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ISOLATED SHAKHBAZIAN COMPACT GROUPS

H. M. Tovmassian[1], J. P. Torres-Papaqui[2], and H. Tiersch[3]

It is more appropriate to study the dynamics and evolution of compact groups using a sample of isolated compact groups in the nearby vicinity of which there are no accordant redshift galaxies. To look for isolated compact groups we inspected the environment of 78 Shakhbazian compact groups, with known redshifts. We found that 26 of nearby groups with $V < 40000$ km s^{-1} are isolated compact groups in the vicinity of which up to a projected distance of 1 Mpc there are no accordant redshift galaxies. For four of them, the redshift of only two members are known, so their being groups is not certain. In the vicinities of eleven distant groups ($V > 40000$ km s^{-1}) no accordant redshift galaxies are detected as well. The reason for this may be the faintness of galaxies there. These groups may possibly be isolated.

Keywords: galaxies:groups:compact

1. Introduction

It is known that most galaxies in the Universe occur in small groups (e.g., [1]). The so-called compact groups (CGs) contain few members (generally less than 10). They have high space density of about 10^3 or more galaxies per Mpc^3 and a small velocity dispersion of a few hundred km s^{-1}. Galaxy interactions and merging are expected to be very frequent in CGs [2-5]. Numerical simulations predicted a very short lifetime of CGs [3,6,7], so the very existence of CGs has been questioned. Mamon [8], and Walke and Mamon [9] suggested that CGs are not physical entities, but the result of a projection of field galaxies over a small area on the sky. A similar hypothesis has been put forward by

[1] Instituto Nacional de Astrofísica Óptica y Electrónica, Mexico, e-mail: hrant@inaoep.mx
[2] Departamento de Astronomia, Universidad de Guanajuato, Mexico
[3] Sternwarte Königsleiten, München, Germany

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Hernquist, Katz, and Weinberg [10], and by Ostriker, Lubin, and Hernquist [11], who suggested that CGs are filaments seen end-on. In order to explain the existence of physical CGs, Governato, Bhatia, and Chincarini [12], Diaferio, Geller, and Ramella [13], and Ribeiro et al. [14] suggested that field galaxies fall from time to time from denser environments onto CGs and thus prevent them from quick coalescence.

Dynamical studies are very important for understanding the nature of CGs. Various studies of CG dynamics have been conducted [15-18]. In [19-21] attention was drawn to the fact that HCGs [15] have preferentially a prolate space conguration [22], and finding a correlation between the group length and velocity dispersion suggested that members of compact groups tend to move along the large axis of the group. Such quasi-regular movement of the group members may prevent fast collapse of CGs. Note that Mendes de Oliveira and Hickson [16], Zepf, Whitmore, and Levison [23], Zepf [24], and Moles et al. [25] found that the merger rate in CGs is indeed relatively low. Hence, CGs are more stable systems than follows from dynamical simulations.

For dynamical studies it is important to have a sample of isolated compact groups (ICGs) in the environment of which there are no other galaxies with redshifts close to those of the corresponding groups. It has been shown that CGs are often embedded within larger, loose groups (LGs) [26-35]. Tovmassian and Chavushyan [36] showed that members of an ordinary LG predominantly move quasi-regularly around the common gravitational center, as the members of a CG embedded within it. The observed dynamical properties of LGs are also explained, if the groups are in the process of virialization [37]. Generally, it appears that the performed study of dynamics is related not to CGs but to an ordinary LGs. For the study of CG dynamics it is desirable to select a sample of CGs not associated dynamically with LGs, i.e., ICGs. Tovmassian, Plionis, and Torres-Papaqui [38] showed that 12 out of 22 HCGs [15] are embedded in LGs. In the vicinity of only four HCGs at distances < 1 Mpc there are no galaxies with redshifts differing from that of the corresponding group by < 1000 km s^{-1}. In the environment of 6 other groups there are 1-3 galaxies with redshifts differing from the mean of the respective group by < 1000 km s^{-1} but located at projected distances of several hundred kpc from the group. These galaxies may hardly be associated dynamically with the corresponding groups. Hence, about half of the studied 22 HCGs are ICGs.

To look for more ICGs, we searched the environment of Shakhbazian Compact Groups (ShCGs). The list of ShCGs contains nearly 400 groups [39,40 and references therein]. The ShCGs were originally selected by an eye inspection of the Palomar Sky Survey Prints (PSSP) without knowledge of the candidate member redshifts. Therefore some members could have been field galaxies projected over the group. Furthermore, since the groups were selected as consisting of compact galaxies, some members could in reality be stars. Redshifts of a few ShCGs were measured in papers [41-50]. We conducted spectroscopic and photometric study of several dozens ShCGs [51-52 and references therein]. It was shown that the overwhelming majority of selected groups are real systems, and that most of the group membership candidates have accordant redhifts ($\Delta V < 1000$ km s^{-1}) [52].

