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LOBULAR CLUSTER CANDIDATES IN THE GALAXIES NGC 2366, IC 2574 AND NGC 4236

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Magnitudes and colors of 30 star cluster candidates in three galaxies of the complex M81 – IC 342 are given, obtained from the plates obtained at the 6 m telescope. The color-magnitude diagrams of the cluster candidates are similar to those of the clusters in M33 and LMC. The apparent and absolute magnitudes of the bright cluster candidates in the galaxies studied are about 19.2 and –8.5 mag, respectively. One object in IC 2574 is very bright – its apparent and absolute magnitudes are estimated to be 17.4 and –10.6 mag, respectively.

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

1 INTRODUCTION

A comparison of star clusters in our Galaxy and in the Magellanic Clouds showed their essential differences in size, color and luminosity (van den Bergh, 1991). The difficulties in global characteristics of star cluster determination in various types of galaxies can be resolved by statistics extension of the studied galaxies. Unfortunately, the Local group is limited both in number and type of galaxies and the only way is to study the remote galaxies. A convenient case is the group M81 where the galaxies from large Sb (M81) to dwarf Irr (HoIX) are observed. The distance to the group (3.5 Mpc) allows us to distinguish star clusters from single stars with good atmospheric images on the plates.

Late-type spiral galaxies studied here belong to the group M81 (Sandage and Tammann, 1974; Tikhonov *et al.*, 1991). The distance moduli of NGC 2366, IC 2574 and NGC 4236 are 27.6, 27.8 and 27.4 mag., respectively (Tikhonov *et al.*, 1991). According to Hodge (1988), in the galaxies of similar luminosity ($M \cong -17.0$ mag.) several hundred star clusters can be expected, but there can be only some single

Table 1. The plates used

<i>object</i>	<i>filter</i>	<i>emulsion</i>	<i>exposure (min)</i>	<i>seeing (arcsec)</i>	<i>data</i>
NGC 2366	B	Ila O	20	1.3	22.12.1984
NGC 2366	V	103a D	30	1.4	22.12.1984
IC 2574	B	Ila O	20	2.3	23.12.1984
IC 2574	V	Ila D	40	2.2	25.12.1984
NGC 4236	B	Ila O	25	1.5	3.07.1986
NGC 4236	V	Ila D	40	1.5	3.07.1986

globular clusters (GC) among them. A scattered character of the galaxy IC 2574 allows us to hope to find large star clusters in it, if the general dependence between cluster size and galaxy density (van den Bergh, 1991) is true.

Among all types of star clusters, old globular clusters (GC) similar to the GC in the Milky Way are easiest detected by structure, color and luminosity, therefore such objects – globular cluster candidates (GCC) – we tried to select in the galaxies studied. The same search of GCC in the galaxy M81 allowed us to find and estimate brightness and color for 60 such objects. (Georgiev *et al.*, 1991a and 1991b – there after Paper I and Paper II).

Revealing clusters of other types presents certain difficulties, because it requires spectral observations and images in H_{α} . We note that in the galaxy NGC 2403, a member of the M81 – IC342 complex, 19 GCC were observed (Battistini *et al.*, 1984).

GCC systems of the galaxies studied may be compared to the well studied GC of the LMC and M33 galaxies, as most closely appropriate galaxy types in the Local group. Galactic absorption in the directions of LMC, M33, NGC 2366, IC 2574 and NGC 4236 galaxies is about 0.2 mag. Distance moduli of LMC and M33 are equal to 18.5 mag. and 24.6 mag. (Freedman *et al.*, 1991).

In the papers by van den Bergh (1981) and Christian and Schommer (1988) it is shown that the magnitudes of the brightest old GC of LMC and M33, with $(B-V) > 0.5$, are about 10.2 and 16.2 mag., respectively. Allowing for the distance modulus and galactic absorption, their absolute magnitudes are equal to -8.5 and -8.6 mag., respectively. In M33, contrary to LMC, numerous old GC are also observed, with an average absolute magnitude of its brightest members being about -7.8 mag. LMC, M33 and SMC galaxies also show a large number of young GC with $(B-V) < 0.5$. Their photometric characteristics are changing in less definite limits and, at the M81 group distance, young clusters are practically indistinguishable by color from compact HII regions.

