АСТРОФИЗИКА

ТОМ 51 НОЯБРЬ, 2008 ВЫПУСК 4

THE BASIC PROPERTIES OF GALAXY GROUPS FROM THE VOLUME-LIMITED MAIN GALAXY SAMPLE OF SDSS DR6

XIN-FA DENG, JI-ZHOU HE, SONG JUN, CHENG-HONG LUO, PING WU

Received 27 February 2008
Accepted 15 July 2008

Using Berlind et al. algorithm and Davis et al. algorithm, we find that the mean velocity dispersion, virial radius and virial mass of the group catalogs identified in the volume-limited sample are much smaller than those of ones identified in the flux-limited sample. Our study shows that these properties of groups are heavily influenced by the relative values of the linking parameters and that there may be no values for the linking lengths that will work perfectly for every sample. In addition, we note that the luminosity distribution of member galaxies of groups identified by different algorithms is nearly the same, but member galaxies of groups identified using the linking lengths $b_\perp = 0.14$, $b_\parallel = 0.75$ have a higher proportion of blue galaxies and a lower proportion of red galaxies than member galaxies of groups identified using the linking length $b = 0.2$ and the early-type fraction of member galaxies of groups identified using the linking length $b = 0.2$ is higher than that of member galaxies of groups identified using the linking lengths $b_\perp = 0.14$, $b_\parallel = 0.75$.

Key words: *galaxies:fundamental parameters - galaxies:large scale structure*

1. *Introduction.* Galaxy groups have been a very important issue about the large-scale structure of the universe for a long time. The informations obtained from such systems can allow us to understand many important issues better: properties of the large-scale structure, galaxy formation and evolution, environmental studies. For group identification, the friends-of-friends (FoF) algorithm developed by Huchra & Geller [1] is the most frequently applied method for redshift surveys. Geller & Huchra [2] constructed the first sizeable sample of groups, which contains 176 groups with three or more galaxies from the CfA galaxy redshift survey. Using the friends-of-friends algorithm developed by Huchra & Geller [1] or slightly modified versions, many authors compiled the catalogs of groups from different redshift surveys [3-12], particularly from Sloan Digital Sky Survey and 2 degree Field Galaxy Redshift Survey.

To identify galaxy groups, Berlind et al. [11] applied the simplest friends-of-friends algorithm and used constant linking lengths:

$$D_{\perp ij} = (c/H_0)(z_i + z_j)\sin(\theta_{ij}/2) \le b_\perp \bar{n}^{-1/3},$$

$$D_{\parallel ij} = (c/H_0)|z_i - z_j| \le b_\parallel \bar{n}^{-1/3},$$

where $\bar{n}$ is the mean number density of galaxies and $b_{\perp}$ and $b_{\parallel}$ are the projected and line-of-sight linking lengths in units of the mean intergalaxy separation. The linking lengths of Berlind et al. [11] are: $b_{\perp}=0.14$, $b_{\parallel}=0.75$, which are best at grouping together galaxies that occupy the same dark matter halos. These values are different from those used in previous FoF group analyses. For example, Eke et al. [9] adopted $b_{\perp}=0.13$, $b_{\parallel}=1.43$ in their analysis of groups in the 2dF Galaxy Redshift Survey. In addition, Berlind et al. [11] also showed that there are no values for linking lengths that can pass all tests and the right choice of linking lengths depends on the scientific objectives of the work.

By allowing a longer linking length in the radial direction, the algorithm of Berlind et al. [11] successfully accounted for redshift space distortions. But as the criterion of radial distance is much larger than that of the projected separation, groups identified by such a method may be seriously contaminated by background/foreground galaxies. Deng et al. [12] tried two approaches: the algorithm of Berlind et al. [11] and the friends-of-friends algorithm of Davis et al. [13] which defines the three-dimensional linking length as $b\times\bar{n}^{-1/3}$ where the linking length choice of $b=0.2$ yields a halo mass function that is independent of redshift and Ω_0 and thus provides a good definition of the underlying dark matter haloes [14]. Though Davis et al. [13]'s algorithm became three dimensional and thus less subject to projection effects, this algorithm did not take into account the stretching of groups in redshift space along the radial direction-redshift space distortions. But when we have no ability to correct redshift-space distortions, we must face the choice between two effects: the projection effects or redshift space distortions.

