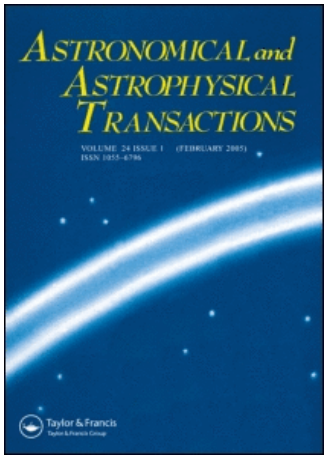

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Ts. B. Georgiev [a]; N. A. Tikhonov [b]; I. D. Karachentsev [b]
[a] Department of Astronomy and National Astronomical Observatory of the Bulgarian Academy of Sciences, Sofia, Bulgaria
[b] Special Astrophysical Observatory of the Russian Academy of Sciences, Russia

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BRIGHTEST STAR CLUSTER CANDIDATES IN EIGHT LATE-TYPE GALAXIES OF THE LOCAL COMPLEX

Ts. B. GEORGIEV[1], N. A. TIKHONOV[2], and I. D. KARACHENTSEV[2]

[1] *Department of Astronomy and National Astronomical Observatory of the Bulgarian Academy of Sciences, Sofia 1784, Bulgaria*
[2] *Special Astrophysical Observatory of the Russian Academy of Sciences, Stavropol Territory, 357147, Russia*

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The magnitudes and colors of 48 star cluster candidates in the galaxies NGC 1560, IC 10, UGCA 86, UGCA 105, DDO 165, Ho I, Ho II and Ho IX are obtained from the plates taken at the 6-m telescope. From 3 to 11 such objects are found in each galaxy. The distribution of all cluster candidates on the color – absolute magnitude diagram is close to the distribution of the LMC clusters. Depending on the luminosity, three groups of objects are distinguished – very bright, bright and of intermediate brightness. Their absolute magnitudes are about –10, –9 and –8 mag, respectively. By the colors, i.e. by the age, three groups of the objects are revealed too - young, intermediate and old. In the galaxies Ho I and DDO 165, old (globular) cluster candidates are not found.

KEY WORDS The Local complex, late-type galaxies, star clusters

1 INTRODUCTION

In recent 10–15 years, owing to the progress of star clusters studies in the galaxies M31 (Battistini *et al.*, 1987), M33 (Cristian and Schommer, 1988) and Magellanic Clouds (van den Bergh, 1991), it has been revealed that star clusters in other galaxies are represented by a wider variety of types than in our Galaxy. For instance, intermediate type star clusters were found in LMC – between classical globulars and open clusters. Size, age and photometric characterictics of the clusters are essentially different in various galaxies, and therefore new observations are needed to specify statistical regularites.

If to mean the possible use of clusters to determine the dynamical mass of the galaxies and also for the study of star formation and parent galaxy evolution history (see Hodge 1988, 1991), the necessity of cluster study in different type galaxies becomes clear.

Brightest star clusters may be used for distance estimation in the Local Complex galaxies. With absolute magnitudes brighter than −10 mag and diameters up to 100 pc, giant star clusters must be distinguishable among stars by their non-stellar profile at distances up to 6–8 Mpc. Unfortunately, modern data on the upper end of star cluster luminosity function and on its universal application are not reliable yet. Therefore we started systematical star cluster search beyond the Local Group of galaxies using 6-meter telescope plates.

Selection of a cluster candidate by its morphology and color does not solve the question of its nature decidedly. Among reddish objects distant galaxies are found, while compact HII regions are among blue ones. It is clear that, because of indefinite conclusions, the task of cluster search out of the Local Group of Galaxies is highly inattractive. However, cluster candidate selection using large scale photographs seems to be the first obligatory step, after which regular photometric and spectral observations can be made.