2 DETECTION AND PHOTOMETRY

The 6 meter telescope plates have been used, the data on which are presented in Table 1. The GCC of the galaxies studied are indicated in Figures 1, 2 and 3. (reproductions of B plates). GCC detection was performed visually from the plates

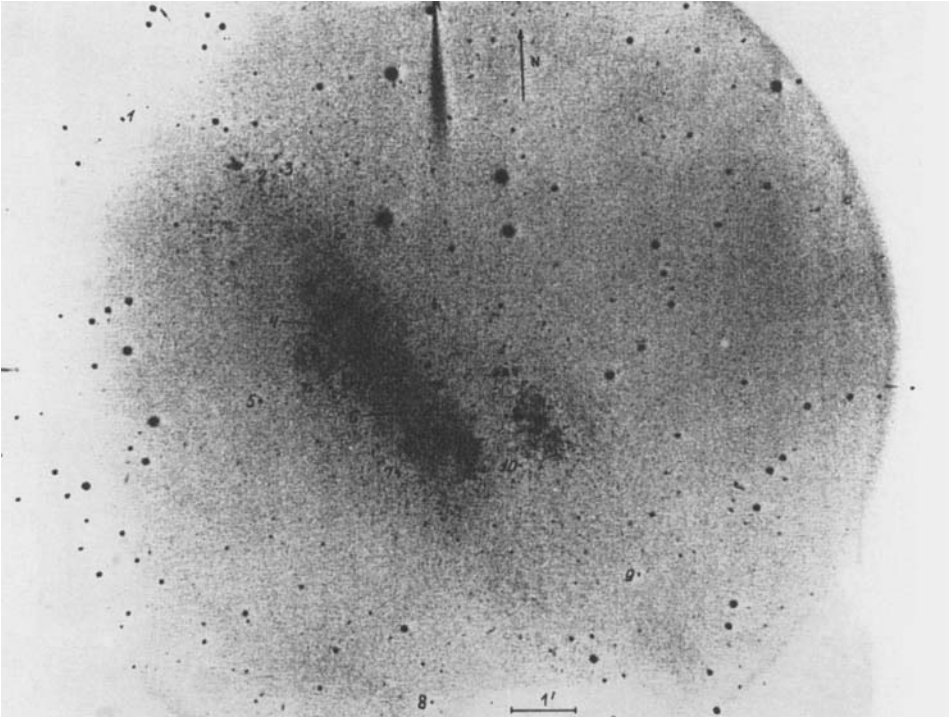


Figure 1 The finding chart of the globular cluster candidates in the galaxy NGC 2366.

and their large scale reproductions. The selection criteria are the same as in our previous papers (Paper I). GCC in NGC 2366 and NGC 4236 are also seen on the appropriate reproductions in the Atlas of Galaxies (Sandage and Bedke, 1988), the galaxy IC 2574 being unfortunately omitted there.

Very blue and red objects, being presumably HII regions, open clusters or distant galaxies were excluded by blinking the band V plates. We retained two such notable objects in the galaxy IC 2574 (#5 and 10) with $(B - V) < 0.5$ and three blue object in the galaxy NGC 4236 (#7, 12 and 13) with $(B - V) < 0.10$, which satisfy completely the applied morphological criteria and are presumably blue GC candidates. Also are marked the objects in the central parts of the galaxies, which are distinct by their blue color and which are likely to be their nuclei.

Most GCC revealed in the present paper are very hard to distinguish from stars, therefore, as in Paper I, we define only two morphological groups - A and B . To class A belong round objects of non-stellar appearance with a wider periphery and lower central density than in the stars with the same brightness. Class B includes GCC with less distinctions from stars than class A objects. It is impossible to establish a strict boundary between the two classes, but we think the probability of real GC to be higher among the class A representatives.

