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PHOTOMETRIC AND SPECTROSCOPIC STUDY OF THE SHAKHBAZIAN COMPACT GALAXY GROUPS SHCG 74, SHCG 188, SHCG 251, AND SHCG 348

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RESUMEN

Continuamos con la presentación de los resultados de estudio espectroscópico y fotométrico de grupos compactos de galaxias Shakhbazian. Estos son una interesante clase de grupos. Por su gran número (el catálogo contiene 377 grupos) podemos estudiarlos en sus diferentes etapas de evolución. En este artículo mostramos los resultados de un estudio detallado de cinco grupos ShCG 74E, ShCG 74W, ShCG 188, ShCG 251 y ShCG 348. Damos a conocer los corrimientos al rojo de cada galaxia en el grupo, los resultados de la fotometría R, los isocontornos de brillo superficial, las masas estimadas, las luminosidades y las razones masa-luminosidad de los grupos, además de algunos parámetros dinámicos como la dispersión de velocidad radial y el tiempo de cruce, así como propiedades generales de 18 grupos ShCGs obtenidas en este trabajo y en artículos previos.

ABSTRACT

We continue the presentation of the results of detailed spectroscopic and photometric study of Shakhbazian compact galaxy groups. They belong to the interesting class of compact groups. Because of their large number (the catalogue contains 377 entries) we are able to study the groups in different stages of evolution. Here we give the results of a detailed study of five groups, ShCG 74E, ShCG 74W, ShCG 188, ShCG 251, and ShCG 348. We present the redshifts of individual galaxies in groups, the results of the surface photometry in R, the contour plots of the surface brightness, and some physical parameters of groups, such as the radial velocity dispersions, the crossing times, and the mass-to-luminosity ratios of groups. The general properties of 18 ShCGs obtained in this and previous works are discussed.

Key Words: **GALAXIES: CLUSTERS: INDIVIDUAL (SHCG 74, SHCG 188, SHCG 251, SHCG 348 — GALAXIES: DISTANCES AND REDSHIFTS — GALAXIES: INTERACTIONS — GALAXIES: PHOTOMETRY**

1. INTRODUCTION

About a decade ago we commenced a spectral and detailed photometric study of Shakhbazian compact groups (ShCGs).

ShCGs generally consist of a few, up to about 15 members; the distances between galaxies are typically 3 – 5 times the diameter of galaxies. ShCGs have a prolate spheroid space configuration (Oleak et al. 1995). The space density of groups is quite high, reaching about $10^4 - 10^5$ galaxies per Mpc^3 in some of them. Such dense groups should undergo strong dynamical evolution, and processes of interaction and merging should be common in them. It is expected that member galaxies will coalesce into one giant elliptical (Barnes 1985, 1989; Mamon 1986; Bode, Cohn, & Lugger 1993). Therefore, the signs of dynamical friction, tidal interaction between galaxies, and galaxy merging should be observed in these groups.

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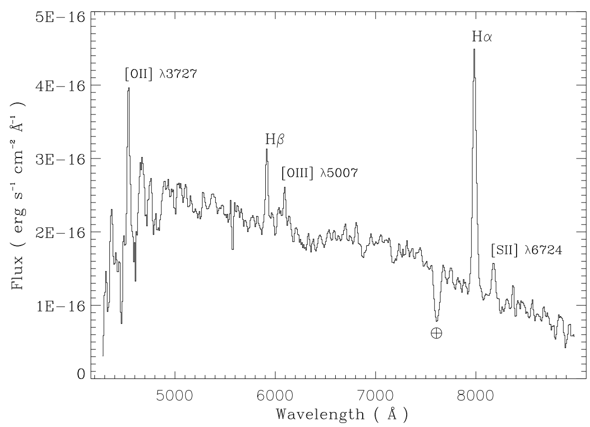

Fig. 1. The spectrum of galaxy ShCG 74-10.

The large number of ShCGs (nearly 400) implies that we may observe groups at different stages of dynamical and morphological evolution. Hence, the study of ShCGs may be very helpful for understanding the evolution of compact groups. In our program we intended to collect data on a large number of ShCGs. The results of the study of 13 ShCGs (ShCG 31, 38, 43, 154, 166, 181, 282, 328, 344, 360, 361, and 262) have been presented in Tiersch et al. 2002, [hereafter Paper I]; Tovmassian et al. 2003a, [hereafter Paper II]; 2003b, [hereafter Paper III]; 2004, [hereafter Paper IV]. In our previous works we already showed that some members of groups are in the process of interaction. Here we present the results on four ShCGs: ShCG 74, ShCG 188, ShCG 251, and ShCG 348. The redshifts of member galaxies in groups and the radial velocity dispersions, the results of the surface photometry in R (the group ShCG 348 has been observed also in the V band), the profiles of the semi-major axis, a, versus the surface brightness μ are presented. On the basis of the latter and by visual inspection of images the morphological types of galaxies are determined. We determined also such physical parameters of groups, as virial masses, luminosities, mass-to-luminosity ratios, and crossing times of groups. On the basis of the results obtained in this and previous works, the general properties of 18 ShCGs are discussed. The study of the brightness contours of galaxies allowed us to reveal processes of interaction between some of them.

2. OBSERVATIONS AND RESULTS

The coordinates of the centers of the studied groups ShCG 74, ShCG 188, ShCG 251 and ShCG 348, taken from Stoll, Tiersch, & Brown 1996; Stoll, Tiersch, & Cordis (1997a, 1997b 1997c) and

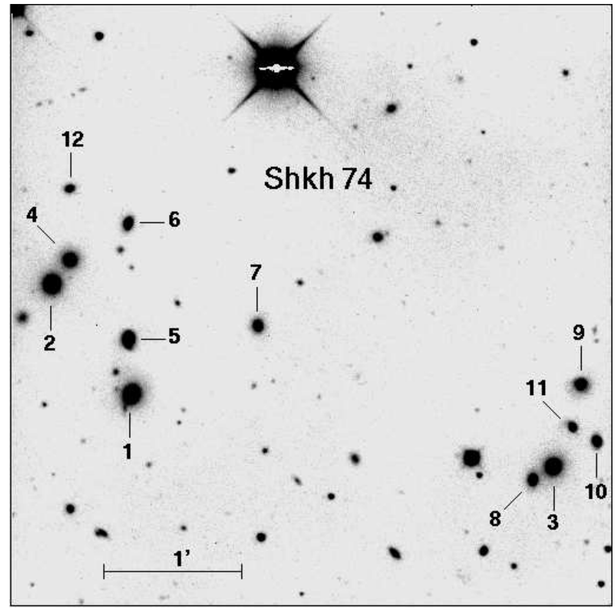

Fig. 2. The image of ShCG 74 in R. North is up, East is left.

TABLE 1

GROUPS' POSITIONS AND FOREGROUND GALACTIC EXTINCTIONS

ShCG	RA (2000)	Dec (2000)	A_R
74	$14^h21^m08^s$	$43°03'58''$	$0\stackrel{m}{.}027$
188	$09^h57^m01^s$	$26°10'25''$	$0\stackrel{m}{.}073$
251	$13^h36^m52^s$	$36°49'56''$	$0\stackrel{m}{.}019$
348	$09^h26^m38^s$	$03°26'32''$	$0\stackrel{m}{.}091$

the extinction in the R band (Schlegel, Finkbeiner, & Davis 1998) are given in Table 1. Spectral observations showed (see below) that ShCG 74 consists of two groups located at different distances.