In the northern sky, globular cluster candidates out of the Local Group of galaxies were first studied in NGC 2403 (Battistini *et al.*, 1984). In our previous papers (Georgiev *et al.*, 1991a, b; 1993) we published magnitudes and colors of globular cluster candidates of four galaxies belonging to the M81 – IC 342 complex: M81, NGC 2366, IC 2574 and NGC 4236. In the present paper, cluster candidates in eight galaxies are collected. We not only searched for old (globular) clusters, but also selected blue objects which satisfied our requirements by their morphological types.

2 THE OBSERVATIONAL MATERIAL AND ITS REDUCTION

The search was made on B and V plates of the 6-meter telescope using the morphological criteria described by Georgiev *et al.* (1991a). Photometry was made with the microdensitometer using the approach of Tikhonov *et al.* (1991). The data of the plates, the light absorption assumed in the directions of various galaxies and the distance moduli were published in our previous papers, where brightest star photometry was carried out and distances to the galaxies were estimated: for HoIX –

Table 1. Data about of the galaxies

galaxy	$E(B-V)$	Av	$m-M$
Ho IX	0.07	0.23	27.67
NGC 1560	0.14	0.45	27.92
DDO 165	0.08	0.25	29.11
Ho II	0.09	0.28	27.78
Ho I	0.08	0.25	29.11
UGCA 105	0.32	1.03	27.60
IC 10	0.87	2.78	25.10
UGCA 86	0.90	2.90	26.30

Table 2. Magnitudes and colors of the cluster candidates

No.	*V*	*B − V*	*class**	*No.*	*V*	*B − V*	*class**
	Ho II			C6	20.47	0.18	B
C1	20.03	0.82	B	C7	21.09	0.18	B
C2	19.57	1.19	A		DDO 165		
C3	19.78	0.0	B	C1(9)	18.89	0.47	A
C4	20.08:	0.96:	B	C2(13)	19.34	0.37	A
C5	19.52	0.03	A	C3(25)	19.89	0.25	B
C6	19.11:	1.13	A		Ho I		
C7	20.26	1.14	B	C1(11)	21.05	0.09	B
C8	19.95	0.52	A	C2(17)	21.33	0.22	B
C9	18.44	1.29	A	C3(18)	20.37	0.50	B
C10	18.38	1.20	A		Ho IX		
	NGC 1560			M81-C4	19.50	0.85	A
C1	20.26	0.69	A	M81-C2	20.42	1.19	B
C2	20.46	0.52	A	HoIX-10	20.51	0.25	B
C3	19.24	0.36	B		IC 10		
C4	19.15:	1.10:	A	C1**	19.24	1.17	A
C5	19.92	0.16	B	C2	18.95	0.93	A
C6	20.02	−0.02	A	C3	20.07	0.80	A
C7	20.32	−0.24	B	C4	19.19	0.73	A
C8	20.51	0.02	B	C5	17.72	1.18	A
C9	20.28	0.57	A	C6	20.03	0.63	A
C10	20.46	0.67	B	C7	20.38	1.44	A
C11	19.10	1.15:	A		UGCA 86		
	UGCA 105			C1(C)	19.25	1.13	A
C1	19.46	1.18	A	C2***	21.32	1.30	A
C2	19.40	0.95	A	C3(24)	21.31	0.66	A
C3	21.13	0.02	B	C4(29)	18.96	1.83	A
C4	20.88	0.13	B	nuc(25)	19.59	0.58	A
C5	20.87	0.28	B				

Note. *The morphological class of the cluster according to Georgiev *et al.* (1991a).
**Located at 25" to the west and 45" to the north from the star No. 3 of Karachentsev & Tikhonov (1992).
***Located at 20″ to the north–east from the cluster C3.

Georgiev *et al.* (1991), for NGC 1560 and DDO 165 – Karachentsev *et al.* (1991), for Ho II, Ho I and UGCA 105 – Tikhonov *et al.* (1992) and for IC 10 and UGCA 86 – Karachentsev and Tikhonov (1992). In Table 1 the data on galaxies studied in the present paper are summarized.