2. Data and Results

We inspected environments of ShCGs with known redshifts of at least two of their members and located in the area of sky covered by the SDSS data Release 7 [53]. In addition to the redshifts determined in Tovmassian and Tiersch

[52 and references therein], we also used redshifts of some galaxies from the SDSS and NED (NASA / IPAC Extragalactic Database). Note that ShCGs were selected without knowledge of redshifts of candidate members. Also, since groups were selected as consisting of compact galaxies, some candidate members could in reality be stars. Tovmassian and Tiersch [52] showed that such are on average about 6% of candidate members (14 out of 222). Non the less the majority of selected groups are real systems. In the area covered by SDSS-7 there are 96 ShCGs. Eighteen of them (ShCG 21, 29, 33, 50, 56, 61, 62, 64, 66, 69, 70, 78, 96, 133, 184, 221, 243, and 343) turned out to be false ones. They consist mostly of stars and/or galaxies with non-accordant redshifts, i.e., with radial velocities V differing from each other by more than 1000 km s^{-1}.

By cross-correlation with lists of clusters of galaxies included in NED, we found that 20 out of 78 ShCGs are condensations in clusters of galaxies. The group was identified with a cluster with projected positional coincidence < 0.5 Mpc, and when redshifts of both systems coincide with an accuracy of about 1000 km s^{-1}. In most cases the groups are located in the central regions of the corresponding clusters. Two clusters are found at the position of ShCG 26. For groups ShCG 26b and ShCG 223 the photometric distance of the corresponding clusters is used. The distance

TABLE 1. ShCGs in Clusters of Galaxies

ShCG	V_{ShCG} km s^{-1}	Cluster	$V_{cluster}$ km s^{-1}	d kpc
6	23687 (2)	A1218	23354	180
15	27970 (3)	NSC J142048+443333	27070	250
20	32540 (3)	SDSS-C4 3146	33225	0
26a	37820 (3)	A1143	37290	300
26b	41894 (4)	J110155+502218	43020*	480
45	25466 (3)	SDSS-C4 2071	26397	130
53	36953 (4)	A1050	36240	0
54	24766 (6)	A1067	25330	0
154	21900 (6)	A1238	21975	160
191	34540 (12)	A1097	35250	0
202	8107 (8)	PCC N79-283	7765	100
205	26690 (8)	NSC J123518+273413	27490	0
219	37360 (4)	A1984	37320	0
223	24750 (6)	NSC J154955+291014	22140*	0
245	18400 (7)	RXC J1224.6+3159	18887	0
348	26520 (7)	SDSS-C4 1080	26290	0
351	8580 (7)	SDSS-C4-DR3	8994	100
352	14830 (8)	SDSS-C4-DR3 1079	14945	0
354	21306 (3)	SDSS-C4 1019	21309	0
357	23370 (9)	SDSS-C4 1045	22988	0
360	32460	A 2113	-	0

TABLE 2. Loose Groups

ShCG	V km s^{-1}	n	ShCG	V km s^{-1}	n
10	39920	7	15 181	27920	8
small 14	21834	7	198	44870	6
35	20126	8	224	23240	4
108 52	29860	6	253	18424	6
78 74E	30870	3	303	25160	10
75	50228	3	347	39224	8
95	23740	5	356	26700	6
25 131	34990	3	369	26700	8

of the cluster A 2113 identified with ShCG 360 is unknown.

The list of groups identified with clusters is presented in Table 1. In columns 1 and 3 the designations of groups and clusters identified with them from Abell, Corwin, and Ollowin [54], Gal et al. [55], Miller et al. [56], and Koester et al. [57] are presented; in columns 2 and 4, the corresponding radial velocities; and in column 5, the projected distance d between the centers of groups and the corresponding clusters are presented.

We looked for possible isolated CGs among other ShCGs confirmed to be physical systems. The environment of these ShCGs was searched for accordant redshift galaxies with V differing by no more than 1000 km s^{-1} from the mean $\langle V \rangle$ of the corresponding group members. The area with projected radius 1 Mpc around each group was analyzed. We adopted H_0 = 72 km s^{-1} Mpc^{-1}.