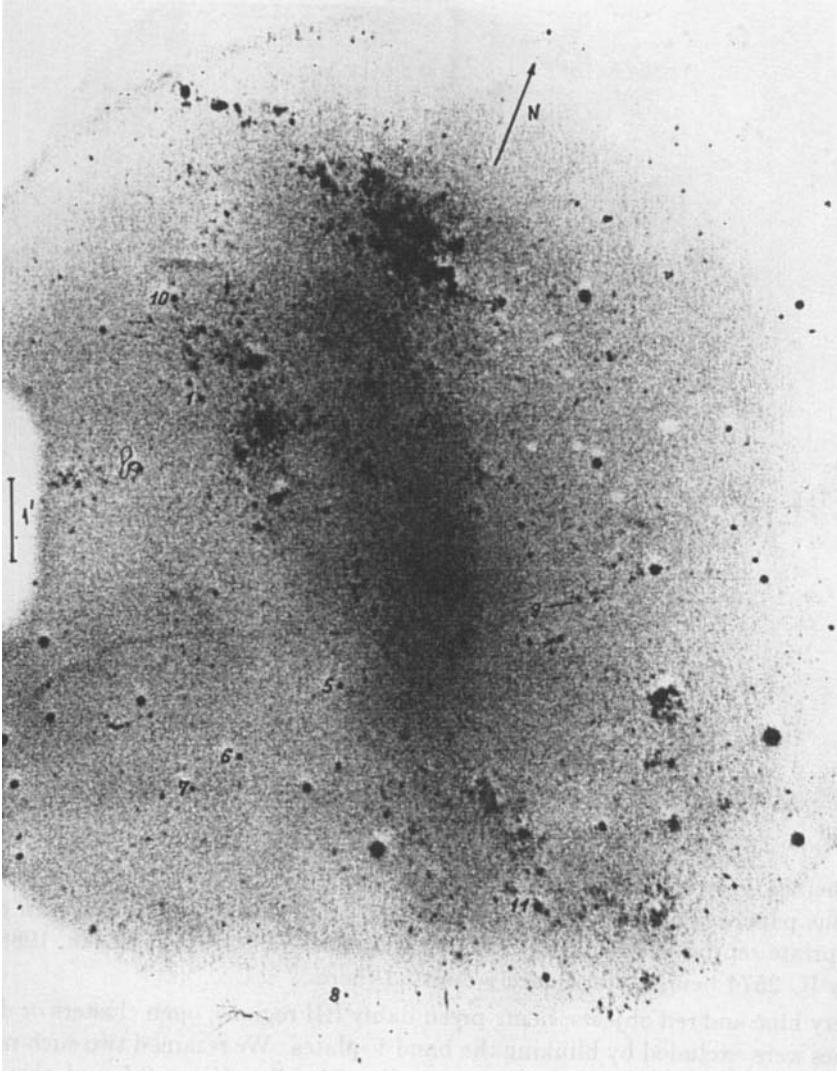


Figure 2 The finding chart of the globular cluster candidates in the galaxy IC 2574.

GCC photometry, as in the case of M81 (Paper II) was carried out with the iris-photometer. The diaphragm used in measuring was $6''$ – $8''$, so that the GCC periphery contribution to the brightness would also be measured. For calibration the stellar photometry of Tikhonov *et al.* (1991) were used. The background nearby stars and GCC were measured and allowed for with the help of a calibration curve. The internal rms photometry error is estimated by us as about 0.2 mag. We note that GCC #10 and #11 in NGC 2366 correspond to the objects #43 and #61 in Table 3 of Tikhonov *et al.* (1991).