The limiting magnitude of the search depends on the plate quality. Therefore some even relatively bright compact objects may be omitted on low-quality plates. Given the fact that old clusters may not necessarily be present in some galaxies, we extended the color criteria for the selected candidates, allowing $B - V$ to be negative.

Photometric results with the standard error 0.1 mag are summarized in Table 2. In brackets is given the designation of the object from the previous paper if it was not distinguished there as a cluster. The star cluster candidate locations for

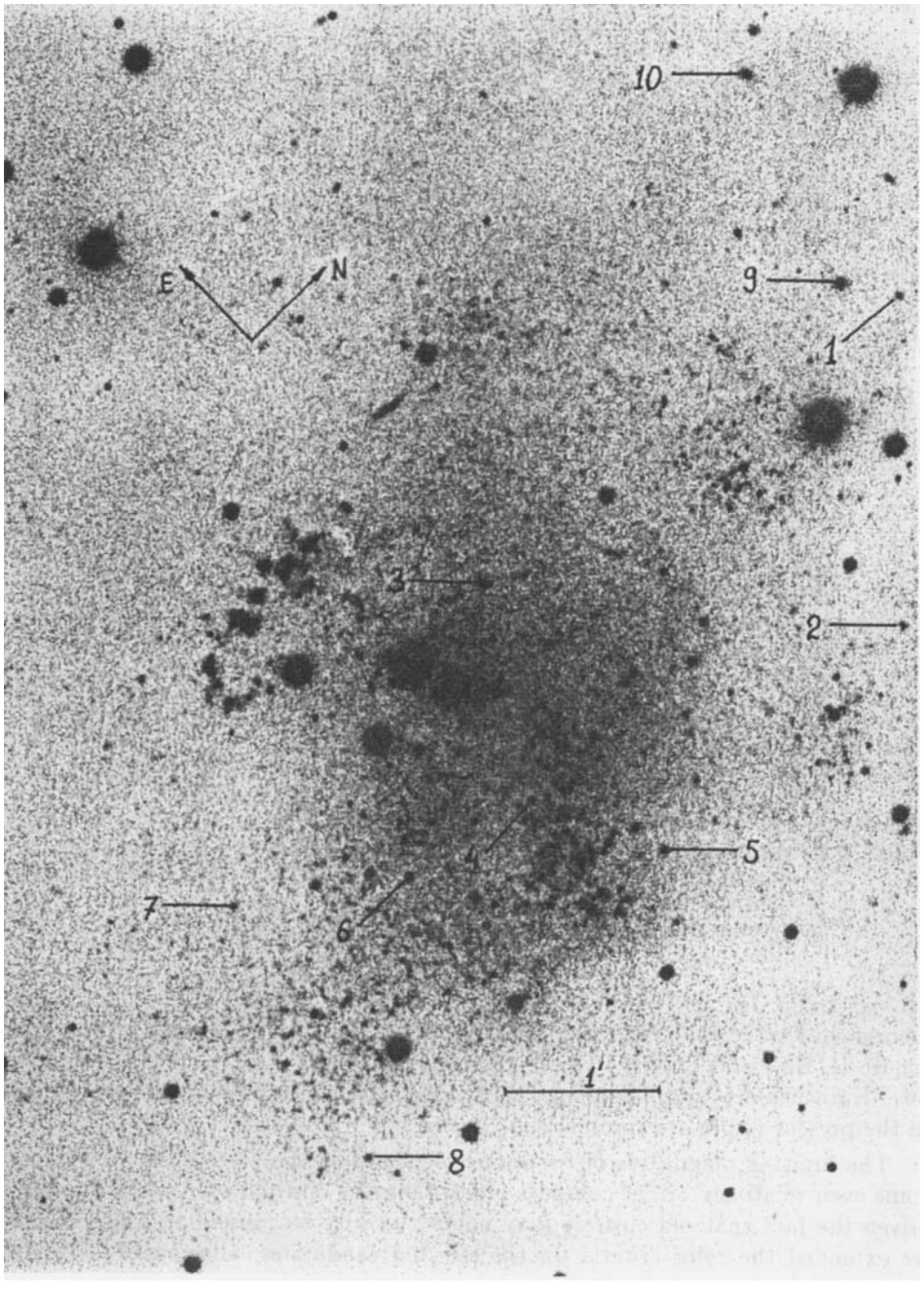

Figure 1 Finding chart of the globular cluster candidates in the galaxy Ho II printed from the *B* plate of the 6-m telescope.

