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REDSHIFTS OF 19 SHAKHBAZIAN COMPACT GROUPS OF GALAXIES

H. M. Tovmassian[1], H. Tiersch[2], V. H. Chavushyan[1], and S. G. Navarro[3]

By observations at Calar Alto (Spain), La Silla (Chile) and Cananea (Mexico), we measured redshifts of 108 candidate members in 19 Shakhbazian compact galaxy groups ShCG 44, 105, 149, 168, 270, 276, 278, 279, 298, 303, 304, 310, 317, 331, 339, 340, 345, 358, and 359. Redshifts of another ten members were taken from the NED. We found that nine out of 118 candidate member galaxies are stars, and twelve galaxies are not members of the corresponding groups and are projected over them. The group ShCG 168 is the core of a cluster. The groups ShCG 276, ShCG 298, and ShCG 303 are either strongly contaminated by field galaxies with redshift differing not very much from that of the corresponding group, or are the results of a chance projection of field galaxies.

Keywords: *galaxies: groups of galaxies*

1. Introduction

It has been shown that the overwhelming majority of observed galaxies in the Universe are contained in poor groups [1,2 and references therein]. They consist of 3-4 up to about 10-20 members. More interesting from the evolution point of view are the so-called compact groups (CGs) which usually contain not more than about 10 members, and the space density of which reaches up to $10^4 \div 10^5$ Mpc^3. The well-known and intensively studied groups are Hickson compact groups (HCGs) [3], the list of which consists of 100 entities. Dynamical simulations showed that the CG members merge into one galaxy in a relatively short time, and contrary to observations, CGs should not exist [4-7]. Therefore, Rose [8], Mamon [9], and Walke and Mamon [10] suggested that CGs may not be gravitationally bound physical systems, but may be chance alignments of galaxies in loose groups (LGs). According

[1] Instituto Nacional de Astrofisica Optica y Electronica, Luis Enrique Erro 1, Tonantzintla, Mexico, e-mail: hrant@inaoep.mx
[2] Sternwarte Königsleiten, München, Germany
[3] Instituto de Astronomía y Meteorología, Universidad de Guadalajara, Mexico

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to Hernquist, Katz, and Weinberg [11] and Ostriker, Lubin, and Hernquist [12], CGs are filaments seen end-on. However, there have been presented arguments that HCGs are real physical systems [13-16]. It has been also suggested that CGs are small subsystems in larger LGs [e.g., 17-22]. Diaferio, Geller, and Ramella [23] and Governato, Bhatia, and Chincarini [24] concluded that CGs are being continually formed in collapsing LGs.

For explanation of the existence of CGs Tovmassian, Martinez, and Tiersch [25], and Tovmassian [26] draw attention to the fact that HCGs preferentially have prolate space configuration (e.g., Malykh and Orlov [27], Plionis, Basilakos, and Tovmassian [28]) and finding a correlation between the group length and velocity dispersion suggested that members of compact groups most probably move preferentially along the group large axis. The proposed quasi-regular movement of the group members may prevent the fast collapse of CGs and explain their existence. Hence, CGs are more stable systems than follows from dynamical simulations. Tovmassian and Chavushyan [29] and Tovmassian, Plionis, and Torres-Papaqui [30] showed that members of ordinary LGs, in which CGs are embedded, have the same character of movement. Recently, Tovmassian and Plionis [31] showed that the observed dynamical properties of LGs are valid also, if the groups are in the process of virialization.

Hence, measurements of the CG member redshifts allow one to study the dynamics of groups and their evolution and is an important step for checking the theory of hierarchical formation of galaxies. The largest list of CGs is that of Shakhbazian (ShCGs) with nearly 400 groups [32,33 and references therein] compiled in the 70s. These groups were selected by visual inspection of the Palomar sky survey. Due to overexposure, some members of distant groups looked like compact galaxies, and therefore the groups were initially named compact groups of *compact* galaxies. However, already the first detailed photographic observations [34-36] showed that the so-called compact galaxies were in reality ordinary galaxies of presumably early morphological types. Hence, Shakhbazian groups are CGs of ordinary galaxies. It is worth noting that in Shakhbazian [32] the first group is mentioned as a dense group of red stars. However, Robinson and Wampler [36] showed shortly that members of this group are galaxies. Namely, this result stimulated the search for similar compact groups carried out by Shakhbazian in collaboration with Petrosian, Baier, and Tiersch [33 and references therein]. In spite of the fact that ShCGs have been selected without knowledge of redshifts of their members, already the first spectral observations [e.g., 37-41] of a small number of ShCGs showed that redshifts of the group members differ insignificantly from each other.