Deng et al. [12] used the flux-limited Main galaxy sample[15] of the SDSS Data Release 5 [16] and found the significant difference between group properties of catalogs identified by above two algorithms. In the group catalog identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$, there is a higher proportion of loose groups, clusters, and even of superclusters, the richest group contains 41806 galaxies, which is a huge Great Wall of galaxies [17-19]. Deng et al. [12] indicated that for group identification the choice of linking lengths may depend on structure properties of the spatial distribution of galaxies. For the galaxy sample with filamentary morphology, such linking lengths are too large and many groups will be fused together into a huge system.

The major problem of flux-limited galaxy samples is the magnitude selection effect: at large distances faint galaxies are not visible and faint distant groups cannot be detected. Praton, Melott & McKee [20] argued that distortions in redshift space may enhance structures perpendicular to the line of sight, such as the Great Wall of galaxies and that in the flux-limited galaxy samples such an effect becomes more apparent. In order to decrease selection effects, a simple method is to use a volume-limited galaxy sample. But in volume-limited samples fainter galaxies are excluded at all distances from the observer. The price for this replacement is that a large fraction of the data is not used. In this study, we use the volume-limited Main sample of the SDSS Data Release 6 [21] and again investigate group properties of catalogs identified by above two algorithms.

2. *Data.* The Sloan Digital Sky Survey (SDSS) is one of the largest astronomical surveys to date. Many of the survey properties were discussed in detail in the Early Data Release paper [22]. Galaxy spectroscopic target selection can be implemented by two algorithms. The Main galaxy sample [15] comprises galaxies brighter than $r_{petro} < 17.77$ (r-band apparent Petrosian magnitude). This sample has a median redshift of 0.10 and few galaxies beyond $z = 0.25$, in which most galaxies are within the redshift region $0.02 \le z \le 0.2$. The Luminous Red Galaxy (LRG) algorithm [23] selects galaxies to $r_{petro} < 19.5$ that are likely to be luminous early-types, based on the observed colors. These LRGs are intrinsically red and at higher redshift.

In our work we used the Main galaxy sample. The data were downloaded from the Catalog Archive Server of SDSS Data Release 6 [21] by the SDSS SQL Search (with SDSS flag: best Primtarget&64>0) with high-confidence redshifts ($z_{warning} \ne 16$ and $z_{status} \ne 0$, 1 and redshift confidence level: $z_{conf} > 0.95$) (http://www.sdss.org/dr6/). From this sample, we selected 469199 Main galaxies in the redshift region $0.02 \le z \le 0.2$. We used the volume-limited Main galaxy sample constructed by Deng et al. [24], which contains 112889 galaxies, extends to $z_{max} = 0.089$ and is limited to the absolute magnitude region $-22.40 \le M_r \le -20.16$. The absolute magnitude M_r is calculated from the r-band apparent Petrosian magnitude, using a polynomial fit formula [25] for the K-correction [26] within $0 < z < 0.3$:

$$K(z) = 2.3537(z - 0.1)^2 + 1.04423(z - 0.1) - 2.5\log(1 + 0.1).$$

In calculating the distance we used a cosmological model with a matter density $\Omega_0 = 0.3$, cosmological constant $\Omega_A = 0.7$, Hubble's constant $H_0 = 100\,h\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$ with $h = 0.7$.

3. *The comparisons of group properties between catalogs identified by different algorithms.* Using the constant linking lengths of Berlind et al. [11], we extract a total of 4166 groups with richness $N \ge 4$ (N is the number of member galaxies in each system). There are 55412 member galaxies in groups, about 49.1% of total galaxy number in the volume-limited sample. The richest group contains 14898 galaxies. The fraction of grouped galaxies is higher than that found by Berlind et al. [11]. In the three volume-limited samples of Berlind et al. [11], 37.2%, 40.6% and 42.3% of galaxies are in groups of three or more members.

At the linking length $b = 0.2$ which corresponds to the linking length

$R_0 \approx 1.36$ Mpc(for the volume-limited Main galaxy sample the mean galaxy density is about $3.15\times10^{-3}\,\mathrm{Mpc}^{-3}$), 2153 galaxy groups with richness $N\geq4$ are identified, in which the richest group contains 28 galaxies. The whole group sample contains 11493 galaxies, in which 10848 galaxies are also located in the groups identified using the constant linking lengths of Berlind et al. [11]. This sample is actually a sample of small and dense groups, typically containing four members.

We estimate basic physical properties of groups such as velocity dispersion, virial radius, virial mass and crossing time. Apparently, these measures are heavily influenced by the relative values of the linking parameters. The mean physical properties of two group catalogs are listed in Table 1.

