 50 14.93	69 11 25.8	20.21	1.33	B
C38		9 50 8.85	69 9 49.5	20.57	1.47	B
C39		9 50 45.22	69 14 17.6	20.26	0.94	A
C40		9 51 6.64	69 15 52.9	20.72	0.80	B
C41		9 50 59.89	69 14 0.9	20.45	1.16	A
C42		9 51 32.19	69 13 29.8	20.68	0.50	A
C43		9 52 12.62	69 13 31.4	20.51	0.59	B
C44	ZH479	9 52 15.14	69 17 1.9	19.80	0.51	A
C45		9 51 50.24	69 21 46.5	20.54	0.86	B
C46		9 52 3.91	69 22 30.8	20.43	0.78	B
C47		9 50 44.47	69 22 0.2	20.35	1.29	B
C48		9 50 33.25	69 17 36.2	20.12	1.04	A
C49		9 51 2.65	69 20 2.1	19.51	0.97	A
C50		9 51 0.58	69 20 37.6	20.46	0.21	B
C51		9 51 1.69	69 21 7.5	20.66	0.78	B
C52		9 51 11.19	69 21 4.0	21.06	1.19	B
C53		9 51 42.86	69 19 33.9	--	--	B
C54		9 51 52.79	69 17 47.8	20.90	1.02	B
C55		9 51 43.63	69 15 27.0	--	--	A

Table 3 (continued)

N	α(1950)	δ(1950)	V	(B-V)	class*
C56	9 51 9.12	69 19 34.7	20.15	1.03	B
C57	9 51 9.34	69 19 58.5	--	--	A
C58	9 51 24.97	69 20 13.7	--	--	A
C59	9 51 30.15	69 20 8.3	--	--	A
C60	9 51 33.36	69 19 44.2	--	--	A
C61	9 51 43.80	69 10 46.4	19.96	1.35	A:
C62	9 51 53.79	69 5 16.9	20.20	1.11	B:
C63	9 52 14.05	69 3 56.3	18.63	1.08	A:
C64	9 52 57.42	69 11 7.2	19.83	1.26	A:
C65	9 50 47.06	69 6 18.9	19.97	1.03	A:

*The morphologic class of the cluster by Georgiev et al., (1991b)

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