Tiersch et al. [42,43 and references therein] and Tovmassian et al. [44,45 and references therein] carried out spectral and detailed photometric studies of a large number of ShCGs. It was found that only a small number of the candidate group members are stars and that only a few groups are the result of a chance projection of field galaxies and/or stars [45]. At the same time, a few galaxies in some groups were classified as stars for the compactness of their images and were excluded from the content of originally selected groups. Hence, ShCGs are gravitationally bound real physical systems. The study of the compact group dynamics may be more efficient for the isolated Shakhbazian CGs, the list of which was compiled recently by Tovmassian, Torres-Papaqui, and Tiersch [46], who showed that 28% out of 98 ShCGs with known redshifts of their members are dense condensations in clusters of galaxies, 28% are condensations in LGs, and 26% are isolated compact groups. At projected distances of up to 1 Mpc in the environment of the latter there are no galaxies with redshifts differing from the mean redshift of the corresponding group by less than 1000 km s^{-1}.

In this paper we present the results of spectral observations of 19 Shakhbazian compact groups. We determined the redshifts of 108 members of these groups and their velocity dispersion and crossing time.

2. Observations and results

Observations of ShCGs reported in this paper have been made with the 2.2 m telescope at Calar Alto (Spain), the 2.12 m telescope at Gillermo Haro Observatory in Cananea (Mexico), and the 1.5 m telescope at European Southern Observatory in La Silla (Chile). The list of observed groups and corresponding telescopes is presented in Table 1. At Calar Alto the Cassegrain spectrograph with the TEK CCD having 1024 × 1024 pixels with sizes 24 μm and a 600 lines/mm grating blazed at 5000Å with a dispersion 120Å/mm in the range 4900-7650Å was used. The used slit width was 2.5 arc sec. The wavelength calibration was done with HeAr comparison spectra taken before and after the galaxy observation. Pixel-to pixel variations were calibrated with the use of the dome flats. At Cananea the

TABLE 1. Observational Log.

ShCG	Telescope	Data
44	2.12 m, Cananea	Oct.96, Nov. 99
105	2 m, Calar Alto	Nov. 94
149	2.12 m, Cananea	Nov. 95, Jan 99
168	2.12 m, Cananea	May 98
270	2.12 m, Cananea	Oct.96
276	1.5 m, La Silla	Oct. 95
-//-	2.2 m, Cananea	Aug. 96, Sep. 96
278	1.5 m, La Silla	Oct. 95
279	1.5 m, La Silla	Oct. 95
298	1.5 m, La Silla	Oct. 95
-//-	2.12 m, Cananea	July 96
303	2.12 m, Cananea	July 97, Oct. 96
304	2.12 m, Cananea	Oct. 96
310	2.12 m, Cananea	Oct. 96
317	1.5 m, La Silla	Oct. 95
-//-	2.12 m, Cananea	Oct. 96
331	1.5 m, La Silla	Oct. 95
-//-	2.12 m, Cananea	Aug. 98
339	2 m, Calar Alto	Dec. 93
340	2 m, Calar Alto	Dec. 93
345	2.12 m, Cananea	Oct. 95, March 99
358	2.12 m, Cananea	May 95, Apr. 96
359	2.12 m, Cananea	Apr. 96, March 99

TABLE 2. Rerdhifts of ShCG Members

Galaxy	44	105	149	168	270	276	278	279	298
1	0.0880p	0.0927	0.0900	0.1239	0.0811	0.1067	0.1185n	0.0652	0.1563p
2	0.0777	0.0956	0.0910	0.1282	-	*	0.1219	0.0674	0.1692
3	*	0.0933	0.0849p	-	0.0830	0.1069	0.1223	0.0689	0.1676
4	0.0770	-	-	-	0.0828	*	0.1207e	0.0644	0.1707
5	0.0789	-	0.0885	-	-	0.1111	0.1242	*	0.1668
6	0.0789	-	0.0881	0.1285	-	0.1067	0.1197	0.0666	0.1693
7	0.0787	-	-	-	-	0.1053	0.1192	-	0.1652
8	0.0770	0.0939	-	-	-	-	-	0.0669e	-
9	-	-	-	-	-	-	-	-	-
10	-	-	-	0.1130p	-	*	-	-	-
11	-	0.0898p	-	0.1241	-	-	-	-	-

TABLE 2. (continued)