Table 1

THE MEAN PHYSICAL PROPERTIES OF THE TWO GROUP CATALOGS FOR THE VOLUME-LIMITED MAIN GALAXY SAMPLE OF THE SDSS DATA RELEASE 6

Sample	N_{grou}	N_{gala}	σ_V (km/s)	R_V (Mpc)	M_V ($M_\odot$)	$H_0 t_{cr}$
identified at the linking length $b=0.2$	2153	11493	51.76	1.93	3.99×10^{12}	0.93
identified at the linking lengths $b_\perp=$ [illegible], $b_\parallel=0.75$	4166	55412	184.44	3.19	1.02×10^{15}	0.41

The line-of-sight velocity dispersion σ_v is estimated by:

$$\sigma_V=\frac{1}{1+\bar{z}}\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(cz_i-c\bar{z})^2}$$

where N is the number of galaxy members and $\bar{z}$ the mean redshift of the group. Fig.1 shows the velocity dispersion distribution of group catalogs identified using the linking length $b=0.2$ and the linking lengths $b_\perp=0.14$, $b_\parallel=0.75$, respectively. Due to shorter linking length in the radial direction, the mean velocity dispersion ($\bar{\sigma}_V=51.76\ \mathrm{km\,s^{-1}}$) of the group catalog identified using the linking length $b=0.2$ is much smaller than that of other group catalogs (see Table 1 of Merch'an & Zandivarez [10]), also far smaller than that of the group catalog identified using the linking lengths $b_\perp=0.14$, $b_\parallel=0.75$ ($\bar{\sigma}_V=184.44\ \mathrm{km\,s^{-1}}$). We also notice that the mean velocity dispersion of the group catalogs identified in the volume-limited sample is much smaller than that of ones identified in the flux-limited sample (see Table 1 of Deng et al. [12]).

The virial radius is estimated using the following equation:

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

where R_{ij} is the galaxy projected distances. Fig.2 shows the virial radius distribution of group catalogs identified using the linking length $b=0.2$ and the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$, respectively. The mean virial radius of two group catalogs is much larger than that of other group catalogs(see Table 1 of Merch'an & Zandivarez [10]). As indicated by Praton, Melott & McKee

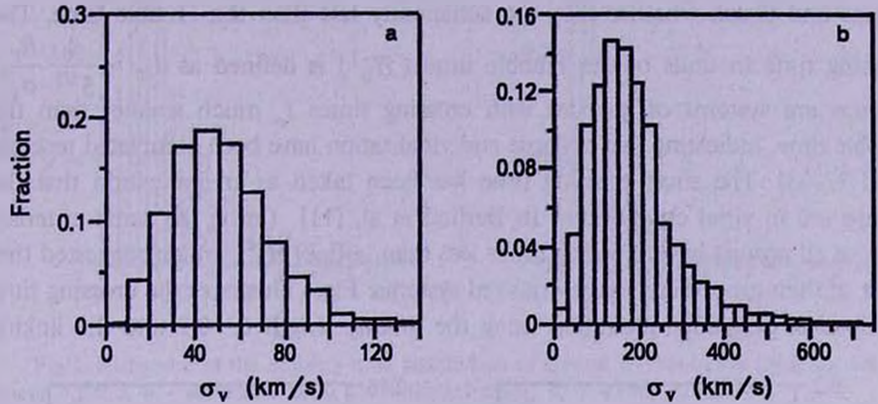

Fig.1. Histogram of the velocity dispersion distribution of groups: a - identified using the linking length $b=0.2$, b - identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$.

[20], in a flux-limited galaxy sample, structures perpendicular to the line of sight are enlarged. We notice that the richest group (the Great Wall of galaxies) identified in the volume-limited sample (containing 14898 galaxies) is much smaller than one identified in the flux-limited sample (containing 41806 galaxies). In addition, the mean virial radius of the group catalogs identified in the volume-limited sample also is much smaller than that of ones identified in the flux-limited sample(see Table 1 of Deng et al. [12]).

The virial mass is computed as $M_V=3\sigma_v^2 R_V/G$, where G is the gravitational constant. Similarly, the mean virial mass of the group catalogs identified in