We found several accordant redshift galaxies in the immediate environment of three groups (ShCG 14, 35, 95), suggesting that these groups are in fact compact condensations in LGs. Determination of redshifts of member galaxies, and consequently the group distance, showed that 12 other ShCGs, have large projected linear length a of the order of $400 \div 600$ kpc. The length a was determined by from each other members of the group most distant. The space density of galaxies in these groups is < 10^2 per Mpc^3, which is not characteristic for CGs. Therefore, we qualify these groups as ordinary LGs and not CGs with high space density. The list of 16 ShCGs which are in fact LGs, is presented in Table 2. In columns 2-3 of Table 2 the radial velocity V of the group and the number of member galaxies with measured redshifts are presented.

In Table 3 we present the list of 41 ShCGs that are IGCs. In the area with projected radius 1 Mpc around most of these groups there are no accordant redshift galaxies. In the environment of some of them there are a couple of galaxies with radial velocities not differing significantly from that of the corresponding group. However, being located at sufficiently large distance from the centers of these groups, they may hardly be their physical members. The space density of these groups determined by using the listed candidate members [58-63] is > 10^2 galaxies per Mpc^3. In consecutive columns of Table 3 the following information is given: 1 - ShCG designation; 2 - the radial velocity V of

TABLE 3. Isolated Compact Groups

ShCG	V km s^{-1}	σ_v km s^{-1}	n	a kpc	Re-marks	ShCG	V km s^{-1}	σ_v km s^{-1}	n	a kpc	Re-marks
1	34415	713	7	212		186	22962	248	4	112	
3	45292	-	2	80		188	24626	306	7	350	
7	29783	-	2	80		212	39208	-	2	100	
8	32980	290	6	90		216	44916	74	3	390	
11	28525	240	4	420	a	220	31123	-	2	290	
19	20620	440	4	26		237	22082	-	2	130	d
22	24790	212	4	210		244	26273	104	5	150	
31	56180	407	5	210		251	18150	433	4	170	
49	44103	-	2	80		257	21424	146	3	235	
51	27837	364	10	500		266	42720	-	2	200	
60	32414	130	5	260		270	24960	254	3	200	
62	18590	84	3	330		344	23390	93	5	280	e
72	46520	-	2	66		345	34990	37	3	283	
74W	65610	108	3	170		346	40530	107	6	230	f
104	62090	205	3	110		350	22317	244	3	144	
105	28275	327	4	57		355	27970	112	6	73	
119	27753	115	3	294	b	358	15115	219	6	165	
120	21150	464	7	210	c	359	9660	372	4	50	
123	35060	556	7	280		371	39030	160	4	90	
128	43318	-	2	145		376	19805	547	9	215	g
182	32420	181	4	270							

a - 1 galaxy at projected distance $\approx$ 500 kpc; *b* - 1 galaxy at about 350 kpc; *c* - 3 galaxies at 400-500 kpc; *d* - 2 galaxies at $\approx$ 500 kpc; *e* - 3 galaxies at 400-500 kpc; *f* - 2 galaxies at 380 and 460 kpc; *g* - 1 galaxy at $\approx$ 800 kpc.

the group; 3 - the radial velocity dispersion σ_v; 4 - the number of member galaxies by which the former two parameters were determined; 5 - the projected maximum size *a*; 6 - remarks on the galaxies located within an area with a projected radius 1 Mpc. For 9 groups (ShCG 3, 7, 49, 72, 128, 212, 220, 237, and 266) the redshifts of only two members are determined. Some of these groups could simply be double galaxies.

Note that the rate of finding ICGs may be biased against the distance. In Fig.1 we present the histogram of the number of ShCGs of three categories: clusters, ordinary LGs and ICGs (including possible groups with known redshifts of two members). Figure 1 shows that the number of ShCGs associated with clusters and LGs decreases more sharply at radial velocities $V > 30000 \div 40000$ km s^{-1} than that of the supposed isolated groups. We suggest that faint galaxies in the distant group vicinities could fall below the detection threshold of spectral observations: the *r*-band Petrosian magnitudes $r \leq 17.77$ and the *r*-band Petrosian half-light surface brightnesses $\mu_{50} \leq 24.5$ mag arcsec^{-2} [64].

Therefore, some of the supposed isolated distant groups may in fact be not isolated. We suggest that in the environment of distant groups with radial velocities $V > 40000$ km s^{-1} there could be no detected faint members. Therefore, the isolated nature of groups ShCG 3, 10, 31, 49, 72, 74W, 104, 128, 216, 266 and 346 with $V > 40000$ km s^{-1} is not certain. For four of the nearby ShCGs ($V < 40000$ km s^{-1}) the redshifts of only two members are known. Thus, 26 out of 41 ShCGs are found to be truly isolated ones. Fifteen others may also be ICGs. The projected linear size *a* of most ICGs is < 300 kpc, and for six of them it is < 100 kpc.