Galaxy	303	304	310	317	331	339	340	345	358	359
1	0.0842n	0.0760	0.1135n	0.0427	0.0539e	0.1102	0.1052	0.1169	0.0505	0.0355
2	0.0788p	0.0720	0.1132n	0.0419	-	0.1098	-	-	0.0499	0.0329n
3	0.0858	0.0747e	0.1134	0.0426	-	-	0.1028	-	0.0492e	0.1015p
4	0.0801n	*	0.0446p	0.0412	0.0547e	0.1092	0.1059	*	0.0514	0.0314
5	0.0842	*	0.1132	0.0414	0.05426	0.1096	0.1045n	-	0.0512	0.0339
6	0.0843n	-	0.1097	0.0426	-	-	0.1050	0.1171	0.0513	-
7	0.1787p	-	-	0.0435	0.0550	-	0.1046	-	0.0453p	0.1034p
8	0.0823n	-	-	-	-	-	0.1032	0.1172	-	-
9	0.0845	-	-	-	-	-	-	-	-	-
10	0.0858n	-	-	0.0426	-	0.0426p	-	-	-	-

LFOSC spectrograph was used. Observations were made with a mean dispersion of 5.5Å/pxl and mean resolution of 13Å. At La Silla the Cassegrain Boller & Chivens spectrograph equipped with a CCD FA2K 24 and a dispersion 114Å/mm was used.

The reduction of observations was done with the MIDAS program or the IRAF package. Redshifts were measured with an accuracy of about 0.0002. In the case of very faint objects the error may reach 0.0003. The redshifs of 108 supposed members in 19 ShCGs are presented in Table 2, in which the redshifts of ten member galaxies of the studied ShCGs found in the NED (NASA/IPAC Extragalactic Database) are also included. The latter are marked by "*n*". The numeration of member galaxies of groups is presented according to Stoll, Tiersch, and Braun [47 and references therein] and Stoll, Tiersch, and Cordis [48 and references therein]. We found that eight of the supposed members, marked by "*" in Table 2 (objects №3 in ShCG 44, №2, 4 and 10 in ShCG 276, №5 in ShCG 279, №4 and 5 in ShCG 304 and №4 in ShCG 345), are stars. It is worth noting that Bettoni and Fasano [36], from results of a photometric study, mention that objects 6, 7, 8, 9, and 10 in ShCG 340 are stars. Meanwhile, our spectroscopic investigation showed that objects 6, 7, and 8 are in fact galaxies. Galaxies №4 in ShCG 278, №8 in ShCG 279, №3 in ShCG 304, №1 and 4 in ShCG 331, and №3 in ShCG 358 have emission lines in the spectra. Twelve galaxies in the area of the studied groups have redshift that differ appreciably from the mean redshifts of the corresponding group and thus are projected over these groups. Such are galaxies №1 in ShCG 44, №11 in ShCG 105, №3 in ShCG 149, №10 in ShCG 168, №1 in ShCG 298, №2 and 7 in ShCG 303, №4 in ShCG 310, №10 in ShCG 339, №7 in ShCG 358, and №3 and 7 in ShCG 359. Redshifts of these galaxies are marked by "*p*" in Table 2. Hence, we found that 82% of the candidate members of the studied groups are accordant redshift galaxies.

In Table 3 we present the mean redshift z, velocity dispersion σ_V and crossing time τ_c of the studied groups. We adopted H = 75 km/s/Mpc. The velocity dispersions of 17 groups are less than 500 km s^{-1} which is typical for groups. The velocity dispersion of clusters of galaxies is generally higher, reaching about 1000 km s^{-1}. The velocity dispersion of the group ShCG 168, which is the core of the cluster ZwCl 1832.4+8306, is about 650 km s^{-1}. The velocity dispersion of two other groups, ShCG 276 and 298, also exceeds 500 km s^{-1}. We suggest that the latter two groups may be contaminated by the projection of field galaxies over them, or the result of a chance projection of unrelated field galaxies. Mamon [9] and Walke and Mamon [10] suggested that CGs generally may not be gravitationally bound physical entities but may be chance alignments of galaxies in LGs. Note that Niemi et al. [49] showed that about 20% of groups found by the friends-of-friends algorithm may not be gravitationally bound real groups but spurious systems. Crossing time of groups is generally less than 20×10^7 y. The only exception is the group ShCG 345, the τ_c of which is 135×10^7 y.

TABLE 3. Radial Velocity Dispersion, σ_V and Crossing Time τ_c of ShCGs

ShCG	z	σ_V km/s	$\tau_c\times10^7$	ShCG	z	σ_V km/s	$\tau_c\times10^7$
44	0.07818	250	5.4	304	0.0759	324	4.7
105	0.09425	327	5.6	310	0.11343	292	12.8
149	0.09009	350	7.1	317	0.04259	213	18.2
168	0.12705	653	14.7	331	0.05537	113	7.5
270	0.08231	254	26.4	339	0.11026	108	18.2
276	0.10616	175	14.6	340	0.10514	324	11.2
278	0.12036	578	4.2	345	0.11662	37	135
279	0.06675	399	3.5	358	0.04956	335	7.1
298	0.16854	503	7.9	359	0.03368	447	1.8
303	0.08486	240	17.6				

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