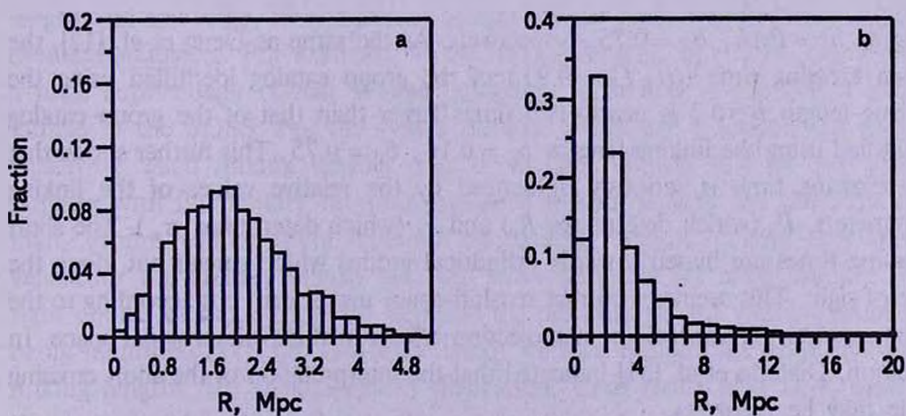

Fig.2. Histogram of the virial radius distribution of groups: a - identified using the linking length $b=0.2$, b - identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$.

the volume-limited sample is much smaller than that of ones identified in the flux-limited sample (see Table 1 of Deng et al. [12]). Fig.3 illustrates the virial mass distribution of groups identified using the linking length $b=0.2$ and the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$, respectively.

In order to test whether groups are virialized, we compute crossing times of groups and check whether they are sufficiently less than the Hubble time. The crossing time in units of the Hubble time (H_0^{-1}) is defined as $t_{cr}=\frac{3}{5^{3/2}}\frac{R_V}{\sigma_v}$. Groups are systems of galaxies with crossing times t_{cr} much smaller than the Hubble time, indicating that collapse and virialization have been completed recently [5,11,27-33]. The short crossing time has been taken as an indication that the groups are in virial equilibrium. In Berlind et al. [11] (using the same criteria), 80% of all groups have crossing times less than $\approx 0.29 H_0^{-1}$, which suggested that most of their groups are likely virialized systems. Fig.4 illustrates the crossing time distribution of groups identified using the linking length $b=0.2$ and the linking

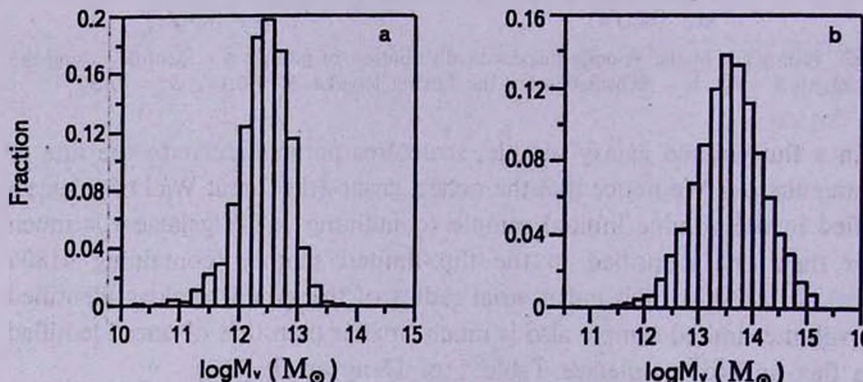

Fig.3. Histogram of the virial mass distribution of groups: a - identified using the linking length $b=0.2$, b - identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$.

lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$, respectively. As the same as Deng et al. [12], the mean crossing time ($H_0\bar{t}_{cr}=0.93$) of the group catalog identified using the linking length $b=0.2$ is nearly two times larger than that of the group catalog identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$. This further shows that the crossing time is seriously influenced by the relative values of the linking parameters, D_0 (which determines R_V) and V_0 (which determines σ_V). The short crossing times are biased towards cylindrical groups which spread out along the line of sight. This seems to correct redshift-space distortions, but according to the above analysis, it also results in projection effects in three-dimensional space. In addition, Diaferio et al. [31] indicated that the interpretation of the short crossing time may be incorrect.

In fact, so far, there has been no a widely accepted algorithm and criterion which is suitable for all galaxy samples. For different galaxy samples, many authors often developed different algorithms and criteria. Different methods and different galaxy samples means that the resulting catalogs of groups and the mean physical properties of groups are rather different. We also compare the

