Environments of Redshift Survey Compact Groups of Galaxies

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ABSTRACT

Redshift Survey Compact Groups (RSCGs) are tight knots of $N \geq 3$ galaxies selected from the CfA2+SSRS2 redshift survey. The selection is based on physical extent and association in redshift space alone. We measured 300 new redshifts of fainter galaxies within $1h^{-1}$ Mpc of 14 RSCGs to explore the relationship between RSCGs and their environments.

13 of 14 RSCGs are embedded in overdense regions of redshift space. The systems range from a loose group of 5 members to an Abell cluster. The remaining group, RSCG 64, appears isolated.

RSCGs are isolated and distinct from their surroundings to varying degrees, as are the Hickson Compact Groups. Among the 13 embedded RSCGs, 3 are distinct from their general environments (RSCG 9, RSCG 11 and RSCG 85).

Subject headings: galaxies: clusters: general — galaxies: distances and redshifts — galaxies: interactions

1. Introduction

Compact groups, the densest known systems of galaxies in the universe, are apparent knots on the sky where member galaxies may be close enough to interact and merge. Compact groups were originally selected as apparently dense systems on the sky (Rose
1977; Hickson 1982; Prandoni et al. 1994; see Hickson (1997) for a review). More recently, Barton et al. (1996) identified an objectively-selected sample of Redshift Survey Compact Groups (RSCGs) from the CfA2 and SSRS2 magnitude-limited redshift surveys. The physical properties of RSCGs (velocity dispersion, density, membership distribution) are similar to those of the Hickson Compact Groups (HCGs). RSCG selection criteria include only physical extent and association in redshift space.

The abundance of compact groups is a challenge for dynamical models because their crossing times are often much less than the Hubble time. Some simulations and observations suggest that actual galaxy merging times are longer. Simulated compact groups may take up to a few Gyr to merge if a substantial amount of the group mass is located in the common group potential well (Mamon 1987, Barnes 1989, Bode et al. 1993), or possibly longer if the galaxies have a range of masses on particular quasi-stable orbits (Governato et al. 1991). Pildis (1995) reports evidence that the diffuse light in HCG 94 traces the same group potential as the hot gas, suggesting a stable group potential on timescales $\geq 1$ Gyr.

Short lifetimes are not a problem if the groups form continually in dense environments like loose groups (Barnes 1989; Diaferio et al. 1994), or if they are chance projections of galaxies and thus less dense than they appear on the sky. Mamon (1986) suggested that about half of compact groups are chance alignments of galaxies within loose groups, not physical subcondensations. Similarly, Hernquist et al. (1995) proposed that some compact groups are superpositions of galaxies viewed along filaments. In these three scenarios, compact groups are embedded in environments that are overdense in redshift space. If some are collapsing physical systems forming in loose groups, they will on average bear a different relationship to their environments than if they are chance projections. The environments of compact groups thus provide clues about the likelihood that they are physically dense.

Previous studies of galaxies near HCGs led to mixed conclusions about their surroundings. Sulentic (1987), Rood & Williams (1989), de Carvalho et al. (1994) and Palumbo et al. (1995) examined the distribution of galaxies on the sky around HCGs; Rubin et al. (1991), Ramella et al. (1994) and de Carvalho et al. (1997) examined HCG environments in redshift space. These studies generally conclude that some fraction of HCGs are embedded in denser environments, with varying isolation from their environments. These results raise the questions (1) what does “isolation” mean for a compact group and (2) how does Hickson’s isolation criterion affect his sample? The RSCG catalog provides an approach to this issue; in contrast with Hickson, Barton et al. included no isolation criteria in their sample selection.

Catalogs of compact groups contain a mixture of systems. When we refer to a “compact group” we refer to a member of a catalog, a member which may differ from all the
others in fundamental ways and which may or may not be a physically associated system. Compact group environment studies seek to answer two distinct questions: (1) what are the environments of compact group catalog members and (2) are individual compact groups distinct, gravitationally bound systems or subsystems? In almost all cases we cannot answer the latter question definitively without precise distance measurements.

Tidal distortions of member galaxies and x-ray emission are indicators of a gravitationally bound system. However, tidal distortions are not a necessary consequence of a gravitationally bound system and x-ray emission may be associated with individual galaxies in an unbound system. Nor do luminosity function or morphological distinctions between “field” and compact group galaxies indicate that individual compact groups are bound. They can show only that the set of compact group galaxies differs from the typical population.