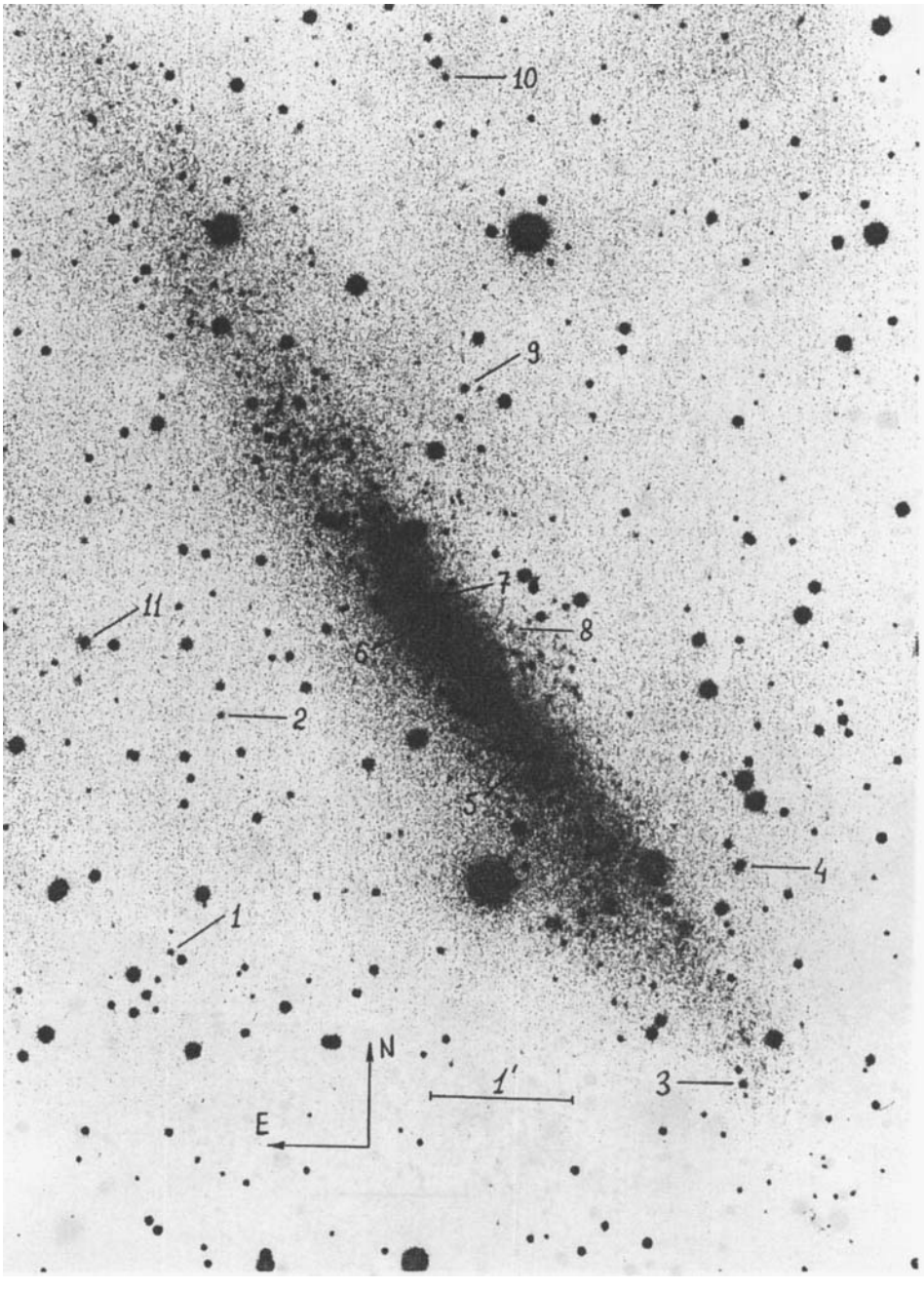

Figure 2 Finding chart of the globular cluster candidates in the galaxy NGC 1560 printed from the V plate of the 6-m telescope.