2.1. *Spectroscopy*

Spectroscopic observations of 32 objects in the fields of ShCG 74, ShCG 188, ShCG 251, and ShCG 348 have been carried out with the 2.1 m telescope of the Guillermo Haro Observatory in Cananea, México (operated by the National Institute of Astrophysics, Optics, and Electronics) with the use of the Faint Object Spectrograph and Camera (Zickgraf et al. 1997). Observations have been made during four observing sessions in February 2004 (ShCG 74, galaxies 3, 8, 9, 10, and ShCG 348), April 1996 (ShCG 188), and May 1998 (ShCG 251). Some galaxies were observed in the spectral range

4000–7000 Å with a dispersion of 5.5Å/pixel, and some others in the spectral range 4000–9000 Å with a dispersion of 8.2Å/pixel. All 12 objects in ShCG 74 were observed also with the 2.1 m telescope of the Observatorio Astronómico Nacional in San Pedro Mártir (OAN, SPM), México, in April 2004. The Boller-Chivens spectrograph was used for the latter observations.

The redshifts were determined using the MIDAS or IRAF packages. The sky lines were removed and absorption lines of MgIb, FeI, and NaD were identified in the spectra of almost all galaxies. In the spectra of some galaxies the CaK and CaH absorption lines, the G bands and the Hα and $H\beta$ lines were also observed. In a few galaxies $H\alpha$ and/or $H\beta$ emission lines were identified. For measuring the redshift of a galaxy the profile of each observed line was fitted by a Gaussian. We determined the redshift of a galaxy as the mean of the values measured with different lines. The dispersion of these values determines the error of measurement. The radial velocities (RV) were generally measured with an accuracy better than 200 km s^{-1}. In the case of very faint galaxies the uncertainties may reach $\approx$ 400 km s^{-1}. The RVs have been corrected for solar motion according to $\Delta v = 300\ \sin l \cdot \cos\ b$ km s^{-1}. The results of spectral observations are summarized in Table 2 in which the galaxy number in the corresponding group and the measured RV are given. Seven galaxies have emission lines (marked by "e" in Table 2). The emission-line spectrum of galaxy ShCG 74-10 is shown in Figure 1. Galaxies 5 in ShCG 251 and 8 in ShCG 348 have discordant redshifts, i.e., they are projected over the corresponding group. Object 6 in ShCG 251 turned out to be a star. Measured redshifts show that the group ShCG 74 consisits in fact of two groups. The nearby one, almost all members of which are located in the eastern part, was marked as ShCG 74E. The small and more distant group of three members (galaxies 8, 10, and 11) is located in the western part. It was marked as ShCG 74W.

2.2. *Photometry*

Photometric observations were made with the 1.5 m telescope of the Observatorio Astronómico Nacional in San Pedro Mártir (OAN, SPM), México, in March of 1998 and 1999. Observations were made at a seeing better than $2''$.

The TEK CCD detector used in observations covers a sky area of about 4.3 square arcmin. The twilight images of blank sky areas were taken to correct images for flat fields (Christian et al. 1985).

All four groups were observed in R. Additionally, the group ShCG 348 was observed also in the V band. Observations were calibrated in the Kron-Cousins photometric system. The star cluster NGC 4147 has been used as a standard. The instrumental magnitudes were transformed to standard magnitudes in the conventional way.

The image of ShCG 74 in R is presented in Figure 2. The galaxy identification numbers are from Stoll et al. (1996). The isophotes of objects in the area of this group (in arbitrary units) are presented in Figure 3. The left panel of Fig. 3 corresponds to ShCG 74E. In the right panel the isophotes of the group ShCG 74W are presented. The images of groups ShCG 188, ShCG 251 and ShCG 348 in R are presented in the left panels of Figures 4, 5, and 6, respectively. The galaxy identification numbers are from Stoll et al. (1997a, 1997b, 1997c). In the right panel of Figs. 4 to 6 the isophotes of galaxies of the corresponding groups are presented.

In our observations a limit of the surface brightness usually lower than $\mu = 26\overset{m}{.}5/\mathrm{arcsec}^2$ is reached. The magnitude of a galaxy is estimated generally within the $\mu = 26\overset{m}{.}5/\mathrm{arcsec}^2$ contour. This contour was used also for determination of the galaxy diameter and the axial ratio b/a. In the case of overlapping halos of galaxies they were separated using the MIDAS program by extrapolation of fitted ellipses in the undisturbed part down to the surface brightness $\mu = 26\overset{m}{.}5/\mathrm{arcsec}^2$. The measured magnitudes in R and V are corrected for extinction within our Galaxy according to Schlegel et al. (1998). Corresponding extinctions Q(R) taken from the NED are presented in Column 4 of Table 1. The estimated accuracy of magnitudes is about $0\overset{m}{.}06$, and could be worse for galaxies with overlapping halos.

For the determination of the morphological types of galaxies the spiral arms of which are not clearly seen on direct images, we constructed the graphs $a^{1/4} - \mu$ where a is the semi-major axis of the galaxy and μ is the surface brightness. Elliptical galaxies follow the $a^{1/4}$ law (de Vaucouleurs 1948). In cases in which the $a^{1/4} - \mu$ profile deviates from a straight line, we constructed the $a - \mu$ graph. The $a - \mu$ curves of S0 and S galaxies generally consist of two components corresponding to a bulge and disc (Kent 1985; Schombert & Bothun 1987). The bulge in lenticulars is more dominant than in spiral galaxies. Moreover, the profile of lenticulars is less steep (Kent 1985). Thus, by the appearance of the $a - \mu$ profile we distinguished galaxies of S and S0 types. However, not all galaxies can be represented by such simple profiles. Deviations from ellipticity in both the core and envelope, as well as deviations from concentric ellipses, are sometimes observed (Pildis, Bregman, &

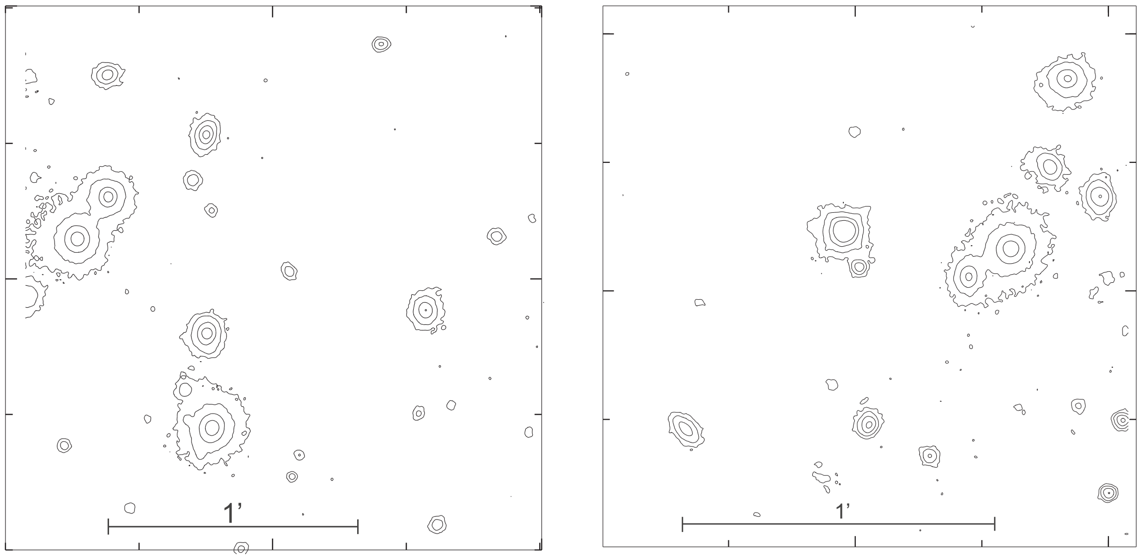

Fig. 3. The isophotal contour plots of galaxies in the eastern (left panel) and western (right panel) parts of ShCG 74.