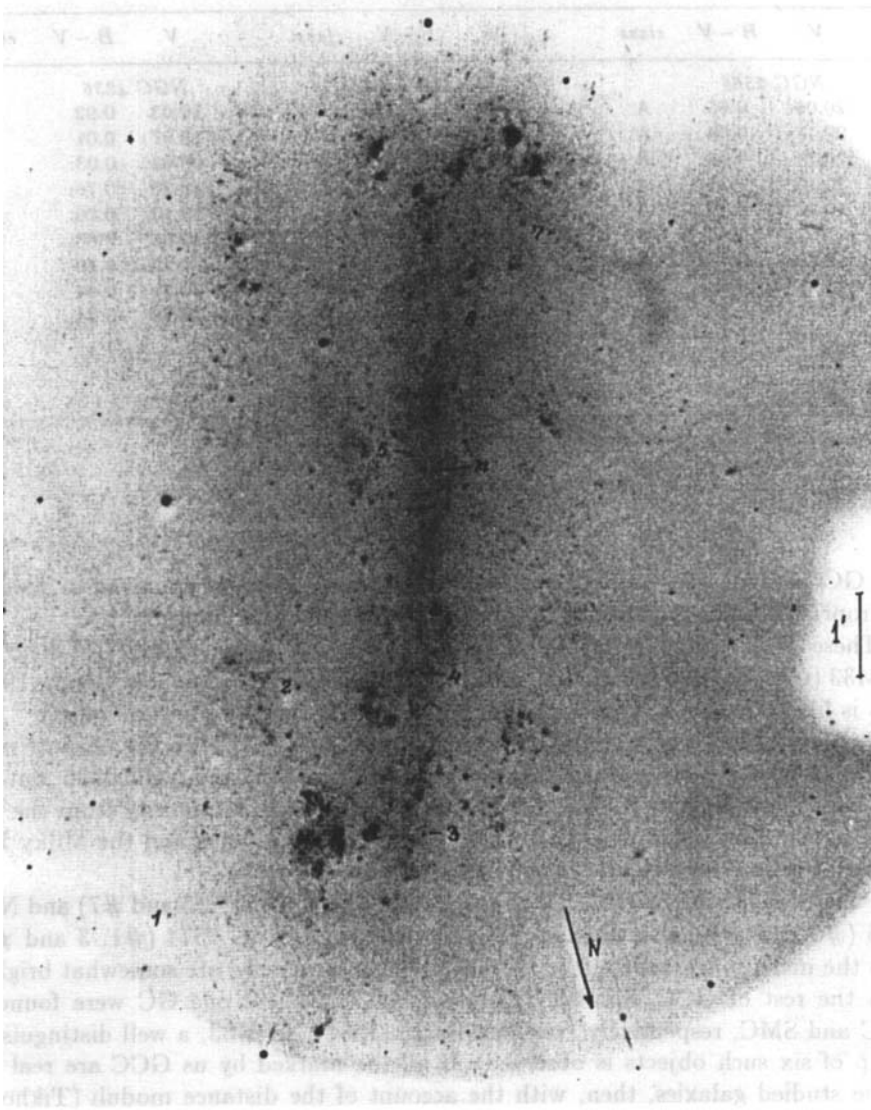


Figure 3 The finding chart of the globular cluster candidates in the galaxy NGC 4236.

Seeing on the plates of NGC 2366, IC 2574 and NGC 4236 galaxies is different, therefore the appropriate limiting magnitudes of GCC detection are also different. They are about 21.0, 20.0 and 20.5 mag, respectively. The GCC survey of the NGC 4236 galaxy is limited by the field of the 6 meter telescope with the diameter 13', being about 2 times as small as this galaxy size along its major axis.

Table 2. The magnitudes and colors of the globular cluster candidates

<i>N</i>	<i>V</i>	<i>B - V</i>	<i>class</i>	<i>V</i>	<i>B - V</i>	<i>class</i>	<i>V</i>	<i>B - V</i>	<i>class</i>	
	<i>NGC 2366</i>			<i>IC 2574</i>			<i>NGC 4236</i>			
1	20.06	0.65	A	19.34	0.98	A	19.63	0.92	A	
2	20.11	0.94	A	19.83	0.64	A	19.97	0.01	B	
3	20.74	0.92	B	19.63:	0.99:	A	20.08:	-0.03:	A	
4	20.10	1.24	A	19.82:	0.54:	A	19.20	0.76:	B	
5	19.20	0.85	A	19.73	0.25	B	19.10:	0.76:	A	
6	21.02:	0.46	B	19.88	0.78	B	20.06:	0.83:	A	
7	19.39	0.67	A	19.48	1.40	A	20.13	0.10	B	
8	20.95	0.62	A	19.92	0.89	B	20.21	0.64	A	
9	20.71	1.13	A	20.04	1.47	B	nuc	19.28:	-0.24:	A
10	20.26	1.10	B	19.08	0.25	A				
11	20.20	1.12	B	17.43	0.61	A				
nuc	20.28:	-0.16:	B	nuc	19.36.	0.28.	A			

3 RESULTS

The GCC magnitudes and color indexes in the three galaxies are given in Table 2. Appropriate “color-magnitude” diagrams are presented in Figure 4.