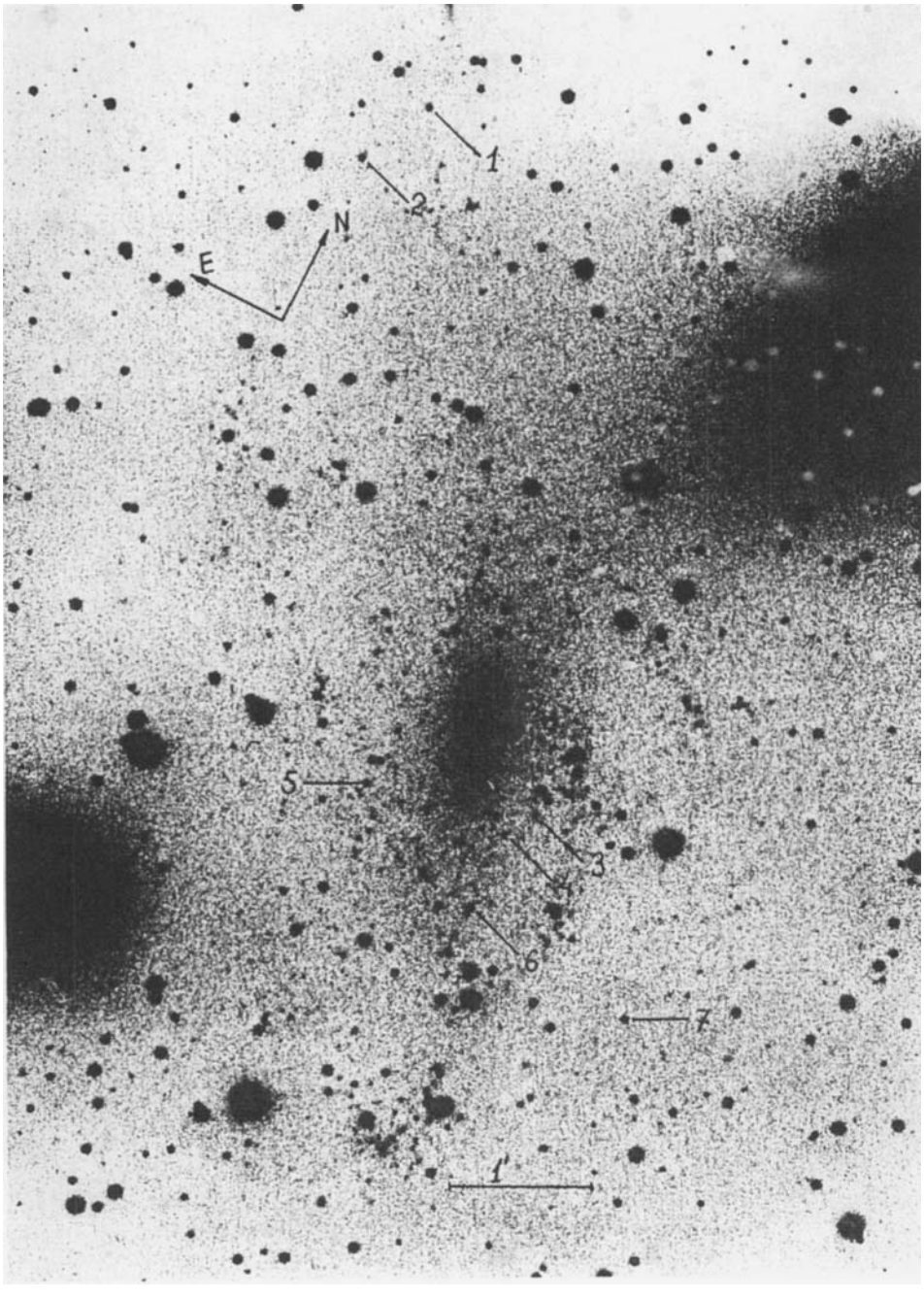

Figure 3 Finding chart of the globular cluster candidates in the galaxy UGCA 105 printed from the B plate of the 6-m telescope.