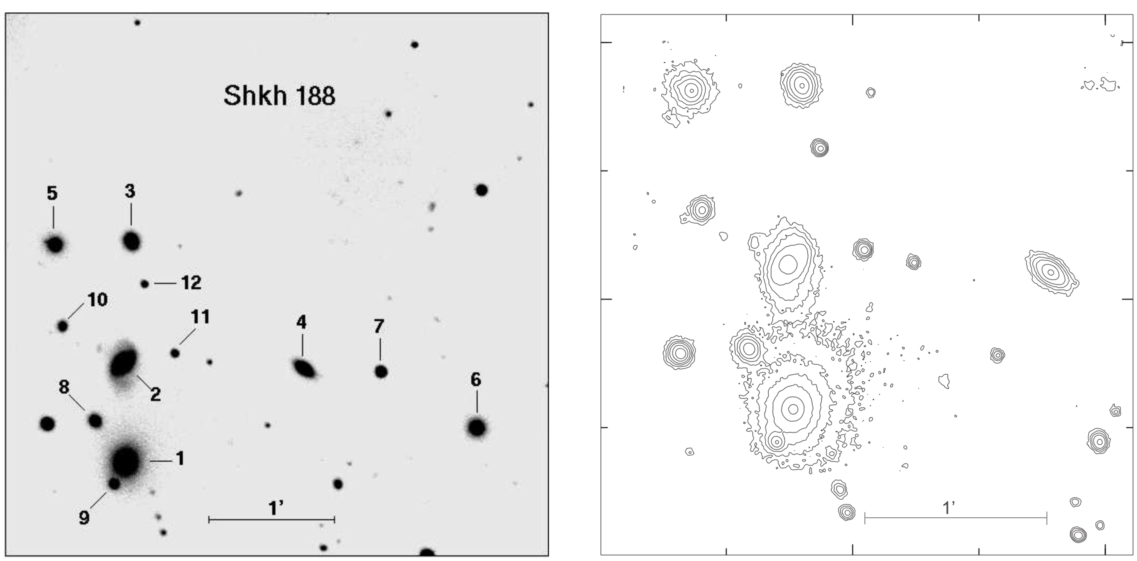

Fig. 4. The images of ShCG 188 in R and the isophotal contour plots of galaxies.

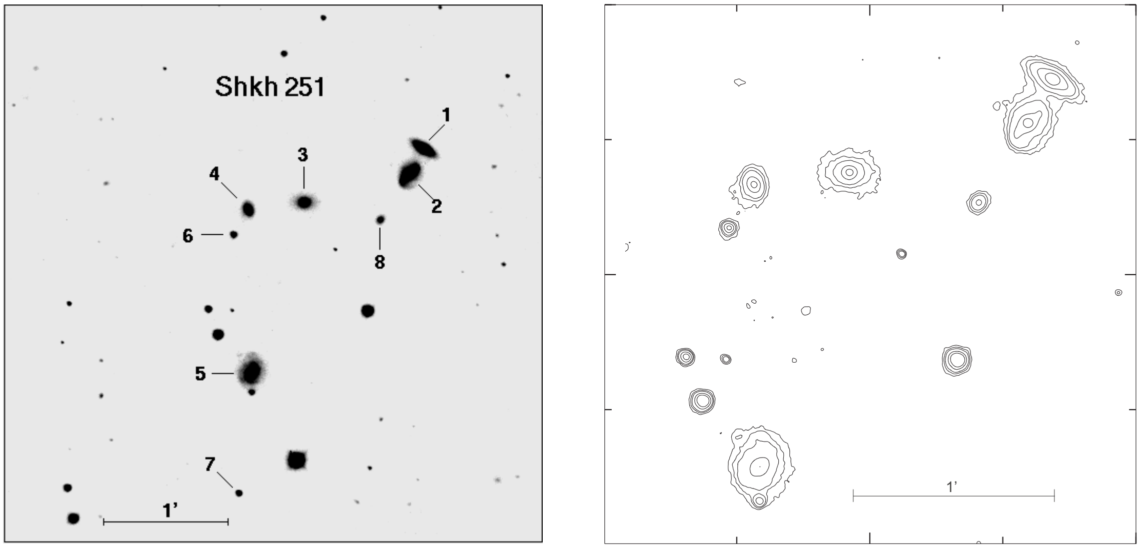

Fig. 5. The images of ShCG 251 in R and the isophotal contour plots of galaxies.

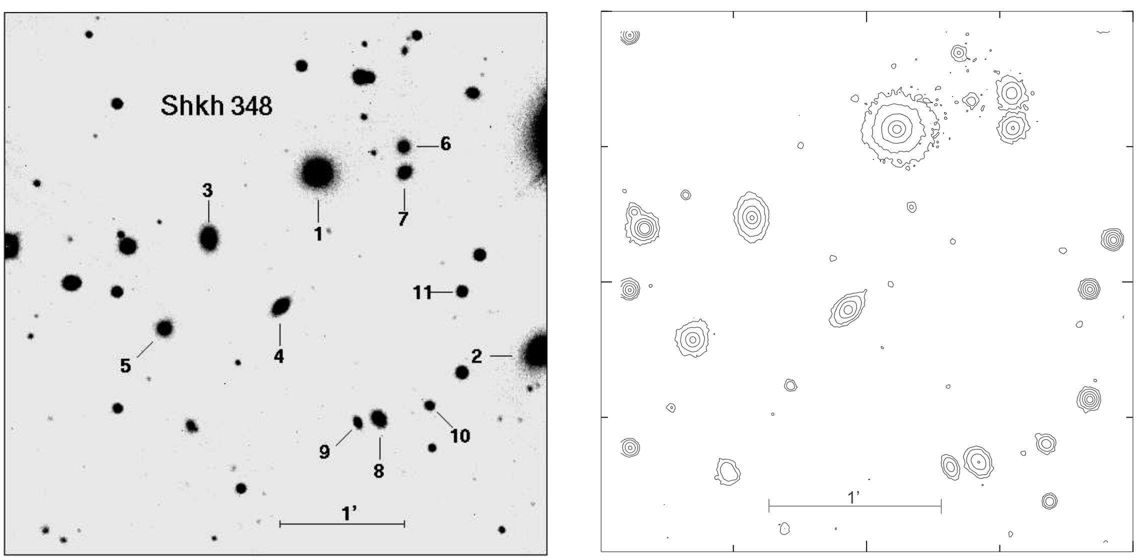

Fig. 6. The images of ShCG 348 in R and the isophotal contour plots of galaxies.

TABLE 2

RADIAL VELOCITIES OF MEMBER GALAXIES

ShCG 74E		ShCG 74W		ShCG 188		ShCG 251		ShCG 348	
g	v_{rad} km s^{-1}	g	v_{rad} km s^{-1}	g	v_{rad} km s^{-1}	g	v_{rad} km s^{-1}	g	v_{rad}
01	31020	8	65550 e	1	24610	1	17980	1	26640
02	30780	10	65520 e	2	24100	2	17930	2	25580
03	31260 e	11	65760 e	3	25850	3	18490	3	26370
04	31110	···	···	4	24610	4	18490	4	27140
05	31200	···	···	5	24280	5	12100	5	26630
06	30390	···	···	6	24760	6	star	6	25080
09	31290 e	···	···	9	25090	7	19120	7	26420 e
12	31840 e	···	···	···	···	···	···	8	32800

Schomberg 1995). Although such deviations might imply that a galaxy has probably undergone an interaction, this is not always the case. Therefore, the deviations must be interpreted with restraint.