Optical galaxy distribution studies provide a statistical measure of the probability that compact groups are physical systems. Here we characterize the environments of 14 RSCGs with \( cz > 2300 \text{ km s}^{-1} \) from the CfA2North and CfA2South redshift surveys in order to: (1) characterize the environments of RSCGs and (2) explore how distinct RSCGs are from their environments, as a clue to whether they are chance projections. We address the first issue by testing whether the environments are overdense in redshift space. We apply statistical measures of the relationship between each compact group and its redshift space environment to explore the second issue.

In Sec. 2 we describe the subsample of RSCGs and the construction of redshift catalogs around RSCGs. Sec. 3 is a description of our method of defining the RSCG environment. In Sec. 4 we address the embeddings of RSCGs. Sec. 5 contains our evaluation of individual RSCG embeddings; this section addresses the distinction between individual compact groups and their environments. We conclude in Sec. 6.

### 2. Selection and Construction of RSCG Environment Catalogs

We select our subsample of 14 groups from the 47 RSCGs in the CfA2 redshift survey with \( cz > 2300 \text{ km s}^{-1} \). We choose groups located on POSS-II plates for which object catalogs are available (except RSCG 29). The 14 RSCGs are marginally representative of the larger sample of all 58 RSCGs in the CfA2+SSRS2 survey with \( cz > 2300 \text{ km s}^{-1} \). Table 1 lists the K-S probabilities that several RSCG parameters have similar distributions in the observed subsample and the sample of 44 RSCGs with \( cz > 2300 \text{ km s}^{-1} \) in the CfA2+SSRS2 survey. Figure 1 compares the distributions of velocity (redshift), membership
frequency, velocity dispersion and overdensity of the environment (compared with the average over the redshift survey) for the two subsamples. Most of the 14 RSCGs are in dense regions of the redshift survey. Our sample excludes the densest environments.

We extract catalogs of all objects from the Digitized POSS-II sky survey (Djorgovski et al. 1997) to a limiting magnitude of $m_{\text{lim}} \sim 16.9$ in g to include the faintest galaxies that we can observe efficiently with the Tillinghast telescope. We use SKICAT object classifications, which are based on a Decision Tree algorithm (Weir et al. 1995; Weir 1994), to identify a sample of 573 galaxies within 1 h$^{-1}$ Mpc (projected) of the center for 13 of the RSCGs in our subsample. Because we are looking for relatively bright objects, for which SKICAT classifications are the most uncertain, we examined either the POSS-I or POSS-II image of each object to check the SKICAT classifications. We also checked the regions for bright galaxies missed by the SKICAT algorithm. For the remaining group, RSCG 29, we used the FOCAS object identification package in IRAF on the Digitized Sky Survey image to identify 30 nearby galaxies.

To avoid remeasuring known redshifts, we checked the CfA Redshift Catalogue (Geller & Huchra 1989; Huchra et al. 1990; Huchra et al. 1995a; Huchra et al. 1995b; Giovanelli & Haynes 1985; Giovanelli et al. 1986; Haynes et al. 1988; Giovanelli & Haynes 1989; Wegner et al. 1993; Giovanelli & Haynes 1993; Vogele 1993) for velocity measurements of the sample galaxies. In ambiguous cases we remeasured velocities, including those for several RSCG galaxies. Table 2 describes the measured sample, which contains a total of 509 galaxies, including 300 newly measured galaxies. In order to save space and avoid redundant publication of data, Table 3 lists only the newly measured galaxies, and identifies the galaxies in each RSCG or its environment, according to the criteria described below. A complete list of the galaxies in our catalog, including new redshifts and redshifts taken from the CfA Redshift Catalogue, is available via anonymous ftp at: ftp://cfa0.harvard.edu/pub/barton. The RSCG coordinates in the table differ from those in the original RSCG paper because we now have coordinates good to $\sim 1$ arcsecond for RSCG 29 (POSS-I) or $\sim 0.5$ arcseconds for the other regions (POSS-II).

