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COMPACT GROUPS: LOCAL GROUPS?

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ABSTRACT

It is concluded that faint members found in the vicinities of compact groups (CGs) are gravitationally bound with corresponding groups. All members of CGs, faint and bright, move preferentially in the direction of the elongation of the group. We suppose that the number of faint members may be much larger than previously assumed. These two circumstances should apparently change the conclusion about the short lifetime of CGs. Consequently, many puzzles related to CGs, such as their very existence, the absence of strong radio and infrared sources, and the absence of strong signs of interaction and merging will probably vanish.
Key words: Local Group

1. INTRODUCTION

N-body simulations have shown that members of compact groups (CGs) of galaxies should merge into one single cD-type galaxy in a relatively short cosmological time, about 10^8–10^9 yr (Carnevali, Cavaliere, & Santangelo 1981; Ishizawa et al. 1983; Barnes 1985, 1989; Ishizawa 1986; Mamon 1986; Zheng, Valtonen, & Chernin 1993). Meanwhile, many investigators (Menon 1992, 1995; Leon, Combes, & Menon 1998; Zepf & Whitmore 1991; Zepf 1991; Moles et al. 1994; Sulentic & de Mello Rabaça 1993; Bettoni & Fasano 1993; Fasano & Bettoni 1994; Pildis, Bregman, & Schombert 1995; Sulentic & Rabaça 1994; Sulentic & de Mello Rabaça 1993; Sulentic 1997) have mentioned many puzzles and inconsistencies related to CGs. The greatest puzzle is the very existence of CGs, since they should disappear in a very short cosmological time. The investigators mentioned above draw attention to the strange absence of strong radio sources, the absence of strong signs of interaction and merging, such as blue colors or far-infrared (FIR) emission, and the fact that the elliptical members (best candidates for ongoing mergers) are not more frequently ranked first than spirals are.

To get rid of all these puzzles and controversies, Rose (1977), Mamon (1986, 1995), and Walke & Mamon (1989) suggested that CGs simply do not exist, that they are just a result of a projection of field galaxies over a small area on the sky. Similarly, Hernquist, Katz, & Weinberg (1995) and Ostriker, Lubin, & Hernquist (1995) suggested that CGs are filaments seen end-on.[1] Yet Hickson & Rood (1988), Mendes de Oliveira & Giraud (1994), Mendes de Oliveira (1995), Ponman et al. (1996), Hickson (1997), Oleak et al. (1995, 1998), and recently Tovmassian, Martinez, & Tiersch (1999a, hereafter TMT, 1999b) have presented firm evidence for the physical reality of CGs.

As for solving the problem of longer lifetimes of CGs, Diaferio, Geller, & Ramella (1994) and Governato, Bhatia, & Chincarini (1991) have suggested that field galaxies fall from time to time from the denser environments onto CGs, thus preventing them from coalescing quickly (see Rose 1977; Sulentic 1987; Rood & Williams 1989; Ramella et al. 1994; de Carvalho, Ribeiro, & Zepf 1994). In this scenario, all puzzles related to CGs, except their existence, still remain.

To solve these puzzles, one probably needs to look for other possible scenarios. All of the puzzles arise from unconditional acceptance of the results of N-body simulations. Perhaps they should be reconsidered.

In this paper, we present some arguments that raise doubts about the validity of N-body simulations of CGs. We use the data from the extensive multifiber spectroscopic study of the regions around some compact and poor groups made by de Carvalho et al. (1997, hereafter CRCZ), and Zabludoff & Mulchaey (1998, hereafter ZM). The data analysis is presented in § 2.

2. DISCUSSION

TMT found that the line-of-sight radial velocity dispersion σ_v depends on the elongation of the group: the smaller b/a is, i.e., the closer the direction of elongation of the group is to the perpendicular to the line of sight, the smaller is σ_v (Rood 1979).[2] Thus, in the case of elongated chainlike groups that are oriented close to the perpendicular to the line of sight the velocity components directed toward us of member galaxies are small, and the values of σ_v are consequently also small. For groups with larger values of b/a, i.e., for those in which the elongation is oriented close to the line of sight, the measured velocities are large, and hence the values of σ_v are also large. From this correlation TMT concluded that member galaxies in CGs are moving along the group's longest axis and hence that CGs are undoubtedly gravitationally bound physical formations.

