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GALAXY GROUPS IN THE THIRD DATA RELEASE OF THE SLOAN DIGITAL SKY SURVEY

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ABSTRACT

Q1 We present a new sample of galaxy groups identified in the Sloan Digital Sky Survey Data Release 3. Following previous works, we use the well-tested friends-of-friends algorithm developed by Huchra and Geller, which takes into account the number density variation due to the apparent magnitude limit of the galaxy catalog. To improve the identification, we implement a procedure to avoid the artificial merging of small systems in high-density regions and then apply an iterative method to recompute the group centers position. As a result, we obtain a new catalog with 10,864 galaxy groups with at least four members. The final group sample has a mean redshift of 0.1 and a median velocity dispersion of 230 km s^{-1}.

Subject heading: galaxies: clusters: general

1. INTRODUCTION

Galaxy group samples have become a very important issue in cosmology. Since hierarchical clustering drives the structure formation in the universe, galaxy groups can be considered a fundamental piece of the chain joining galaxies and clusters of galaxies.

The information obtained from these systems allows us to understand the internal processes ruling the intragroup medium, and to find the most suitable cosmological model to describe their distribution.

The first large samples of groups comprised ~1000 galaxy groups and were constructed from different redshift surveys (Merchán et al. 2000; Giuricin et al. 2000; Tucker et al. 2000; Ramella et al. 2002). More recently, larger galaxy group catalogs were constructed from different releases of the Two-Degree Field Galaxy Redshift Survey (2dFGRS). The first was constructed from the 2dFGRS 100K Data Release by Merchán & Zandivarez (2002) with a total of ~2200 groups; while using the final release of the 2dFGRS, Eke et al. (2004a) constructed a catalog containing ~7000 galaxy groups with at least four members. Research involving these samples included studies ranging from local physical properties (Martínez et al. 2002; Domínguez et al. 2002; Díaz et al. 2004; Eke et al. 2004b; Ragone et al. 2004) to large-scale structure (Zandivarez et al. 2003; Padilla et al. 2004).

At the present, the largest galaxy redshift survey is the Third Data Release of the Sloan Digital Sky Survey (SDSS DR3). This release has ~530,000 spectra, of which ~380,000 are galaxies with a redshift accuracy of 30 km s^{-1}. The size and deepness of this sample make it an ideal source of information for obtaining a new galaxy group sample.

The aim of this work is to construct a group catalog[2] from the galaxies in the SDSS DR3. The group identification is performed using the algorithm developed by Huchra & Geller (1982). We also apply a technique to improve the identification for groups with at least 10 members.

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[2] The complete galaxy group catalog with the physical properties estimated in this work is available at https://www.iate.oac.uncor.edu/SDSSDR3GG/ or upon request from the authors.

A description of the group identification algorithm is given in § 2, while the identification of groups of galaxies and the sub- Q2
sequent improvements are carried out in § 3. Finally, in § 4 we summarize our results.

2. THE GROUP-FINDING ALGORITHM

Group identification is performed using the friends-of-friends algorithm developed by Huchra & Geller (1982). According to these authors, given a pair of galaxies with mean radial comoving distance $D = (D_1 + D_2)/2$ and angular separation θ_{12}, the algorithm links galaxies satisfying the conditions

$$D_{12} = 2\sin\left(\frac{\theta_{12}}{2}\right)D \leq D_L = D_0 R \qquad (1)$$

and

$$V_{12} = |V_1 - V_2| \leq V_L = V_0 R, \qquad (2)$$

where D_{12} is the projected distance and V_{12} is the line-of-sight velocity difference. Comoving distances D_i are estimated using the relation corresponding to an Einstein–de Sitter model,

$$D_i(z) = \frac{c}{H_0}\int_0^z \frac{dz'}{\Omega_M(1+z')^3 + \Omega_\Lambda}, \qquad (3)$$

with density parameters $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, and $H_0 = 100\,h$ km s^{-1} Mpc^{-1}. The transverse (D_L) and radial (V_L) linking lengths scale with R, to compensate for the number density variation due to the apparent magnitude limit of the survey. The scaling factor R is computed using the galaxy luminosity function of the sample $\phi(M)$:

$$R = \left[\frac{\int_{-\infty}^{M_{12}} \phi(M)dM}{\int_{-\infty}^{M_{\rm lim}} \phi(M)dM}\right]^{-1/3}, \qquad (4)$$

where $M_{\rm lim}$ and M_{12} are the absolute magnitude of the brightest galaxy visible at the fiducial D_f and mean galaxy D distances,