We measured the new redshifts with the FAST spectrograph at the 1.5m Tillinghast reflector on Mt. Hopkins. We used a grating with 300 lines/mm to disperse the light into the wavelength range 4000 – 7500 Å; typical exposure times were 10 - 20 minutes. We measured radial velocities using the XCSAO program in IRAF (Kurtz et al. 1992). The program implements the cross-correlation technique of Tonry & Davis (1979) on data binned logarithmically in wavelength. Errors in velocity for emission-line redshifts are dominated by fluctuations in the small number of emission regions contributing to the measurement. To account for this effect empirically we add 75 km s$^{-1}$ in quadrature to the
cross-correlation errors for emission line redshifts (Kurtz et al., private communication). We did not change original CfA2 Redshift Survey errors, so errors for emission redshifts may be underestimated.

3. Identifying Systems Surrounding the RSCGs

We implement a slight modification of the friends-of-friends group-finding algorithm with “volume scaling” to identify members of loose systems around the RSCGs (Huchra & Geller 1982). We use a code from Ramella et al. (1997). We identify galaxy systems as linked sets of “neighboring” galaxies. To determine whether two galaxies belong to the same system, we consider both their projected separation, $\Delta D$, and their line-of-sight velocity difference, $\Delta V$. At low redshift, $\Delta D = 2 \left( \frac{v}{H_0} \right) \sin \left( \frac{\Delta \theta}{2} \right)$, where $\Delta \theta$ is the angular separation on the sky and $v = cz$ is the average redshift. We scale $\Delta D$ and $\Delta V$ in accord with the sampling of the luminosity function. The volume we search for “neighbors” is inversely proportional to the integral of the luminosity function at the median redshift of the RSCG. Throughout the paper we use $H_0 = 100$ km s$^{-1}$ Mpc$^{-1}$.

We restrict the density contrast of our groups to $\delta \rho/\rho \geq 80$ by specifying fiducial parameters, $D_0$ and $V_0$, and requiring $\Delta D \leq R D_0$ and $\Delta V \leq R V_0$, where $R$ is the redshift-dependent scaling parameter. $D_0$ and $R$ are functions of the limiting Zwicky magnitude, $m_{\text{lim, Zw}}$. As we lack photometric calibration for the object catalogs, our sample is inhomogeneous; $m_{\text{lim, Zw}}$, and therefore $D_0$ and $R$, vary among the RSCG environments. Linked sets of “neighbors” satisfying these criteria are part of the same system. Here, $R$ depends on the median velocity of the RSCG:

$$R = \left[ \frac{\int_{-\infty}^{M_{\text{med}}} \Phi(M) dM}{\int_{-\infty}^{m_{\text{lim, Zw}}} \Phi(M) dM} \right]^{-1/3},$$

where $M_{\text{med}} = m_{\text{lim, Zw}} - 25 - 5 \log \left( \frac{v_{\text{med}}}{H_0} \right)$ is the limiting absolute magnitude at the median group velocity, $v_{\text{med}}$; $\Phi(M)$ is the CfA2North or CfA2South luminosity function (Marzke et al. 1994) and $\frac{v_{\text{med}}}{H_0}$ is in Mpc. Similarly, $M_{\text{lim}} = m_{\text{lim, Zw}} - 25 - 5 \log \left( \frac{v_F}{H_0} \right)$, where $v_F$ is an arbitrary fiducial velocity. We choose $v_F = 1000$ km s$^{-1}$.

The parameter $D_0$ determines the minimum galaxy density enhancement, $\delta \rho/\rho$, of systems we identify. We use a different $D_0$ for each field, ranging from $\sim 220$–360 kpc, corresponding to $\delta \rho/\rho = 80$, in accord with Ramella et al. (1989). We adopt $V_0 = 350$ km s$^{-1}$ to prevent groups from spanning voids but to allow large velocity dispersion systems. Barton et al. (1996) used the friends-of-friends algorithm with $D_0 = 50$ kpc and $V_0 = 1000$ km s$^{-1}$ and no volume-scaling ($R = 1$) to identify the original RSCG sample...
from the CfA2+SSRS2 redshift survey. Because we search a limited region on the sky, we may miss parts of the galaxy systems that contain the RSCGs.

We estimate the effective Zwicky limiting magnitude, $m_{\text{lim},Zw}$, of each RSCG environment region. Using only the galaxies for which we know both SKICAT instrumental g magnitudes and Zwicky magnitudes, we estimate the relationship between the two for each region separately using a linear least-squares fit. Because of confusion in the region of Abell 194, we use only a restricted sample in the regions of RSCGs 10 and 11, based on the catalog of Chapman et al. (1988). Table 4 lists the results for each region.