Furthermore, it was statistically shown (Tovmassian, Yam, & Tiersch 2000, hereafter TYT) that members of loose groups in the surroundings of CGs are not just field galaxies unrelated to CGs but are dynamically associated with the latter. Their conclusion is based on the fact that the number of Hickson compact groups (HCGs) associated with loose groups is greatest when the orientation of the HCG elongation is about 45°, i.e., when conditions are most favorable for detection of loose groups. In the context of the latter results, we examined the data on spectroscopy of faint galaxies in the surroundings of some HCGs and poor groups of galaxies (CRCZ; ZM).

[1] This is reminiscent of the history of OB stellar associations discovered by Ambartsumian. At that time, some investigators were arguing against the existence of OB stellar associations, saying that they were just a result of a projection of OB stars located at different distances.

[2] The width of a group is b and its length is a.

TABLE 1

VALUES OF b/a AND σ_v AND NUMBER OF MEMBERS FOR HICKSON COMPACT GROUPS

HCG	b/a	σ_v (km s^{-1})	n
4	0.36	775	5
16	0.38	86	7
19	0.67	170	7
22	0.26	40	4
23	0.54	316	8
40	0.32	280	7
42	0.37	211	20
48	0.67	450	10
62	0.91	376	41
67	0.62	351	14
86	0.79	513	8
87	0.22	249	8
88	0.35	72	6
90	0.66	193	16
97	0.62	425	14

As in TMT, we determined the ratio b/a for HCG 4, 16, 19, 22, 23, 40, 42, 48, 62, 67, 86, 87, 88, 90, and 97, considering them together with the detected faint members.[3] In the cases of HCG 42, 62, and 90, the richer data of ZM were used. The deduced values of b/a and the values of σ_v are presented in Table 1. Radial velocity dispersions are taken from Ribeiro et al. (1998) and ZM. In the case of HCG 23, we deduced a smaller value of σ_v by not including galaxy 18, which has a much different radial velocity. We compared the values of b/a with the values of σ_v for corresponding groups in Figure 1.

From Figure 1 it is seen that σ_v increases with the ratio b/a. Only HCG 4 departs from the trend in Figure 1. It may well be that this is not a real physical group. It has been considered a chance projection of field galaxies by Ribeiro et al. (1998). The dashed line in Figure 1 is drawn without taking into account this supposedly false group. It was shown by TMT that the increase of σ_v is not dependent upon the number of members of a group. The labels near each point on Figure 1 mark the corresponding number of group members. It is evident that there is not any correlation between the number of group members and the values of σ_v.

By using the data on HCG 42, 62, 67, 86, 90, and 97 (CRCZ; ZM), which contain at least 14 galaxies, we determined the distribution of the surface density of galaxies over these groups. The observed area of each group (1.0–1.5 deg^2) was divided into strips of 0.1–0.2 Mpc width ($H_0 = 75$ Mpc^{-1} km s^{-1}), which are directed approximately along and perpendicular to the direction in which the brightest four or five members of the group are located. The values of the surface density, ρ, of all the galaxies in the corresponding strips were deduced. Then we deduced the normalized distribution of ρ for each considered group along the longest elongation (a) and perpendicular to it (b). It is found that the surface density is relatively strongly peaked in the direction perpendicular to the elongation of the group and is more widely spread along the elongation. The half-widths

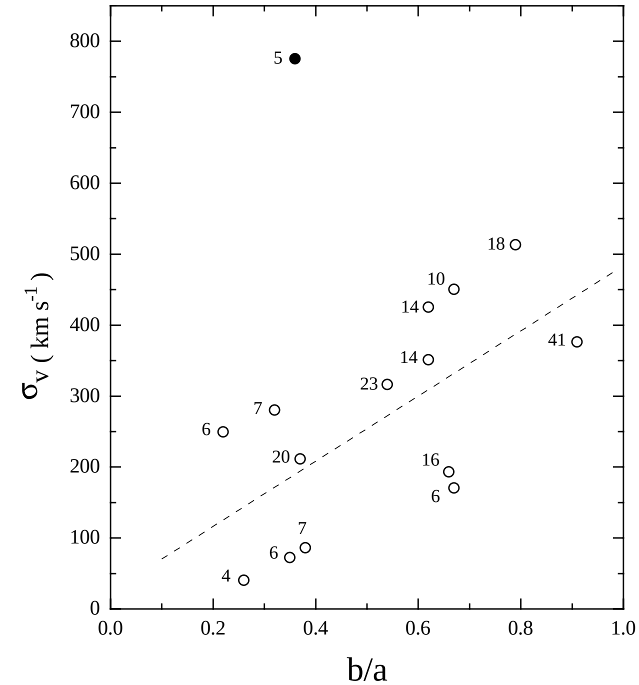

FIG. 1.—Correlation of σ_v with b/a determined for all members (*open circles*) detected in the vicinities of the HCGs. Labels indicate the number of members in the corresponding groups. The dashed line is the least-squares fit drawn without taking into account the group HCG 4 (*filled circle*).