The $a - \mu$ surface brightness profiles for galaxies in ShCG 74, ShCG 188, ShCG 251, ShCG 348 are presented in the upper panels of Figures 7, 8, 9, and 10, respectively. For galaxies in the studied groups we constructed also the curves of isophotal twisting $a - PA$ (PA is the position angle), and the curves, $a - a_4$ where a_4 is the Fourier parameter. Although Lima Neto & Combes (1995), Bettoni & Fasano (1993; 1995), Fasano & Bettoni (1994) have argued that they are not strictly correlated with interaction and merging processes, both $a - PA$ and $a - a_4$ curves may illustrate signs of mutual tidal perturbations or galaxy collisions (Kormendy 1983; di Tullio 1979; Bender & Möllenhoff 1987). The $a - PA$ and $a - a_4$ profiles are presented in the middle and lower panels of Figs. 7, 8, 9, and 10. These figures show that none of the members of the studied four ShCG have "box-like" isophotes; all galaxies have a "disk-like" feature.

The results of the photometry of member galaxies in ShCG 74, ShCG 188, and ShCG 251 are presented in Table 3 in which the following information is given: Column 1, the galaxy identification number; Column 2, the magnitude in $R_{26.5}$; Column 3, the color $R - K_{\mathrm{total}}$ for galaxies observed with the $2MASS$[6]; Column 4, the b/a axial ratio; Column 5, the diameter of the galaxy; Column 6, the morphological type. Photometric data on the group ShCG 348, observed also in V, are given in Table 4. Here in Column 2, the V magnitudes of member galaxies are given (corrected for galactic absorption, Q(V) = 0.113, according to Schlegel et al. 1998), and in Column 3, the colors $V - R$. Columns 4 to 7 correspond to Columns 3 to 6 of Table 3. In Table 5 the photometric data on discordant redshift galaxies in ShCG 251 and ShCG 348 are given. Since the observed groups are relatively nearby, the K correction is neglected, except for the group ShCG 74W (see below) at $z \approx 0.2$. According to Pogianti (1997), the K-correction for Sa type galaxies at R-band is $\approx 0\overset{m}{.}2$.

[6] Jarrett et al. 2000, http://www.ipac.caltech.edu/2mass).

3. DISCUSSION

ShCG 74. Spectral observations showed that the group ShCG 74 is in fact composed of two separate groups. The first one, ShCG 74E, consists of eight galaxies (Nos. 1–6, 9, and 12). The majority of its members are located on the eastern part of the original group. This group is relatively nearby. It is located at $\approx$ 560 Mpc (H=55 km s^{-1} Mpc^{-1}). Inspection of the isophotes of this group (Fig. 3, left panel) shows that the halo of Galaxy 1 has an extension towards Galaxies 2 and 4. It may be a sign of interacton between these three galaxies. One has to be cautious, however. The mentioned extension embeds a faint compact object located north-east from Galaxy 1. According to the direct image (Fig. 2) this object seems to be a star. However, the isophotes show that it may well be a dwarf galaxy. Then, the extension of Galaxy 1 is possibly illustrating interaction with this dwarf, but not with Galaxies 2 and 4. In the case of another compact object located south of the main body of Galaxy 1, the isophotes do not show any peculiarities. The latter object certainly is a star.

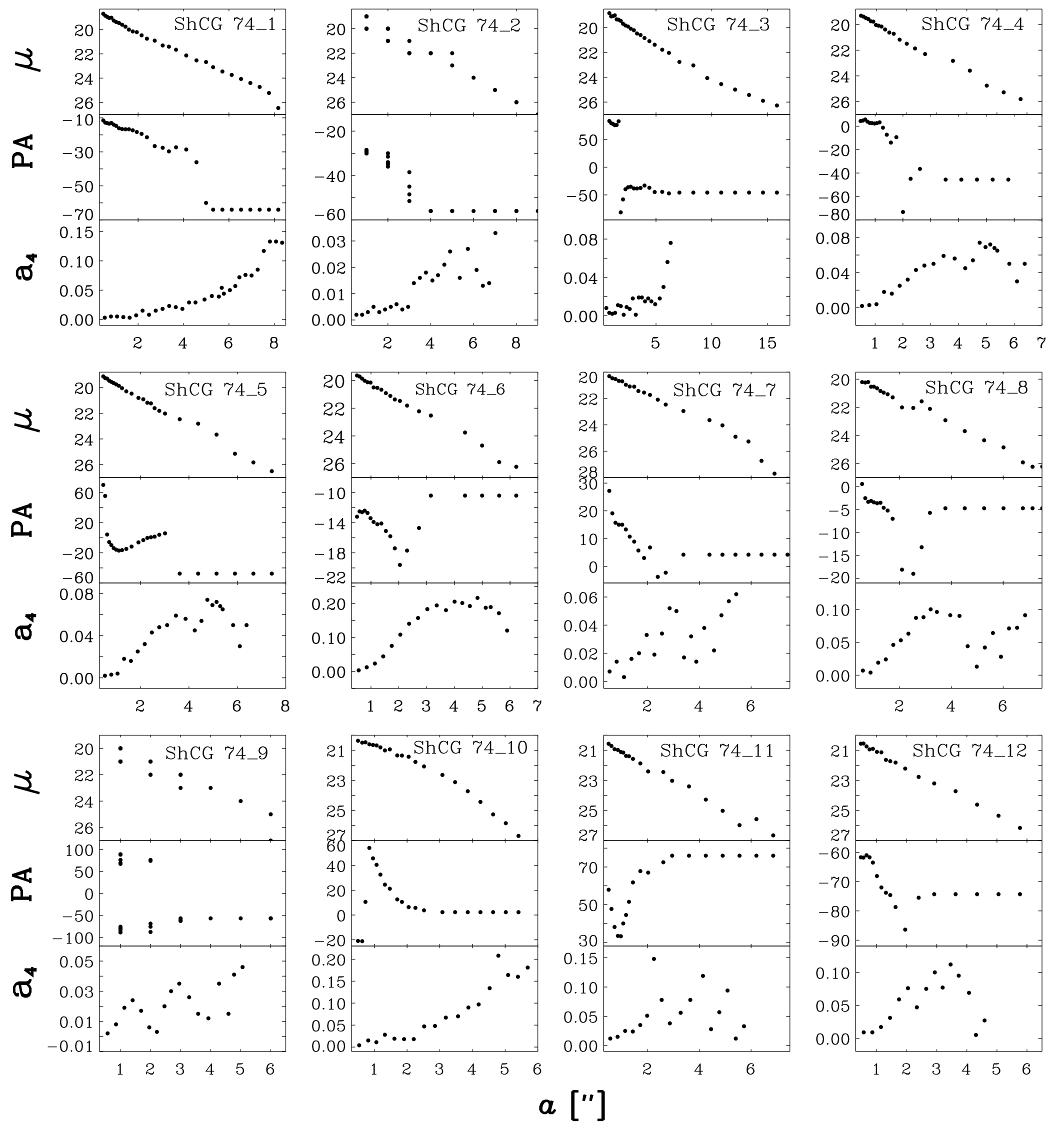

Fig. 7. The profiles $a - \mu$, $a - PA$ and $a - a_4$ for galaxies in ShCG 74.

The group ShCG 74W consists of three galaxies (Nos. 8, 10, and 11) and is located at the western side of the original group. This very dense triplet is located at a distance of about 1200 Mpc. Its length (the distance between Galaxies 8 and 10) is $\approx$ 170 kpc. It is notable that all three galaxies have emission-line spectra. The spectrum of Galaxy 10 is shown in Fig. 1. According to the diagnostic diagrams log([N II]λ6583/Hα), and log([S II]$\lambda\lambda$6717+6731/Hα) versus log([O III]λ5007/Hβ) (Veilleux & Osterbrock 1987) this galaxy may be classified as a Narrow Emission Line Galaxy[7]. The emission lines of Galaxies 8 and 11 are too faint for a diagnostic classification. Galaxy 8 was identified with the radio source FIRST J142057.5+430250 (Tovmassian et al. 1999). In the region of the

[7]Line fitting analysis was done in terms of Gaussian components (Véron, Véron-Cetty, & Zuiderwijk 1981). Also, the width and redshifts of each narrow line component were fixed to the same value. For the fitting, we assumed that the intensity ratios of [N II] $\lambda\lambda$ 6548,6583 and [O III] $\lambda\lambda$ 4959, 5007 lines were equal to 3 and 2.96, respectively (Osterbrock 1989). For Hα and [N II], and Hβ and [O III]$\lambda\lambda$ 4959,5007 we have done the fitting using three gaussian components. The local continuum in the Hβ and Hα spectral ranges was approximated inside 4500–5500 Å and 6000–7000 Å regions (in the restframe), respectively. A least-square fitting was obtained using IRAF/GUIAPPS/SPECTOOL package.