TABLE 1
MEDIAN PHYSICAL PROPERTIES OF GROUPS

Sample	N	N_g	$\bar{z}$	$\bar{\sigma}_v$ (km s^{-1})	$\bar{M}$ (h^{-1} $M_\odot$)	$\bar{R}_V$ (h^{-1} Mpc)
USGC (Ramella et al. 2002)	1168	6846	...	264	4.7×10^{13}	1.06
LCRS Loose Groups (Tucker et al. 2000)	1495	~9250	...	164	1.9×10^{13}	~1.2
2dFGRS (Merchán & Zandivarez 2002)	2209	14634	0.1	232	3.7×10^{13}	1.02
2dFGRS (Eke et al. 2004a)	7020	55753	0.11	260	3.3×10^{13}	...
SDSS DR3 First identification	10152	78410	0.1	240	4.2×10^{13}	1.21
SDSS DR3 Improved identification	10864	66517	0.1	230	3.8×10^{13}	1.12

respectively. Usually D_0 is chosen to obtain the desired overdensity $\delta\rho/\rho$, which is given by

$$\frac{\delta\rho}{\rho} = \frac{3}{4\pi D_0^3}\left[\int_{-\infty}^{M_{\rm lim}} \phi(M)dM\right]^{-1} - 1 \qquad (5)$$

and corresponds to a fixed overdensity contour surrounding a group.

3. GALAXY GROUPS SAMPLE

3.1. *The Galaxy Catalog*

The SDSS DR3 has been validated and made publicly available (Abazajian et al. 2005). This catalog is a photometric and spectroscopic survey covering 4188 deg^2 with five-band (*ugriz*) imaging data and 528,640 spectra of galaxies, quasars, and stars. In this work we use the main spectroscopic galaxy sample, which comprises ~300,000 galaxies with redshifts $z \leq 0.3$ and an upper apparent magnitude limit of 17.77 in the r-band.

3.2. *Group Identification*

The adopted linking length values are motivated by the group identification analysis performed by Merchán & Zandivarez (2002) for the 2dFGRS. Using mock catalogs, they explore a wide range of linking length values in order to maximize the group identification accuracy. Since the SDSS DR3 and 2dFGRS have similar redshift distributions and luminosity functions (Norberg et al. 2002), we chose identical values for the group identification: a transversal linking length corresponding to an overdensity of $\delta\rho/\rho = 80$, a line-of-sight linking length of $V_0 = 200$ km s^{-1}, and a fiducial distance of $D_f = 10\ h^{-1}$ Mpc. The scaling factor R is estimated using a galaxy luminosity function fitted using a Schecter function with parameters ($\alpha = -1.05 \pm 0.01$, $M_* - 5\log\ h = -20.44 \pm 0.01$) given by Blanton et al. (2003). The main properties of the obtained groups sample are summarized in Table 1 (SDSS DR3 First identification).

3.3. *Rich Groups Identification Improvement*

It should be taken into account that groups obtained from galaxy redshift surveys have unavoidable contamination problems. For instance, the method described previously cannot fully avoid the interloper effect (i.e., spurious inclusion of nonmember galaxies), so an artificial merging of small groups with large systems is likely to happen. Recently, working with groups identified in the 2dFGRS Final Release and the First Data Release of the SDSS, Díaz et al. (2004) have developed a method to minimize the problem of group identification. Their method proposed a second identification of galaxy groups with at least 10 members, in order to split merged systems or eliminate spurious member detections. Analyzing group identifications on mock catalogs in real and redshift space, they found that a higher value for $\delta\rho/\rho$ (~315) produced a more reliable group identification. Performing a redshift space identification with this density contrast is equivalent to a group identification in real space corresponding to $\delta\rho/\rho = 80$. Furthermore, as shown by Mérchan & Zandivarez (2002), adopting lower transversal linking length values improves the identification accuracy (see their Figs. 2 and 3). Therefore, following the suggestion of Díaz et al. (2004), we perform a second identification for groups with at least 10 members.

A very accurate group center determination is required for some studies related to the galaxy distribution inside groups. Trying to measure density profiles of galaxy groups, Díaz et al. (2004) have also proposed a method for correcting the group center position for those systems with at least 10 members. First, their method defines a new group center estimator by using the projected local-number density of each member galaxy for weighting their group center distances. The second part of the method is an iterative procedure to improve the group center location by removing galaxies beyond a given distance and recomputing the center position. The procedure continues until the center location remains unchanged (for more details, see § 2 of Díaz et al. 2004). Given that this procedure needs to compute the projected local number density with five galaxies, it can only be applied to groups with at least 10 members. After applying this correction, the full catalog comprised 9703 galaxy groups with at least four members. Figure 1 shows the spatial distribution of groups identified in the SDSS DR3 with at least four members and $z \leq 0.15$.