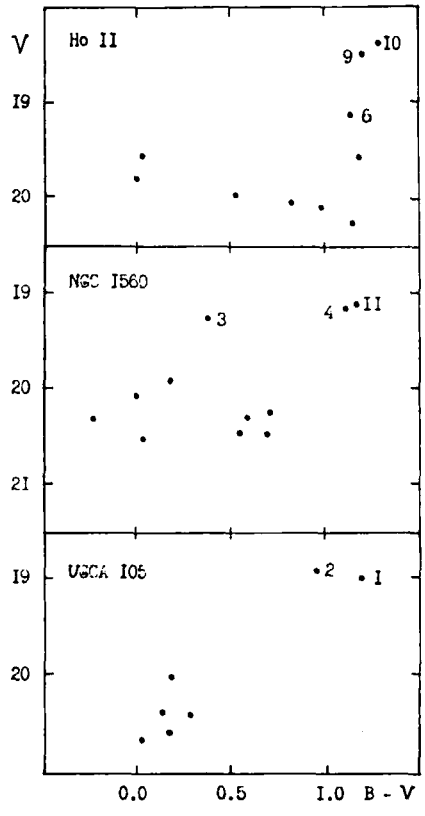

Figure 4 The color-magnitude diagrams of star cluster candidates in the galaxies Ho II, NGC 1560 and UGCA 105.

the galaxies Ho II, NGC 1560 and UGCA 105 are shown in Figures 1, 2 and 3, respectively.

3 RESULTS

In Figure 4 the color-magnitude diagrams are shown for the star cluster candidates in the galaxies Ho II, NGC 1560 and UGCA 105. It is clearly seen that two or three objects in each galaxy are significantly different from the rest because of their brightness. Star cluster candidates are well distinguished also by color, falling into at least two groups. We note that the galaxy UGCA 105 is observed under conditions of stronger light absorption in the Milky Way (see Table 1) which notably influences its star cluster candidates diagram.

In Figure 5 the selected star cluster candidates of the dwarf galaxies Ho IX, Ho I and DDO 165 are compared in the same way. Three such brightest objects are

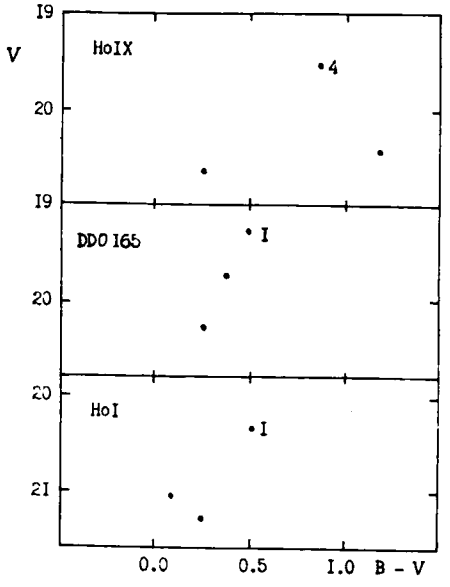

Figure 5 The color-magnitude diagrams of the star cluster candidates in the galaxies Ho IX, Ho I and DDO 165.

selected in each of them. In these comparatively small irregular galaxies traces of recent star formation bursts are clearly seen. Two reddish objects, marked by us as globular cluster candidates in the M81 galaxy (Georgiev *et al.*, 1991a, b) are located near Ho IX. Of course, it is not clear whether they are belong to this galaxy. In the rest two galaxies there are evidently no old clusters.