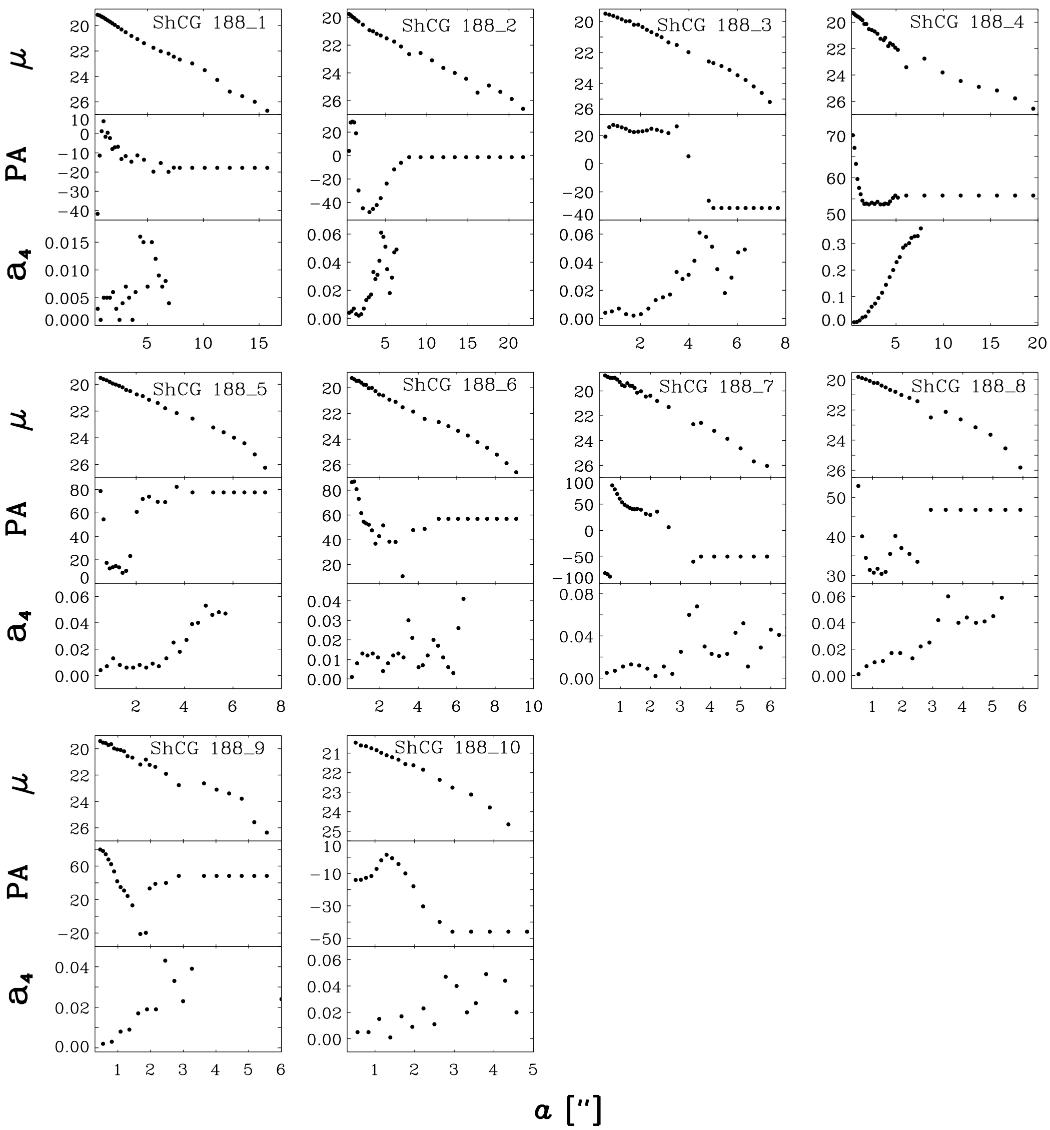

Fig. 8. The profiles $a - \mu$, $a - PA$ and $a - a_4$ for galaxies in ShCG 188.

distant triplet ShCG 74W another faint infrared source, F14189+4317, is located (Tovmassian et al. 1998). It may be associated either with Galaxy 9 of the nearby, eastern group, or with Galaxy 11 of the triplet. Both galaxies have faint emission-line spectra. The faint extension of the isophotes of Galaxy 9 towards the south-east (see Fig. 3, right panel) shows that it may possibly be in interaction with Galaxy 3. If this is so, then the IR-source most probably is associated with Galaxy 9 of the nearby group.

ShCG 188. In this group, out of the supposed 12 members we obtained spectra for 7 objects, Nos. 1-6 and 9. All have concordant redshifts. According to the image of the group (Fig. 4), objects 11 and 12 are most probably stars. Other supposed members are very faint and might be foreground objects. However, the surface density of objects of about the same brightness is apparently smaller in the environment of the group. Therefore, these objects very probably belong to the group.

The enlarged halos of Galaxies 1 and 2 show that they are interacting. It is remarkable that the halo of Galaxy 2 is directed towards Galaxy 1, and is turned by about 45° in relation to its own bulge. The bulge of Galaxy 10 seems to be shifted with respect to its halo towards Galaxies 1 and 2. This may mean that this galaxy also is involved in interaction.

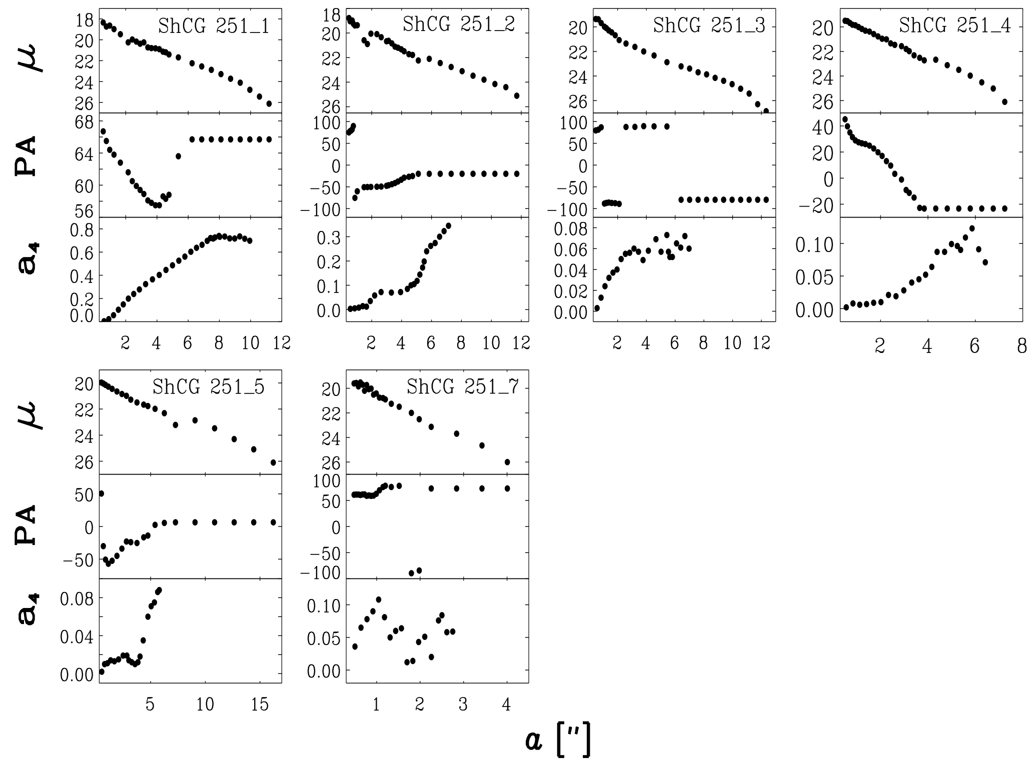

Fig. 9. The profiles $a - \mu$, $a - PA$ and $a - a_4$ for galaxies in ShCG 251.