3.4. *Group Physical Properties*

In addition to the group identification, we also estimate basic physical properties such as velocity dispersion, virial radius, and virial mass.

The line-of-sight velocity dispersion σ_v, is estimated using the methods described by Beers et al. (1990). The biweight estimator is applied for groups with richness $N_{\rm tot} \geq 15$, whereas the gapper estimator is applied to poor groups (Girardi et al. 1993; Girardi & Giuricin 2000). Following Eke et al. (2004a), we also introduce a correction due to the error in the redshift measurement. This is a second-order correction, since the redshift measurement error in the SDSS is 30 km s^{-1}. The virial radius is estimated using the equation

$$R_V = \frac{\pi}{2}\frac{N_g(N_g - 1)}{\sum_{i>j} R_{ij}^{-1}}, \qquad (6)$$

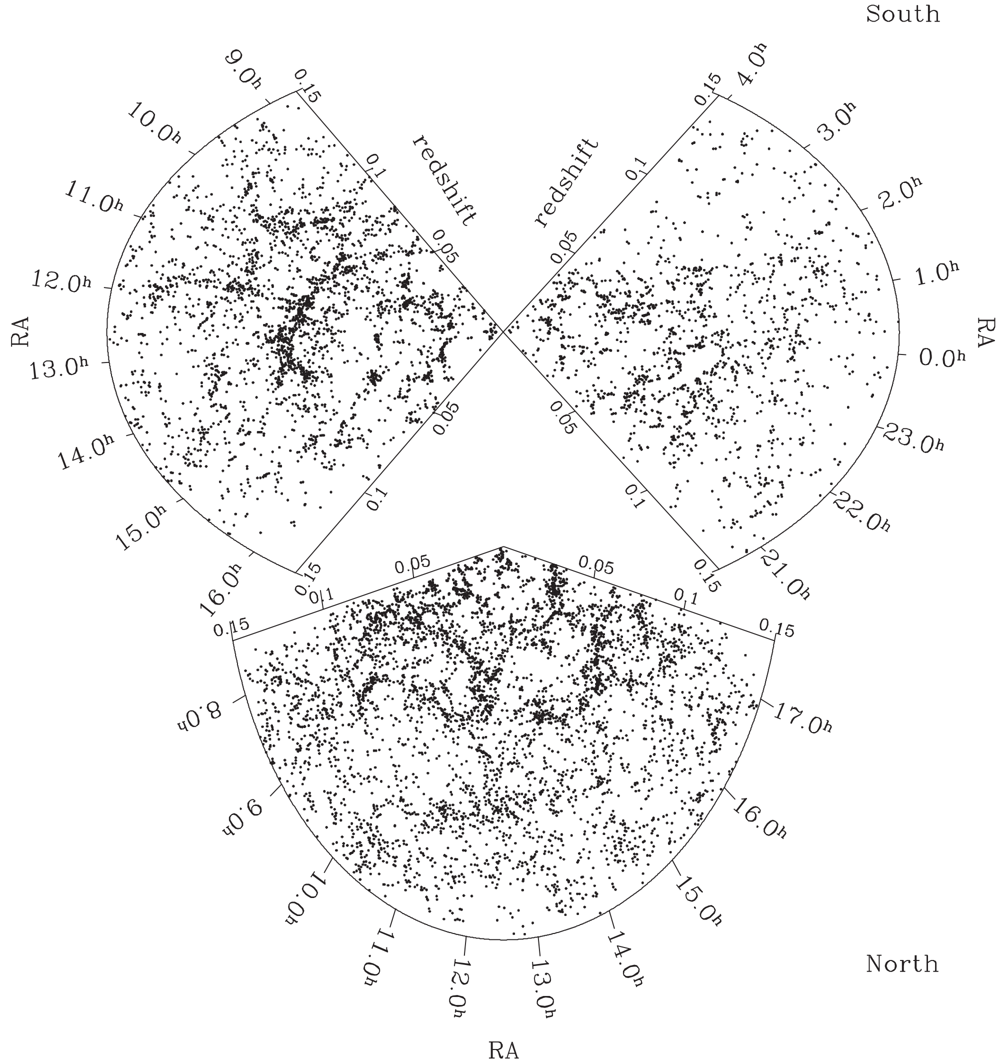

Fig. 1.—Pie plots showing the galaxy groups in the SDSS DR3. The galaxy groups distribution is shown in three different ranges of right ascension and for redshifts $z \leq 0.15$.

where N_g is the number of galaxy members and R_{ij} is the galaxy projected distances. Finally, the virial masses of galaxy groups is computed as

$$M_V = \frac{3\sigma_v^2 R_V}{G}, \tag{7}$$

where G is the gravitational constant.