These GCC “color-magnitude” diagrams are similar to appropriate CM diagrams for M33 (Cristian and Schommer, 1988) and LMC and SMC (van den Bergh, 1981). This is likely to be a reflection of the morphological type of a parent galaxy.

Analogs of the brightest GC of the Milky Way and M31 with the absolute magnitude of the order of -10 mag are not found in NGC 2366 and NGC 4236, but one such object is found in IC 2574. It is sharply distinct in luminosity from the rest GCC of the three galaxies. Allowing for the distance modulus and the Milky Way light absorption, its absolute magnitude is about -10.6 mag.

Pairs of relatively bright GCC in the galaxies NGC 2366 (#5 and #7) and NGC 4236 (#5 and #4), and three such GCC of the galaxy IC 2574 (#1, 3 and #7), with the mean magnitudes 19.3, 19.5 and 19.1, respectively, are somewhat brighter than the rest of GCC. Similarly distinguished three and one GC were found in LMC and SMC, respectively (van den Bergh, 1981). In M33, a well distinguished group of six such objects is observed. If all the marked by us GCC are real GC of the studied galaxies, then, with the account of the distance moduli (Tikhonov *et al.*, 1991), the absolute magnitudes of their bright representatives are about -8.5 mag.

4 DISCUSSION

Despite some uncertainty when separating GCC from distant galaxies and a relatively low precision of the photometry method used, the results of the present paper show that real GC of the studied galaxies are present among the objects selected.

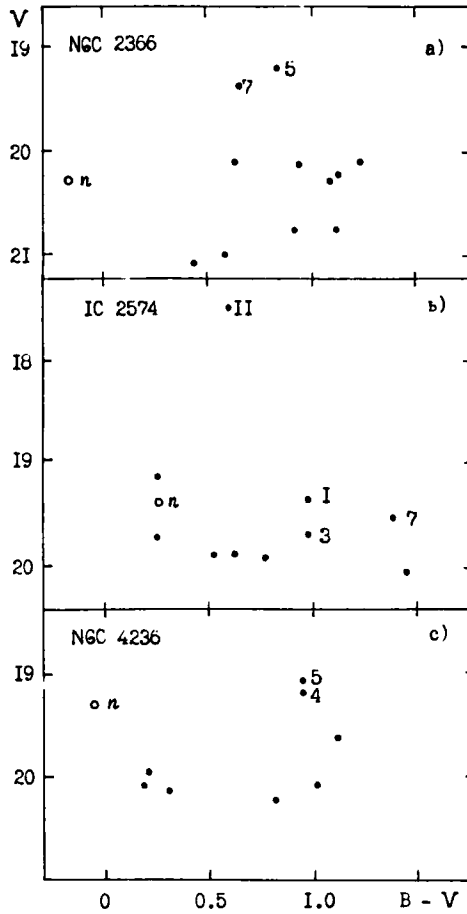


Figure 4 The color-magnitude diagrams of the globular cluster candidates in NGC 2366 (a), IC 2574 (b) and NGC 4236 (c).

According to distributions on the color-magnitude diagrams, the GCC systems in the galaxies NGC 2366, IC 2574 and NGC 4236 are generally similar to GC systems in M33, LMC and SMC.

If one assumes that the absolute magnitudes of bright GC (but not the brightest ones, as ω Cen-type in the Milky Way, or GCC #11 in IC 2574) are -8.5 mag, we find a good agreement of the distance moduli of the galaxies studied (Tikhonov *et al.*, 1991) with the ones of LMC and M33 (Freedman *et al.*, 1991). It should be also noted that Madore *et al.* (1985) determined earlier the distance modulus for M33 as 24.3 mag. Using this value, we find that the bright GCC noted in this paper exceed in integral value the bright GC of M33 by 0.2–0.3 mag. Apparently, there are grounds to think that bright GC with $M \cong -8.5$ mag may be a good enough distance indicator in the Local Complex.

The object #11 in IC 2574 is sharply distinguished by brightness from the rest of GCC. If it is really a GC, then with the accepted distance modulus of IC 2574 its magnitude approximately corresponds to the magnitude of the brightest GC in the Milky Way, M31 and LMC. To answer the question whether this and other GCC belong to GC, spectral observations are needed.

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