We choose the magnitude of the faintest galaxy with a redshift as our limiting magnitude. The completeness of each region to the limiting magnitude is listed in the last column of Table 2. For the most incomplete regions, we test the effects of the choice of limiting magnitude on the galaxy environments. We find that it has no effect for most regions, and no qualitative effects for any regions.

The limiting projected separation we adopt for each environment is more generous than the criterion applied to find the RSCGs and the velocity separation criterion is more strict. Table 4 lists the values of $RD_0$ and $RV_0$. In all cases, the RSCG galaxies are “neighbors”. RSCG 64 is the only system where there are no other galaxies in the environment. Throughout the paper, we refer to the looser aggregate of galaxies identified by the algorithm as the environment of the RSCG.

4. Are Apparent Compact Groups Embedded in Dense Environments?

Previous studies of compact group environments yield an inconsistent picture of the embedding of compact groups. These inconsistencies originate from incomplete data sets along with the assumptions underlying some analyses. For example, some studies argue that a surrounding loose group is not present, based on the distribution of surrounding galaxies on the sky alone. In fact, loose groups are often hard to distinguish from the foreground/background without redshifts.

Studies done in redshift space are cleaner. However, the data must be complete to evaluate the statistical significance of detection. Rubin et al. (1991) examined the incomplete CfA Redshift Survey Catalogue (Huchra et al. 1991) within 1000 km s$^{-1}$ and 2.8 $h^{-1}$ Mpc of 21 HCGs with mixed results. They could not evaluate the significance of the general absence of surrounding loose groups because of the incompleteness of the catalog.

Ramella et al. (1994) extracted galaxies within 1.5 $h^{-1}$ Mpc and 1500 km s$^{-1}$ of 38
HCGs from the CfA2 complete, magnitude-limited redshift survey. They compared the number of detected galaxies, \( N_n \), to the number of galaxies expected in the region, \( N_{\text{int}} \). 29 HCGs have \( N_{\text{int}} \gg N_n \). The properties of the surrounding systems are similar to those of loose groups extracted from the redshift survey by Ramella et al. (1989). Barton et al. (1996) extracted the same-sized regions around the RSCGs and obtained a similar result: of the more distant RSCGs \( (v \geq 2300 \text{ km s}^{-1}) \), 72 % (42/58) have \( N_n > 2N_{\text{int}} \).

Here, we again reach a similar conclusion: 13/14 RSCGs are embedded in regions that would qualify as potentially bound systems according to Ramella et al. \( (\Omega_p \geq 80 \text{ on the sky with additional restrictions on velocity separation}) \). The richness and density of these systems varies from loose groups of 5 members (RSCG 85) to an Abell cluster (RSCG 10 and RSCG 11 in Abell 194). The properties of these systems undoubtedly vary. Zabludoff & Mulchaey (1997) and Mulchaey & Zabludoff (1997) use multi-fiber spectroscopy and ROSAT PSPC data to study poor groups. Some groups in their sample display properties similar to x-ray clusters and others show no definitive evidence that they are bound.

5. Are RSCGs Distinct From Their Environments?

We compare each RSCG with its surroundings to explore the probability that an individual RSCG is a bound physical subsystem by asking whether its redshift-space configuration is likely to arise by chance. We use two parameters, \( p(\Delta v_{\text{max}}) \) and \( D_{mn,s} \), as partial diagnostics, in redshift and on the sky, respectively, of the relationship between the RSCG and its environment. \( p(\Delta v_{\text{max}}) \) is a direct, but insensitive, measure of the probability that the velocity distribution of the RSCG relative to its environment arises by chance. In contrast, \( D_{mn,s} \) only ranks the groups according to their relative isolation from neighbors in their environments.