along the elongation of the group, w_b, and perpendicular to it, w_a, were determined by a Gaussian fit. The center of each group and the directions of the largest elongation were chosen to obtain the largest difference in the widths of corresponding groups in perpendicular directions. The chosen centers sometimes differ slightly from those given by CRCZ and ZM. The positions of centers and position angles of strips directed along the elongation of groups are presented in columns (2)–(4) of Table 2. The values w_a and w_b and the ratios w_b/w_a are listed in columns (5)–(7) of Table 2. The ratio w_b/w_a, like the ratio b/a (Rood 1979), characterizes the ellipticity of the group. In column (8) of Table 2, the errors of the determined ratios w_b/w_a are presented. The values of σ_v from CRCZ and ZM are listed in column (9).

We plot in Figure 2 the dependence of σ_v on the ratio w_b/w_a. Figure 2 shows that in spite of the relatively large errors in w_b/w_a, there is a certain trend: the larger w_b/w_a is, i.e., the closer to the line of sight the elongation of the group is oriented, the larger the radial velocity dispersion σ_v is. And, as in Figure 1, it is seen that the number of members does not have any relation to the correlation.

The observed increase in values of σ_v for CGs with the increase in b/a or w_b/w_a has a natural explanation: member galaxies are moving along the elongations of groups that have a generally prolate spheroid shape (Hickson et al. 1984; Malykh & Orlov 1986). For this reason the differences in σ_v of the groups depend mainly on the orientation of the elongation of the group in relation to the observer. When the large axis of the group approaches the line of sight, σ_v reaches its largest value.

There may be three possible explanations:

1. There is an infall of field galaxies from opposite directions toward the center of the group along its longer axis.

[3] HCG 63 and HCG 64 are omitted from our list because we were not able to identify galaxies with measured redshifts in CRCZ.

TABLE 2

SURFACE DENSITIES OF GALAXIES IN HICKSON AND NGC GROUPS

Group (1)	R.A. (J2000.0) (2)	Decl. (J2000.00) (3)	P.A. (deg) (4)	w_a (5)	w_b (6)	w_b/w_a (7)	σ_{w_b/w_a} (8)	σ_v (km s^{-1}) (9)
HCG 42	10 00 10.2	−19 39 10	60	0.56	2.52	0.22	0.08	211
HCG 62	12 53 21.3	−09 13 12	163	0.75	1.40	0.54	0.13	376
HCG 67	13 49 05.7	−07 11 40	148	0.59	1.30	0.45	0.29	350
HCG 86	19 51 56.4	−30 49 21	36	0.97	1.90	0.48	0.22	294
HCG 90	22 02 36.4	−32 01 02	26	0.45	1.26	0.36	0.16	193
HCG 97	23 47 18.4	−02 18 08	55	0.89	1.79	0.50	0.21	425
NGC 533	01 25 34.4	01 46 32	147	1.18	1.75	0.67	0.22	464
NGC 741	01 56 24.3	05 39 25	126	0.98	1.71	0.57	0.20	432
NGC 2563......	08 20 37.2	21 04 58	113	0.92	2.08	0.37	0.18	336
NGC 4325......	12 23 08.7	10 34 37	52	0.83	1.98	0.42	0.23	265
NGC 5129......	13 24 28.5	13 55 05	15	0.59	1.27	0.45	0.08	294
NGC 5846......	15 06 06.2	01 34 47	142	1.18	2.84	0.41	0.14	368

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

This may happen if CGs are dense formations in filaments, as suggested by Hernquist et al. (1995) and Ostriker et al. (1995). However, in such a case we should observe almost edge-on filaments, though according to Hernquist et al. (1995) and Ostriker et al. (1995) we see CGs in the filaments seen end-on.

2. Galaxies are ejected from a central galaxy and move outward from the group in opposite directions, in accordance with Ambartsumian's (1961) or Arp's (1973, 1997) ideas.