Individual group velocity dispersion estimation allowed us to observe rich-group reidentification and recentering consequences. Figure 2 illustrates the rich group ($N_g \geq 10$) velocity dispersion behavior (*upper panel*) for groups before and after correction (*solid and dotted lines, respectively*). As can be seen, the distribution of groups with high velocity dispersions ($\sigma_v \gtrsim 300$ km s^{-1}) remains unchanged, whereas artificially merged groups in the first identification now appear as a new population with low velocity dispersion. The redshift distribution for groups with at least 10 members is shown in the lower panel of Figure 2. It should be noted that the correction applied to rich groups does not introduce any bias with redshift. Histograms showing the distribution of redshift, velocity dispersion, virial radius, and virial mass of groups with at least four members are plotted in Figure 3. Finally, the median physical properties of the full group catalog are quoted in Table 1.

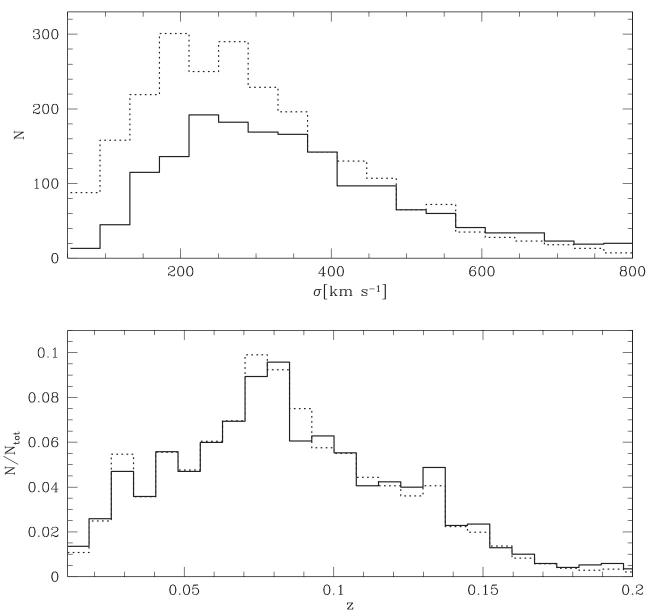

Fig. 2.—Velocity dispersion (*upper panel*) and redshift (*lower panel*) distributions for rich groups. The solid lines are the distributions for groups with at least 10 members after the first identification, while the dotted lines show the group distributions when the corrections on the identification have been applied.