ShCG 251. Spectral observations of 7 objects showed that one of them, No. 6, is a star. Another object, No. 5, is a foreground galaxy. Five other galaxies have concordant redshifts. The redshift of the faintest member, Galaxy 8, is not known, so its membership to the group is not confirmed.

The isophotes (Fig. 5) do not show apparent signs of interaction between member galaxies. However, the faint infrared source found at 60μ at the position of Galaxy 2 (Tovmassian et al. 1998) may be evidence of starburst in this galaxy which may possibly be triggered by interaction with Galaxy 1.

ShCG 348. Radial velocities of four galaxies of this group, Nos. 1, 3, 4, and 5, have been measured by Kodaira et al. (1990). We obtained spectra of another 4 galaxies, Nos. 2, 6, 8, and 9. One galaxy out of these eight, No. 8, is a background object projected over the group. According to the image of the group (Fig. 6), object 11 may be a star. Distances of two supposed faint members, Galaxies 9 and 10, are not known.

No optical signs of interaction between member galaxies of this group are observed (Fig. 6). The emission-line spectrum of Galaxy 7 and the radio emission of Galaxy 2 (NVSS J092629+032617, Tovmassian et al. 1999) may be considered as a consequence of interaction of these galaxies with other members of the group, although both events may be initiated by other reasons.

The physical parameters of groups. As in other papers of this series (Papers I–IV) we determined important physical parameters of the studied groups; they are presented in Table 6. The following information is given in it: line 1, the redshift z (weighted by the masses of member galaxies); line 2, the length D determined by the most separated galaxies of the group ($H_o = 55$ km s^{-1} Mpc^{-1}); line 3, the radial velocity dispersion (RVD), (weighted by the masses of galaxies); line 4, the virial radius, R_{vir}, of the group (weighted by the masses of galaxies); line 5, the virial mass, M_{vir}; line 6, the luminosity of the group, L, in solar units; line 7, the mass-to-luminosity ratio, M/L, in solar units; and line 8, the crossing time, τ_c. For details of determination of these parameters see Paper I.

The physical parameters of the 18 groups studied, including those presented in Papers I–IV, are discussed below. In total, the spectra of 121 objects have been obtained. Six of them are discordant redshift galaxies projected over the groups. It was

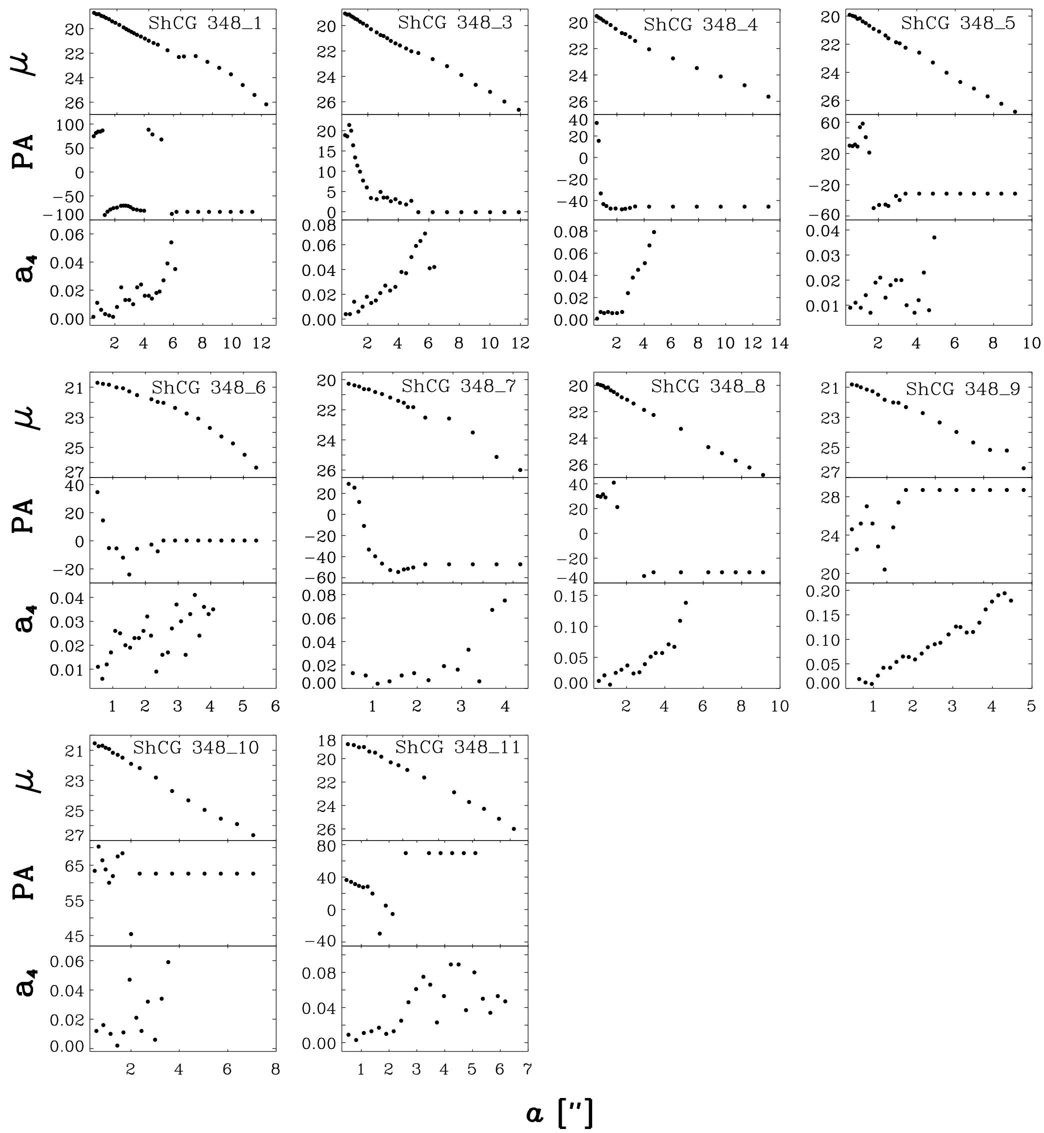

Fig. 10. The profiles $a - \mu$, $a - PA$ and $a - a_4$ for galaxies in ShCG 348.

found that four objects are not galaxies, but stars. Detailed photometric data have been obtained for 154 galaxies, six of which have discordant redshifts.