In Figure 6 the color-magnitude diagram of cluster candidates in the galaxies IC 10 and UGCA 86 is presented. If follows from the stellar photometry of Karachentsev and Tikhonov (1992) that the first of them is a M31 satellite, and the second one is a satellite of IC 342. They both are observed through the disk of the Milky Way, with a color excess of about 0.9 mag (see Table 1). This strongly affects the appearance of their cluster candidate diagrams. The lowest color index object (the UGCA 86 nucleus candidate) does not look blue. In these nearest galaxies of our sample more clusters must be observed, but because of the Milky Way absorption they are not clearly seen. We managed to find only 12 cluster candidates in them, three of which are noteable for their high brightness.

In Figure 7 a summary diagram "improved color index – absolute stellar magnitude" is presented for all the clusters mentioned in this paper. To calculate appropriate colors and magnitudes, the data on the cluster candidates from Table 2 and on the galaxies from Table 1 were used. It can be seen from the diagram that the cluster candidates can be divided into two groups by brightness and into two groups by color. A deficiency of cluster candidates is found in the brightness band M -8.3 – -8.7 mag, which is extends along the whole range of the color index values. The brightest objects can be divided into young ones, with $(B-V) < 0.5$ and old ones,

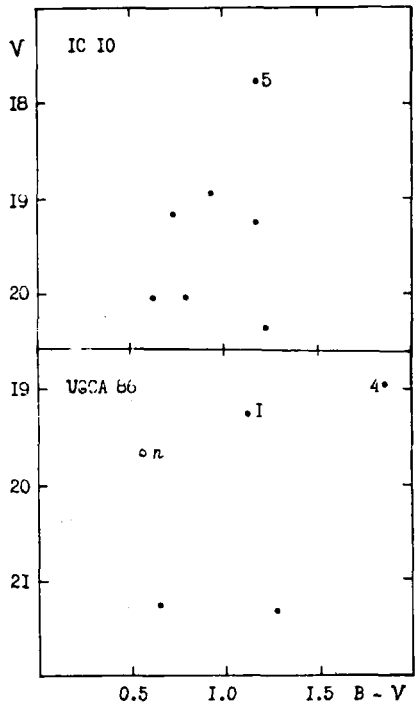

Figure 6 The color-magnitude diagrams of the star cluster candidates in the galaxies IC 10 and UGCA 86.

with $(B-V) > 0.6$. Among fainter objects, only young ones are distinguished and there are practically no old ones, cluster candidate group of intermediate age being notable with $(B-V) = 0.3$–0.5.

Seven brightest cluster candidates, with absolute magnitudes –10 mag, require some special attention. Among them there are three from Ho II (#10, 9 and 6), two from UGCA 86 (#1 and 4) and two from IC 10 (#5) and DDO 165 (#1). Evidently, analogs of the brightest Milky Way clusters, ω Cen, may be present among these objects. About five such clusters are known in M31 and one, similar in brightness, though a young one, is remarkably notable in LMC.

In Figure 8 cluster candidate distribution according to absolute values (Figure 8*a*) and corrected color indices (Figure 8*b*) are given. The distributions are built with the steps 0.25 and 0.10 mag and the count intervals 0.5 and 0.2 mag, respectively. For comparison, the same distributions for LMC (van den Bergh, 1981) and M33 (Christian and Schommer, 1987) are presented, with allowance for the newest distance and light absorption data in the direction of M33 (Freedman *et al.*, 1991). As follows from the above papers, LMC and M33 cluster distributions are very similar having bright, intermediate and faint cluster groups, with absolute star magnitudes about –9, –8 and –7 mag, respectively. However, LMC is well known to be rich of the clusters of all types, especially young ones, and also to host very