The function \( p(\Delta v_{\text{max}}) \) is the probability that \( N_{\text{cg}} \) galaxies drawn from the observed velocity distribution of the environment have \( \Delta v \leq \Delta v_{\text{max}} \). Here, \( N_{\text{cg}} \) is the number of galaxies in the RSCG and \( \Delta v_{\text{max}} \) is the largest velocity difference between members of the RSCG. The environments of the RSCGs were chosen with stricter velocity separation criteria than the RSCGs \( (RV_0 \leq 1000 \text{ km s}^{-1} \text{ in Table 4}) \). Therefore, \( p(\Delta v_{\text{max}}) \) is an upper limit to the value it would have if the environments and RSCGs were chosen with the same velocity criteria. When small, \( p(\Delta v_{\text{max}}) \) is an indicator of association within well-populated environments; the probability is then large that the RSCG is not just a chance superposition. For RSCGs in poor environments, the behavior of \( p(\Delta v_{\text{max}}) \) is dominated by small number statistics and the statistic is not a good discriminant.
The parameter $D_{nn}$ is the projected distance between the center of the RSCG and the nearest neighbor within the environment. A scaled $D_{nn,s} = D_{nn}/R$ accounts for different absolute magnitude limits within different systems. Physically, this measure evaluates the separation between the RSGC center and the nearest galaxy for an equivalent group located at the fiducial velocity, $v_F = 1000 \, \text{km} \, \text{s}^{-1}$. This interpretation assumes a simple model for the galaxies in the neighborhood — the spatial distribution is random, luminosity and position are uncorrelated and the luminosity function is the same around every RSGC. $D_{nn,s}$ is useful only as an indicator of relative compactness on the sky because it has not been calibrated on any complete model of loose groups.

If RSCGs are collapsing subsystems embedded in looser environments, they will on average be tighter on the sky than their surrounding environments. Any particular RSCG can have a high value of $D_{nn,s}$ by chance if it is only an apparent alignment, but groups with high values of $D_{nn,s}$ are less likely to be alignments than other RSCGs. The set of RSCGs with low values of $D_{nn,s}$ may still contain physical subsystems — they are merely more likely to be contaminated with chance projections. We note that Hickson effectively chose only compact configurations with $D_{nn} \geq 3R_{HCG}$ to minimize the number of chance alignments, where $R_{HCG}$ is the radius of the smallest circle on the sky containing all of the HCG galaxy centers. Barton et al. (1996) argue that such a criterion may exclude real, physical systems located in dense environments. They found such an isolation criterion unnecessary because they selected the RSCGs based on redshift separation and were therefore able to eliminate interlopers in redshift space. We compute $D_{nn,s}$ for the RSCGs \textit{a posteriori} to rank the groups as more or less likely accidental superpositions.

Table 5 lists these statistics along with the number of galaxies in the environment ($N_{env}$) and the median velocity ($v_{med,env}$). These parameters refer only to the $1 \, \text{h}^{-1} \, \text{Mpc}$ region we survey around each RSCG.

Figs. 2a and 3 show the sample distributions of $D_{nn,s}$ and $\log(p(\Delta v_{max}))$, respectively, for the embedded RSCGs. Fig. 2a shows the lower limit to $D_{nn,s}$ for the RSCG 64, which has an empty neighborhood. This limit is imposed by the friends-of-friends algorithm and is equal to $D_0$. The lower limit is well above the distribution of $D_{nn,s}$ for the majority of the sample. Fig. 2b shows the $D_{nn,s}$ distribution of the remaining CfA2 RSCGs for comparison, including lower limits for RSCGs with empty neighborhoods in the CfA2 redshift survey. Note that surrounding galaxies fainter than $m_{Zw} = 15.5$ are not included in Fig. 2b.

In the $D_{nn,s}$ plot (Fig. 2a), RSCG 9 and RSCG 85 are the outliers. They appear more isolated from the other galaxies in their environments and thus less likely than the other RSCGs to be chance superpositions of galaxies within looser systems. The distribution of $D_{nn,s}$ for the whole RSCG catalog in Fig. 2b is more spread out than the distribution for
the 14 RSCGs in this study. This spreading may indicate that large values of \( D_{nn,s} \) arise by chance. In Fig. 3, RSCG 11, in Abell 194, is the outlier; the galaxies have a very low probability (< 0.5%) of being associated by chance. RSCG 11 is surprisingly close to the center of the cluster both in velocity space and on the sky. It may be part of a cold core (e.g. Bothun & Schombert 1988; Merrifield & Kent 1991; Mohr et al. 1996). The two large, elliptical galaxies in RSCG 11 appear to be within a common envelope. An additional large elliptical, with a velocity equal to the median velocity of the group environment, lies within 35.5 \( h^{-1} \) kpc of a member of the RSCG.