The radial velocity dispersion (RVD) of the 18 studied groups is somewhat smaller than that of rich galaxy clusters which is $\approx$ 1000 km s^{-1} (Zabludoff, Huchra, & Geller 1990). The groups ShCG 360 and ShCG 361 have the highest RVD, 640 and 670 km s^{-1} respectively. The virial masses of groups are between $14 \cdot 10^{11}\,M_\odot$ and $700 \cdot 10^{11}\,M_\odot$. For some of the groups the virial masses might be underestimated, because some putative members, whose redshift is still unknown, were not included. Furthermore, the real masses of some of the studied groups may be higher, if one takes into account that they are associated with larger systems (Tovmassian & Tiersch 2001), and may be gravitationally bound to them (Tovmassian & Chavushyan 2000). The mean value of mass-to-luminosity ratios for 18 of the studied groups is 37 ± 30. In the case of $H_o = 100$ km s^{-1} Mpc^{-1} the mean M/L is 67 and is higher than that of the HCGs, ≈ 30, (Hickson et al. 1992). The highest value, $M/L = 100$, is found for ShCG 361. The mean crossing time, τ_c, of 17 out of 18 ShCGs is equal to $(138 \pm 90) \cdot 10^6$ yr. Assuming $H_o = 100$ we deduce for the mean τ_c a value $\approx 90 \cdot 10^6$ yr which is smaller than the mean τ_c of HCGs, $\approx 260 \cdot 10^6$ yr (Hickson et al. 1992). The very

TABLE 3

PHOTOMETRIC PARAMETERS OF GALAXIES IN SHCG 74, SHCG 188, AND SHCG 251

gal	R	$R-K_t$	b/a	D''	Type
1	2	3	4	5	6
			ShCG 74E		
1	16.20	3.16	0.94	15.4	S0
2	16.42	3.14	0.79	13.5	S0
3	16.54	2.95	0.82	14.6	S0
4	17.29	3.75	0.88	10.8	S0/S
5	16.89	3.05	0.88	12.4	S0
6	17.59	···	0.77	9.9	S0
7	17.79	···	0.83	11.7	S0
9	17.53	···	0.86	12.8	S0
12	18.39	···	0.82	10.5	S0/S
			ShCG 74W		
8	17.86		0.68	11.3	S
10	18.20		0.74	8.7	S0/S
11	18.61		0.64	9.1	S
			ShCG 188		
1	15.35	3.12	0.78	24.0	S0
2	15.70	2.80	0.66	33.7	S0
3	16.32	2.86	0.90	14.0	S0
4	16.25	···	0.98	27.7	S0
5	16.60	2.97	0.93	14.1	S0
6	16.23	2.54	0.97	16.5	S0
7	16.52	···	0.91	10.4	E/S0
8	17.11	···	0.82	10.8	S0
9	17.21	···	0.83	9.4	S0
10	17.92	···	0.83	8.8	S0
			ShCG 251		
1	15.87	2.95	0.63	17.2	S
2	15.98	2.82	0.76	21.8	S
3	16.57	2.67	0.80	11.1	S
4	16.92	···	0.87	13.5	S0
7	18.01	···	0.95	7.8	S

high value of τ_c deduced for the group ShCG 74W, $\approx 600 \cdot 10^6$ yr may not be reliable, since the redshifts of only three members of this distant group were measured. One has to take into account that the real crossing times of groups in both samples (HCGs and ShCGs) may in reality differ from the deduced values. Tovmassian, Yam, & Tiersch (2001), Tovmassian & Tiersch (2001), Tovmassian (2001; 2002) showed that many ShCGs and HCGs are the cores of larger and elongated systems, whose members are often gravitationally bound to the corresponding compact group (Tovmassian & Chavushyan 2000).

As a result of possible frequent interactions of member galaxies in the considered groups, the spiral galaxies may be converted to S0/E types (Toomre & Toomre 1972; Barnes & Hernquist 1992; Mihos 1995). This explains the low rate of spiral galaxies in ShCGs, $\approx 30\%$. The groups ShCG 74W, ShCG 251, ShCG 344, and ShCG 376 are exceptions. All three members of ShCG 74W, four out of five members in ShCG 251, six out of eight members of ShCG 344, and all nine members of ShCG 376 are spirals. These groups may be young formations.

Elliptical galaxies in ShCGs are very red. The $B-V$ of many of them are of about $1\overset{m}{.}0$ or more. Such a colour is exhibited by the reddest ellipticals in

TABLE 4

PHOTOMETRIC PARAMETERS OF GALAXIES IN SHCG 348

Gal	V	$V-R$	$R-K_t$	b/a	D''	Type
1	2	3	4	5	6	7
			ShCG 348			
1	15.87	0.64	3.03	0.96	22.3	S0
3	16.56	0.57	3.39	0.73	18.9	S0
4	17.07	0.38	3.69	0.55	20.3	S0/S
5	17.56	0.63	···	0.91	14.7	S0
6	18.07	0.28	···	0.91	9.2	E/S0
7	17.78	0.34	···	0.89	11.8	S
9	18.56	0.51	···	0.64	12.5	S0
10	18.54	0.54	···	0.92	10.5	S0
11	17.00	0.39	···	0.94	9.9	S0

TABLE 5

PHOTOMETRIC PARAMETERS OF DISCORDANT REDSHIFT GALAXIES IN SHCG 251 AND SHCG 348

Gal	V	$V-R$	b/a	D''	Type
1	2	3	4	5	6
		ShCG 348			
ShCG 251-5	16.06	···	0.76	28.5	S0
ShCG 348-8	17.50	0.32	0.74	18.9	E/S0

TABLE 6

PHYSICAL PARAMETERS OF THE STUDIED SHCGS

Parameter	ShCG 74E	ShCG 74W	ShCG 188	ShCG 251	ShCG 348
z	0.1040	0.2191	0.0801	0.0611	0.0884
D (kpc)	660	170	460	310	420
RVD (km s^{-1})	280	88	306	265	410
R_{vir} (kpc)	160	130	140	50	160
M_{vir} (10^{11} $M_\odot$)	140	11	142	38	295
L ($10^{11}(L_\odot)$	6.8	3.5	5.9	2.2	4.3
M/L ($M_\odot/L_\odot$)	20	3	24	17	68
τ_c (10^6 years)	235	605	187	76	160

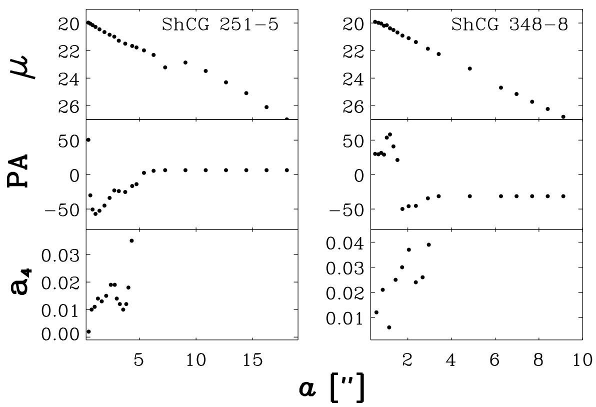

Fig. 11. The curves $a-\mu$, $a-PA$ and $a-a_4$ of the discordant redshift galaxies ShCG 251-5 and ShCG 348-8.

the sample studied by Buta et al. (1995). One of the studied galaxies of E/S0 (ShCG 348–6) type is quite blue. It may belong to a population of bright blue elliptical galaxies (Zepf, Whitmore, & Levison 1991) predicted by the environment-dominated models of evolution of galaxies.

It is remarkable that in the studied groups only a few galaxies with radio emission were found (Tovmassian et al. 1999), although it is expected that in very dense environments of groups the number of radio-emitting galaxies should be high. Klamer, Subrahmanyan, & Hunstead (2004) mentioned that radio emission may not be simply triggered by galaxy-galaxy interaction. Another possible explanation for the absence of strong radio sources in compact groups is their suggested quasi-stable state, and the semi-regular oscillation of the group members around its gravitational center (Tovmassian 2002).