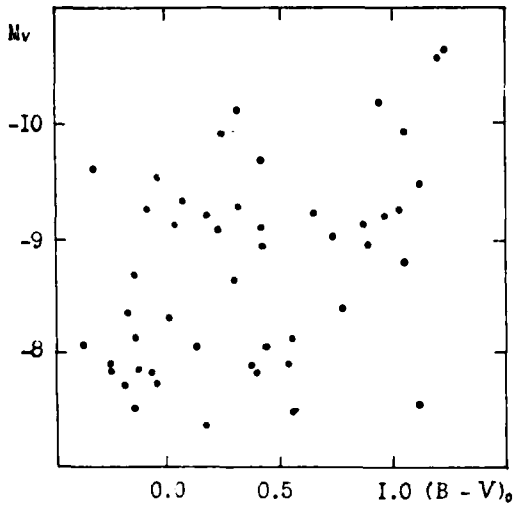

Figure 7 The true color – absolute magnitude diagram of all star cluster candidates of the present work.

bright clusters, young and old, whose analogs in M33 are not found. The absolute magnitudes of these objects are -10 – -11 mag.

In the brightness distribution of our objects (Figure 8*a*), two maxima can be seen. They can be compared with the cluster groups of high and intermediate brightness in LMC and M33. The brightest cluster candidates, both young and old, are similar to the corresponding LMC clusters.

In Figure 8*b*, color distributions are presented for LMC and M33 clusters and the objects discussed in this paper. It can be seen that LMC is remarkably rich in young clusters. In this galaxy, contrary to M33, there are practically no clusters of intermediate age. Various types of the distribution are probably caused by individual peculiarities of star formation in the galaxies.

4 CONCLUSION

Our results indicate that a number of real star clusters can be present among the objects selected as galactic star cluster candidates out of the Local Group. Their brightness and color distributions are similar to those of LMC and M33 star clusters (see Figure 8). This implies that photometry of the brightest clusters can be used to draw preliminary conclusions on star formation history in their parent galaxies.

In the absolute stellar magnitude distribution of all the objects selected (Figure 8*a*), concentration near two define brightness values is notable. This divides them into the groups of bright and moderately bright (intermediate) objects. Besides, a small group of very bright objects can be distinguished. Undoubtedly, the peculiarities of the absolute magnitude distribution of the cluster candidates, also

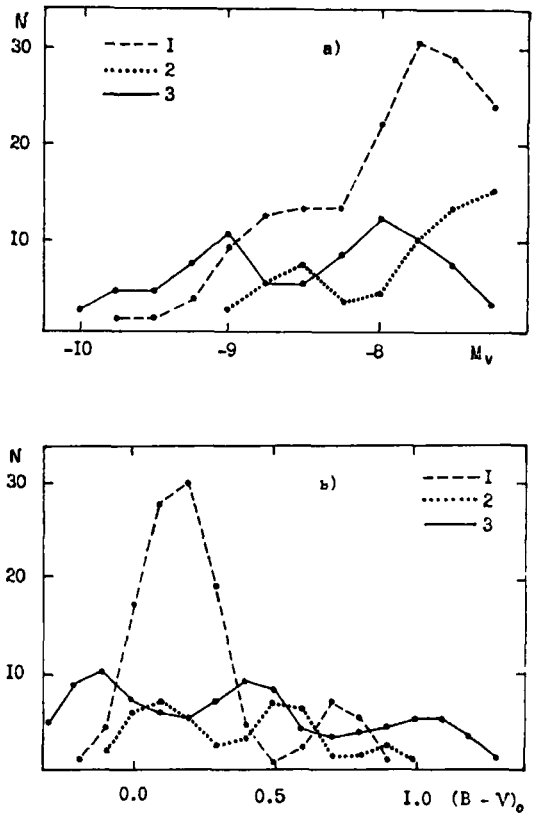

Figure 8 The distributions of the star clusters of LMC (1), M33 (2) and the star cluster candidates of the present work (3) in absolute magnitude (*a*) and true color (*b*).

observed in similar LMC cluster distribution, should be taken into account when using stellar clusters as distance indicators.

Further study of the objects selected with the help of spectral observations seems to us an important task.

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