The statistics \( p(\Delta v_{\text{max}}) \) and \( D_{nn,s} \) indicate that the remaining 10 RSCGs are less distinct from their environments; they may be bound subsystems or chance projections. Kinematic data are inadequate to make a distinction. Next, we discuss aspects of the individual RSCGs which we show in Figs. 4 – 10.

**RSCG 7, RSCG 8, RSCG 12**: RSCG 7 and RSCG 8 are within the same large, dense system of galaxies which is a prominent feature in the redshift survey, the Zwicky cluster (fields 501 and 502, number 5) of 625 galaxies (Zwicky & Kowal 1968). RSCG 12, which consists of the three tightest members of HCG 10, is on the northeast edge of this system.

**RSCG 9**: RSCG 9 appears isolated on the sky and in redshift space. The nearest galaxy coincident in redshift space is \( \sim 500 \ h^{-1} \) kpc from the center of RSCG 9. The velocity dispersion of RSCG 9 is the smallest in our sample (97 ± 49 km s\(^{-1}\)). We conclude that RSCG 9 is isolated and may be gravitationally bound.

**RSCG 10, RSCG 11**: RSCG 10 and RSCG 11 are members of Abell 194, a “linear” cluster of galaxies (Rood & Sastry 1971; Struble & Rood 1982, 1984; Chapman et al. 1988). As mentioned above, RSCG 11 is in the core of the cluster.

**RSCG 29**: RSCG 29 is the most distant RSCG in our sample (\( v_{\text{med}} = 11252 \) km s\(^{-1}\)). The Zwicky magnitudes originally listed in the CfA redshift survey are in error and 3 of the 4 member galaxies are actually fainter than the RSCG survey limit; the group should not have been in our sample. For RSCG 29, the values of \( RV_0 \) and \( RD_0 \) (Table 4 ) are large; the environment of the RSCG defined by the friends-of-friends algorithm is probably overly generous. However, there are some close neighbors and the system appears to be embedded.

**RSCG 42**: RSCG 42 is embedded in a small, loose system. It is very close to one of its neighbors; because this neighbor is only 49 kpc from one of the group members, we would have included it in the RSCG if it were brighter. We add this galaxy and recompute the group parameters, without readjusting \( v_{\text{med}} \); the distance to the nearest neighbor is now 199 \( h^{-1} \) kpc; Table 5 lists the relevant parameters under the group heading “RSCG 42 +
RSCG 43: RSCG 43 is the densest part of HCG 57, an eight-member compact group. Table 5 lists the relevant parameters computed with only the 3 RSCG members, with all 8 HCG members, and with an additional nearby faint galaxy (1.7 arcmin $\approx 45$ h$^{-1}$ kpc away from an HCG member). The three original members of the RSCG are very tight on the sky — the radius of the RSCG is only $\sim 13.3$ h$^{-1}$ kpc.

RSCG 64: RSCG 64 is a very tight system ($< 20$ kpc in radius) with a low velocity dispersion ($\sigma_{RSCG} = 111 \pm 74$ km s$^{-1}$). The system is near the edge of a small apparent void. Only 5 galaxies within the entire region are roughly coincident with the RSCG in velocity space, and the nearest of these is 560 h$^{-1}$ kpc away from the RSCG center. RSCG 64 is probably an isolated, gravitationally bound system. No signs of tidal interaction are evident.

RSCG 73: RSCG 73 is embedded in a dense system of galaxies. The friends-of-friends algorithm identifies 40 galaxies in its environment. The velocity histogram indicates that these galaxies are a superposition of at least 2 systems along with a small number of foreground galaxies. In any case, RSCG 73 is not isolated.

The range of RSCG embeddings (local environments) is qualitatively similar in its extremes to the range of HCG embeddings. de Carvalho et al. (1994) searched automated scans of IIIa-J plates in a $\frac{1}{2} \times \frac{1}{2}$ region, to $m_B \leq 19.5$. They used Hickson’s (1982) compactness criterion, omitting the isolation criterion, to redefine the compact groups, including the faint galaxies. They used available redshifts and assigned classifications to the group environments. They also find a range of systems, including systems like HCG 4 which appears relatively compact and isolated like RSCG 64, and systems like HCG 21 which they find in a rich environment on the sky. In our study, RSCG 10 and RSCG 43 are both parts of HCGs (10 and 57, respectively); here we find that HCG 10 is located on the edge of a rich Zwicky cluster (Zwicky & Kowal 1968).