3. Faint members of groups are gravitationally bound with corresponding groups, as statistically shown by TYT.

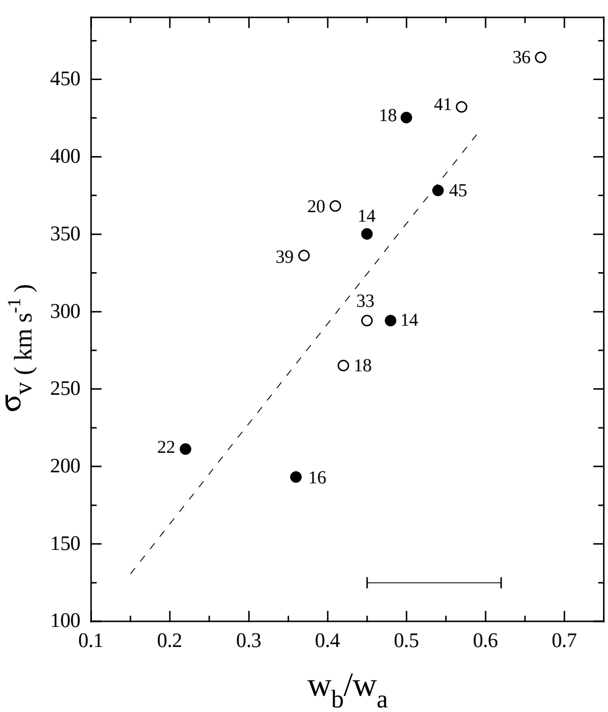

FIG. 2.—Correlation of σ_v with w_b/w_a for HCGs (*filled circles*) and poor groups (*open circles*). Labels indicate the number of members of the corresponding groups. The dashed line is the least-squares fit drawn through the HCGs. The mean error of the ratio w_b/w_a for all groups is shown by a horizontal bar.

Such a conclusion was also made by CRCZ and ZM. Our results show, in addition, that all group members move in orbits directed along the elongation of a group.

In the case of the first two options, it is not possible to explain the multitude of mentioned puzzles related to CGs: absence of strong radio sources, absence of strong signs of interaction and merging, etc. (see § 1). Hence we may conclude that the third explanation is the most realistic, i.e., faint members, along with bright members of CGs, compose gravitationally bound systems. Because of regular movement in a preferential direction along the longest elongation of a group, the number of interactions should be substantially decreased.

In Figure 2 we also plot the corresponding data on six poor groups, NGC 533, 741, 2563, 4324, 5129, and 5846, studied by ZM. It is apparent that the same correlation between σ_v and w_b/w_a holds for poor groups as well.

It is important to note that faint members of the studied groups detected by CRCZ and ZM are relatively bright galaxies, up to about −17 to −18 mag. It is likely that more sensitive observations may detect even fainter members. If CGs are formations similar to our Local Group, then they should contain many dozens of nondetectable, fainter members (Pritchet & van den Bergh 1999). Hence, CGs may be much richer formations than has generally been assumed.

It follows then that the regular movements of member galaxies along the direction of the group's elongation and much larger masses of groups should be taken into account in the *N*-body simulations of CGs.

3. CONCLUSIONS

It has been shown earlier that some CGs are in a dense galactic environment (Rose 1977; Sulentic 1987; Rood & Williams 1989; Ramella et al. 1994). Moreover, it has been shown that some field galaxies surrounding CGs have almost the same radial velocity as the group members (CRCZ), meaning that these galaxies are located at about the same distances from us as the corresponding groups.

Comparison of the elongation b/a or w_b/w_a with the line-of-sight radial velocity dispersion σ_v of CGs, considered together with faint galaxies detected in their vicinities, shows that all members of CGs move preferentially along the direction of the elongation of a group, and that faint galaxies *are gravitationally associated* with CGs. The difference in the observed values of σ_v for CGs is mainly due to the orientation of the group. Observed values of σ_v are smaller for groups for which the elongation is oriented close to the perpendicular to the line of sight. Hence, real values of σ_v for CGs should be close to the largest value found, i.e., about 400–500 km s^{-1}.

It can be concluded that CGs are more stable configurations than assumed previously. Apparently, CGs may contain hundreds of faint members that are not observed because of their large distances. Hence, CGs may be formations similar to the Local Group. The proximity of some bright members to each other on the sky may in many cases be a projection effect.

It is then apparent that the initial conditions of N-body simulations that led to predicting a very short lifetime of CGs should be reconsidered. A very important point here is the regular movement of member galaxies along the elongation of the group. Sulentic & Rabaça (1994) have also suggested a much longer timescale for CGs.

It seems that by taking into account the regular movement of member galaxies within a group and the much larger number of members we may solve all puzzles related to CGs.

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