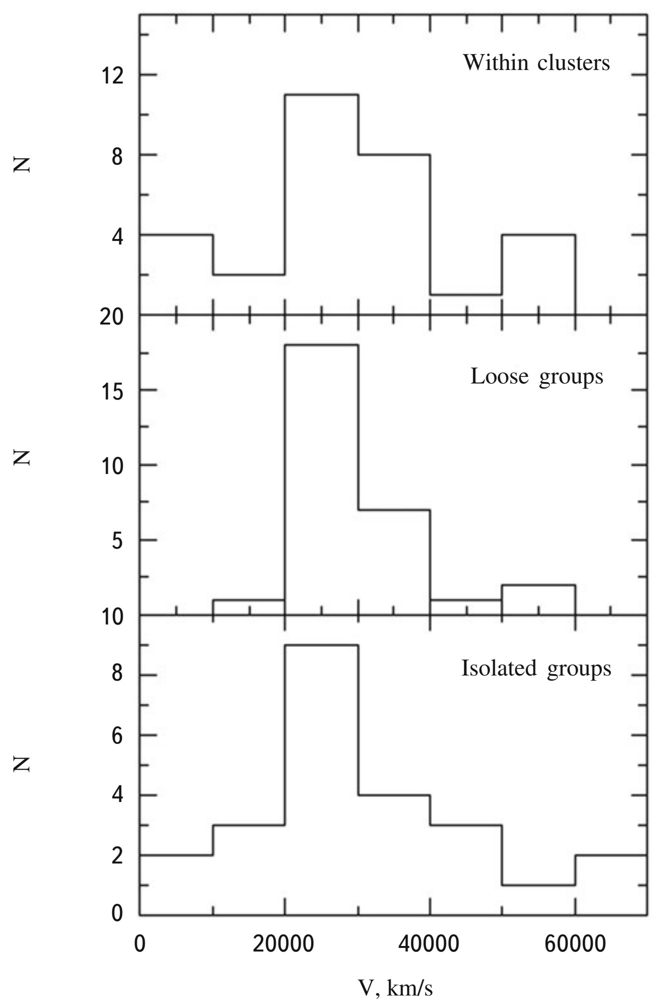

Fig.1. The histogram of the number of ShCGs located in clusters of galaxies (upper panel) and LGs (middle panel) and the number of ICGs (lower panel).

3. The morphological content of ShCG

It has been shown that about 70-80% of ShCG members studied by Tiersch et al. [51 and references therein] and Tovmassian and Tiersch [52 and references therein] are of E and S0 type galaxies. Note that only about half of the Hickson compact groups [66] contain early type galaxies [67]. Using the SDSS data [53] we determined the morphological types of members of isolated ShCGs not studied in Tiersch et al. and Tovmassian and Tiersch [51-52]. Only one ICG, ShCG 376, consists of only spiral galaxies [68]. The relative number of early type galaxies in all other ICGs is about 86% and is higher than generally in ShCGs. Thus, ShCGs are more dynamically evolved systems than Hickson compact groups, and ICGs are even more evolved.

3. Conclusions

Using the SDSS we inspected the environment of 78 ShCGs with known redshifts. We found that 20 ShCGs (Table 1) are condensations in clusters of galaxies, and 16 ShCGs (Table 2) are ordinary LGs with large projected linear size and small space density of galaxies. In the vicinity of most of the other 41 ShCGs (Table 3) there are no accordant redshift galaxies ($\Delta V < 1000$ km s^{-1}) up to 1 Mpc projected distance. In the environment of some nearby $V < 40000$ km s^{-1} groups there are 1-3 galaxies with radial velocities not very different from the mean radial velocity of the corresponding group. Being located at projected distances of several hundred kiloparsecs from the centers of corresponding groups, these galaxies may hardly be dynamically associated with them. For four nearby ShCGs the redshifts are known for only two members, so some of these groups may be double galaxies. Thus, 26 of the studied 78 ShCGs are certainly isolated groups. Fifteen other groups may also be isolated. The space density of ICGs exceeds 10^2 galaxies per Mpc^3. Faint galaxies possibly may not be detected in the environment of distant ShCGs with $V > 40000$ km s^{-1}. It is possible that some of them may also be ICGs.

The sample of isolated ShCGs is more appropriate for studying the CG dynamics. If the group members have quasi-regular movement around the group gravitational center, or if they are virialized, then for a sample of groups with about the same number of members (with about the same mass) there should be a correlation between the group length and the velocity dispersion [19,38]. If, however, CGs exist due to a process of secondary infall of the environmental galaxies [65], there could be no correlation between the group length and velocity dispersion. Note, however, that for many ICGs (Table 3) the redshifts of not all their members are known. Therefore, additional spectroscopic observations are needed for the dynamical study of the compiled sample of isolated ShCGs.

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