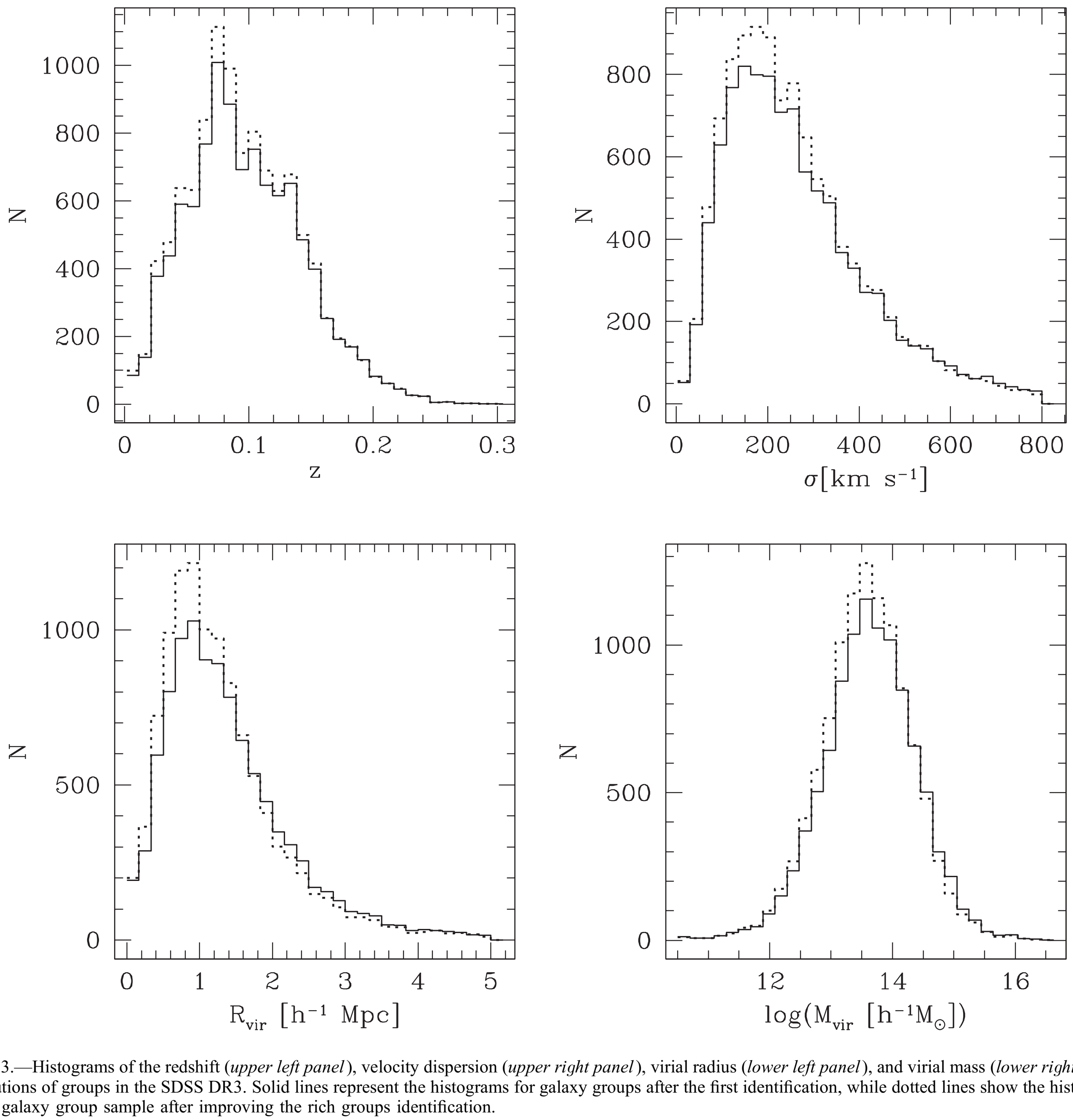

FIG. 3.—Histograms of the redshift (*upper left panel*), velocity dispersion (*upper right panel*), virial radius (*lower left panel*), and virial mass (*lower right panel*) distributions of groups in the SDSS DR3. Solid lines represent the histograms for galaxy groups after the first identification, while dotted lines show the histograms for the galaxy group sample after improving the rich groups identification.

4. CONCLUSIONS

We present the largest galaxy groups catalog to date, constructed from galaxies in the Third Data Release of the Sloan Digital Sky Survey. The group identification was carried out using the friends-of-friends algorithm developed by Huchra & Geller (1982), augmented by the introduction of corrections for Q3 rich groups that improve the group identification and the group center location. The resulting catalog comprises 10,864 galaxy groups with at least four members, and it has a mean redshift of 0.1. The median basic physical properties of our catalog are very similar to those obtained in previous works (Table 1).

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AUTHOR QUERIES

Q1 Au: Your article has been edited for grammar, consistency, and to conform to ApJ journal style (see Instructions to Authors). To expedite publication, we generally do not query every routine grammatical and style change made to a manuscript, although all substantive changes have been noted. Please review the article carefully. Note that we may be unable to make changes that conflict with journal style, obscure meaning, or create grammatical or other problems. Also note that article proofs via PDF do not show corrections that will have been made by the typesetter's proofreader, which generally include corrections of errors of page layout, figure placement, and spacing and font mistakes; feel free to mark any errors you notice in these areas. When sending us your corrections, if you are writing them by hand, please print clearly. If sending a fax, please do not write too close to the margins of the page, as these are often cut off in fax transmission. Finally, please note that a delayed, incomplete, or illegible response may delay the publication of your article while we contact you.

Q2 Au: Replaced "identification on galaxies" with "identification of groups of galaxies"; does this accurately reflect your intended meaning?

Q3 Au: ApJ follows American usage of ‘‘that’’ to introduce restrictive clauses, ‘‘which’’ for nonrestrictive. See redlined copy for all changes.