6. Conclusion

We extend the CfA2 redshift survey to limiting magnitudes of $m_{zw} \sim 16 - 17$ by measuring fainter galaxies within $1 h^{-1}$ Mpc of 14 RSCGs to understand the distinction between RSCGs and their environments, and to explore the nature of the surroundings of apparent compact groups. We define the environments of the RSCGs using the friends-of-friends algorithm and find:
RSCGs are distinct from their environments to varying degrees; qualitatively, the range of RSCG embeddings is similar to the range of HCG embeddings (de Carvalho et al. 1994).

One of the RSCGs is not located in an overdense region in redshift space (RSCG 64). Of the remaining 13 RSCGs, which are embedded in systems, 3 appear distinct from their environments in redshift or position on the sky (RSCG 9, RSCG 11 and RSCG 85).

13 of 14 RSCGs are embedded in systems that qualify as systems that are overdense in redshift space by the standards of Ramella et al. (1989). These systems vary from a loose group of 5 members to an Abell cluster.

Maps of the environments of compact groups in position and redshift provide only one limited measure of whether they are physical systems. These studies provide insufficient constraints on the true spatial distribution of galaxies within loose groups or denser systems to form the basis for extensive modeling. Other techniques for determining whether a compact group is a physical system are deep optical (B-band) imaging to look for evidence of tidal interactions among group members, studies of internal galaxy dynamics to look for distortion, spectroscopic classification to look for star formation and nuclear activity, and x-ray imaging to look for hot gas in the group centers. Other investigators have studied HCGs using all of these techniques (e.g. optical: Hickson et al. 1989; dynamics: Rubin et al. 1991; spectroscopic: Coziol et al. 1997; x-ray: Ebeling et al. 1994). Some similar studies of RSCGs are in progress (optical: Barton et al. 1998; x-ray: Mahdavi et al. 1998).

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Fig. 1.— Distributions of various parameters, including the 44 RSCGs in CfA2+SSRS2 with $cz > 2300$ km s$^{-1}$ not included in this study (solid line) and the 14 RSCGs observed here (dashed line): (a) redshift or velocity, (b) RSCG population, (c) velocity dispersion and, (d) environment overdensity, $\frac{\rho_{\text{env}}}{\bar{\rho}}$, as calculated in Barton et al. (1996).
Fig. 2.— $D_{nn,s}$ distributions: (a) distribution of $D_{nn,s}$ for the 14 RSCGs in our sample. The outliers are RSCG 85 and RSCG 9, with $D_{nn,s} = 250$ scaled kpc and $D_{nn,s} = 359$ scaled kpc, respectively. The vertical dashed line represents the lower limit of $D_{nn,s}$ for RSCG 64, and (b) distribution of $D_{nn,s}$ for the 33 other RSCGs in the CfA2 survey with $cz \geq 2300$ km s$^{-1}$. 26 have environment galaxies according to our criteria and are included in the histogram; 7 have only upper limits, represented by the dashed lines A (4 RSCGs in CfA2North) and B (3 RSCGs in CfA2South).
Fig. 3.— The distribution of $\log(p(\Delta v_{\text{max}}))$ for the 14 RSCGs in our sample. The outlier is RSCG 11, in Abell 194, with $p(\Delta v_{\text{max}}) = 0.004$. 
Fig. 4.—(a) RSCG 7 and (b) RSCG 8: (1) Galaxy positions on the sky (left). Filled squares are galaxies in the RSCG, filled circles are galaxies in the RSCG environment, empty circles are foreground/background galaxies and x’s are galaxies without measured velocities; (2) velocity distributions (right). The upper histogram includes all galaxies with measured redshifts. The lower histogram (right) expands the region around the RSCG. Lightly shaded regions are the RSCG environment; heavily shaded regions are the RSCG itself.
Fig. 5.— (a) RSCG 9 and (b) RSCG 10. Format as in Fig. 4.
Fig. 6.— (a) RSCG 11 and (b) RSCG 12. Format as in Fig. 4.
Fig. 7.— (a) RSCG 29 and (b) RSCG 42. Format as in Fig. 4.
Fig. 8.— (a) RSCG 43 and (b) RSCG 64. Format as in Fig. 4.
Fig. 9.— (a) RSCG 70 and (b) RSCG 73. Format as in Fig. 4.
Fig. 10.— (a) RSCG 76 and (b) RSCG 85. Format as in Fig. 4.