4. CONCLUSIONS

We investigated spectroscopically 33 objects in the regions of five ShCGs: ShCG 74W, ShCG 74E, ShCG 188, ShCG 251, and ShCG 348. We found that object No. 6 in ShCG 251 is a star. Two galaxies, ShCG 251-5 and ShCG 348-8 have discordant redshifts and are projected over the corresponding group. Thirty seven galaxies in these groups were observed in R. Important physical parameters of these groups are deduced (Table 6). The results of the detailed study of these five groups and another 13 groups presented in Papers I–IV may be summarized as follows:

1. In 18 studied ShCGs we obtained spectra of 121 objects. Four of them turned out to be stars. Three more stars were revealed by the detailed photometry of the supposed members. Hence, the overwhelming majority of objects in the selected groups are, indeed, galaxies, although ShCGs have been selected by an eye search of the POSS prints as compact groups of *compact*, red galaxies, and it could not be excluded that some of the objects included in the groups may in reality be stars.

2. The measured RVs of galaxies in the 18 groups prove they are real physical entities and not a chance projection of field galaxies. Out of 121 spectroscopically observed galaxies, only six, or possibly five (if we exclude Galaxy 6 in ShCG 376 which may be a member), have discordant redshifts.

3. The redshifts of 18 ShCGs are in the range from 0.0400 to 0.2190.

4. The majority of members of ShCGs are E and S0 galaxies. Out of 148 photometrically observed member galaxies only 26 or 43 (in the assumption that all dubious S/S0 classifications are spiral galaxies) i.e., at most 29% are spiral galaxies. The low relative number of spirals could be due on the one

hand to the formation of E/S0's as the result of merging of spiral galaxies as a consequence of the expected frequent processes of interaction between member galaxies, and, on the other hand, to the loss of interstellar gas by galaxies caused by tidal forces and/or ram pressure during interactions. Detailed photometry showed that in almost every group there are interacting galaxies.

5. The mass-weighted RVDs of the studied ShCGs are comprised between 90 km s^{-1} and 670 km s^{-1}.

6. The virial radii are quite small; they do not exceed ≈ 160 kpc.

7. The derived virial masses of the groups range from $\approx 10 \cdot 10^{11}\, M_{\odot}$ to $\approx 720 \cdot 10^{11}\, M_{\odot}$. These values are typical for rich galaxy groups and poor clusters. However, one has to take into account that the real masses may be higher, since, as it has been shown by Tovmassian & Tiersch (2001), ShCGs are the cores of larger, elongated systems.

8. The mean mass-to-luminosity ratio M/L of 18 of the studied ShCGs is ≈ 37.0. This ratio does not differ from that of HCGs, the mean value of which is ≈ 30 (Hickson et al. 1992).

9. The crossing time for 17 out of 18 ShCGs ranges from $47 \cdot 10^{6}$ to $340 \cdot 10^{6}$ years. It is generally shorter than the Hubble age. The high value of τ_c for the group ShCG 74W, $\approx 600 \cdot 10^{6}$, may be due to the very small value of the RVD (90 km s^{-1}) deduced by using RVs for only three galaxies.

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REFERENCES

Barnes, J. E. 1985, MNRAS 215, 517
________. 1989, Nature, 338, 123
Barnes J., & Hernquist, L. 1992, ARA&A, 30, 705
Bettoni, D., & Fasano, G. 1993, AJ, 105, 1291
________. 1995, AJ, 109, 32
Bender, R., & Möllenhoff, C. 1987, A&A, 177, 71
Bode, P. W., Cohn, N. H., & Lugger, P. M. 1993, ApJ, 416, 17
Buta, B., Corvin, H. G. Jr., Vaucouleurs, G. de, Vaucouleurs, A. de, & Longo, G. 1995, AJ, 109, 517
Christian, C. A., Adams, M., Barnes, J. V., Hayes, D. S., Siegel, M., Butcher, H., & Mould, J. R. 1985, PASP, 97, 363
de Vaucouleurs, G. 1948, Ann. D'Ap., 11, 247
di Tullio, G. A. 1979, A&AS, 37, 591
Fasano, G., & Bettoni, D. 1994, AJ, 107, 1649
Hickson, P., Mendes de Oliveira, C., Huchra., J. P., & Palumbo, G. G. C. 1992, ApJ, 399, 353
Jarrett, T. H., Chester, T., Cutri, R, Schneider, S., Skrutskie, M., & Huchra, J. P. 2000, AJ, 119, 2498
Kent, S. M. 1985, ApJS, 59, 115
Klamer, K., Subrahmanyan, R., & Hunstead, R. W. 2004, MNRAS, 351, 101
Kodaira, K., Doi, M., Ichikawa, S-I, Okamura, S. 1990, Publ. Nat. Astron. Obs., Japan, 1, 283
Kormendy, J. 1983, in Morphology and Dynamics of Galaxies, Proceedings of the Twelfth Advanced Course of the SAAS, eds. L. Mayor & M. Martinet (Sauverny, Switzerland: Geneva Obs.), 113
Lima Neto, G., & Combes, F. 1995, A&A, 294. 657L
Mamon, G. A. 1986, ApJ, 307, 426
Mihos, J. C. 1995, ApJ, 438, L75
Oleak, H., Stoll D., Tiersch, H., & MacGillivray, H. T. 1995, AJ, 109, 1485
Osterbrock, D. E. 1989, Astrophysics of Gaseous Nebulae and Active Galactic Nuclei (Mill Valley, CA: Univ. Sci.)
Pildis, R. A., Bregman, J. N., Schomberg, J. M. 1995, AJ, 110, 1498
Pogiani, B. M. 1997, A&AS, 122, 399
Schlegel, D. J., Finkbeiner, D. P., & Davis, M. 1998, ApJ, 500, 525
Schombert, J. M., & Bothun, G. D. 1987, AJ, 92, 60
Stoll, D., Tiersch, H., & Brown, M. 1996, Astron. Nachr., 317, 315
Stoll, D., Tiersch, H., & Cordis, L. 1997a, Astron. Nachr., 318, 7
________. 1997b, Astron. Nachr., 318, 89
________. 1997c, Astron. Nachr. 318, 149
Tiersch, H., Tovmassian, H. M., Stoll, D., Amirkhanian, A. S., Neizvestny, S., Böhringer, H., & MacGillivray, H. T. 2002, A&A, 392, 33 (Paper I)
Toomre A., & Toomre J. 1972, ApJ, 178, 623
Tovmassian, H. M. 2001, PASP, 113, 543
________. 2002, AN, 323, 488
Tovmassian, H. M., & Chavushyan V. H. 2000, AJ, 119, 1687
Tovmassian, H. M., Chavushyan, V. H., Verkhodanov, O. V., & Tiersch H. 1999, ApJ, 523, 87
Tovmassian, H. M., Mazzarella, J. M., Tovmassian, G. H., Stoll, D., & Tiersch, H. 1998, A&AS, 130, 207
Tovmassian, H. M., & Tiersch, H. 2001, A&A, 378, 740
Tovmassian, H. M., Tiersch, H., Chavushyan, V. H., & Tovmassian, G. H. 2003a, A&A, 401, 463 (Paper II)
Tovmassian, H. M., Tiersch, H., Navarro, S. G., Chavushyan, V. H., Tovmassian, G. H., & Neizvestny, S. 2003b, RevMexAA, 39, 275 (Paper III)
Tovmassian, H. M., Tiersch, H., Navarro, S. G., et al. 2004, A&A, 415, 803 (Paper IV)
Tovmassian, H. M., Yam, O., & Tiersch, H. 2001, RevMexAA, 37, 173
Veilleux, S., & Osterbrock, D. E. 1987, ApJS, 63, 295
Véron, P., Véron-Cetty, M.-P., & Zuiderwijk, E. K. 1981, A&A, 102, 116
Zabludoff, A. J., Huchra, J. P., & Geller, M. J. 1990, ApJS, 74, 1
Zepf, S. E., Whitmore, B. C., & Levison, H. F. 1991, ApJ, 383, 524
Zickgraf, F.-J., Thiering, I., Krauter, J., Appenzeller, et al. 1997, A&AS, 123, 103

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