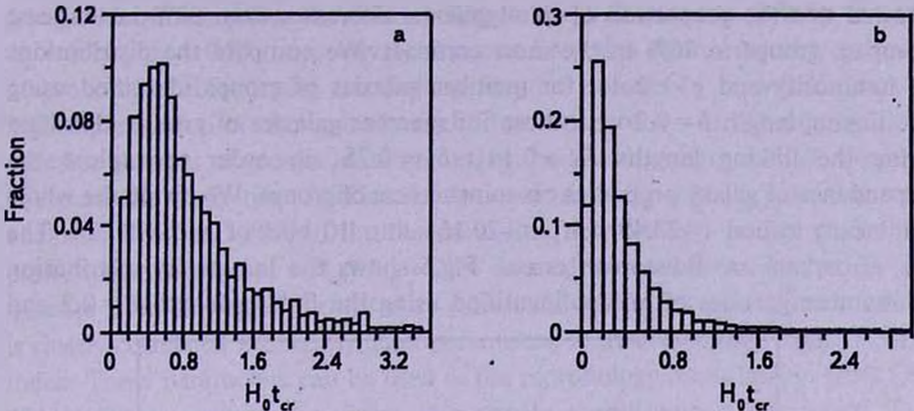

Fig.4. Histogram of the crossing time distribution of groups: a - identified using the linking length $b = 0.2$, b - identified using the linking lengths $b_{\perp} = 0.14$, $b_{\parallel} = 0.75$.

mean physical properties of the group catalog identified using the linking length $b=0.2$ (corresponding to the three-dimensional linking length $R_0 \approx 1.36$ Mpc) with those of 1298 compact groups of galaxies (CGs) identified at the three-dimensional linking length $R = 1.2$ Mpc by Deng et al. [34] and find that the mean velocity dispersion, virial radius and virial mass of the group catalog identified using the linking length $b=0.2$ are apparently larger than those of CGs. This further shows that these properties of groups are heavily influenced by the relative values of the linking parameters. As stated by Berlind et al. [11], the choice of the linking lengths is the most important ingredient of group-finding algorithm. If the linking lengths are too small, then the group-finder will break up groups into double and multiple systems. If the linking lengths are too large, then different groups will be fused together into clusters even superclusters. For example, at the linking lengths $b_{\perp} = 0.14$, $b_{||} = 0.75$, a huge supercluster (Great Wall of galaxies) is formed in our Main galaxy sample of the SDSS. For the galaxy samples which are a simple and central clustering, such linking lengths may be a right choice, but for the galaxy samples with filamentary morphology, such linking lengths are too large and many groups will be fused together into a huge system. There may be no values for the linking lengths that will work perfectly for every sample. The right choice of linking lengths depends on the purpose for which groups are being identified [11]. On the other hand, we also notice that using the same linking lengths, the mean velocity dispersion, virial radius and virial mass of the group catalogs identified in the volume-limited sample are much smaller than those of ones identified in the flux-limited sample. This is mainly due to selection effects in the flux-limited sample.

Groups identified using the linking length $b=0.2$ are denser systems than ones identified using the linking lengths $b_\perp = 0.14$, $b_\parallel = 0.75$. Hickson [35] showed that the proportion of spiral galaxies decreases from 60% in the least compact groups to 20% in the most compact. We compare the distributions of luminosity and $g-r$ color for member galaxies of groups identified using the linking length $b=0.2$ with those for member galaxies of groups identified using the linking lengths $b_\perp = 0.14$, $b_\parallel = 0.75$, in order to explore the dependence of galaxy properties on compactness of groups. We divide the whole luminosity region ($-22.40 \le M_r \le -20.16$) into 10 bins of width 0.224. The 1σ error bars are Poissonian errors. Fig.5 shows the luminosity distribution of member galaxies of groups identified using the linking length $b=0.2$ and

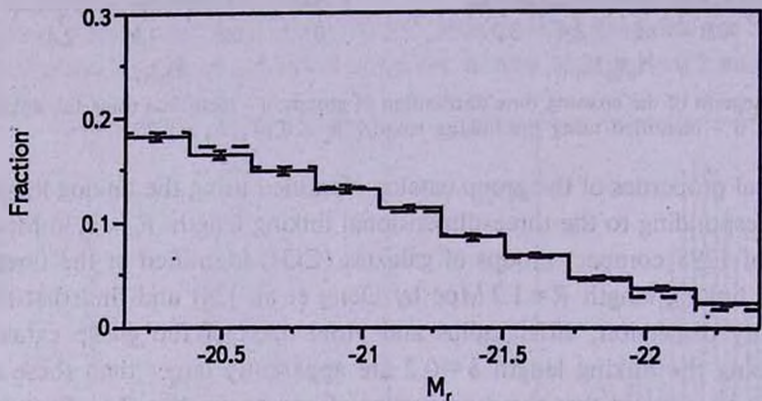

Fig.5. The luminosity distribution of member galaxies of groups identified using the linking lengths $b_\perp = 0.14$, $b_\parallel = 0.75$ (dashed line) and using the linking length $b=0.2$ (solid line). The error bars are 1σ Poissonian errors for member galaxies of groups identified using the linking length $b=0.2$.

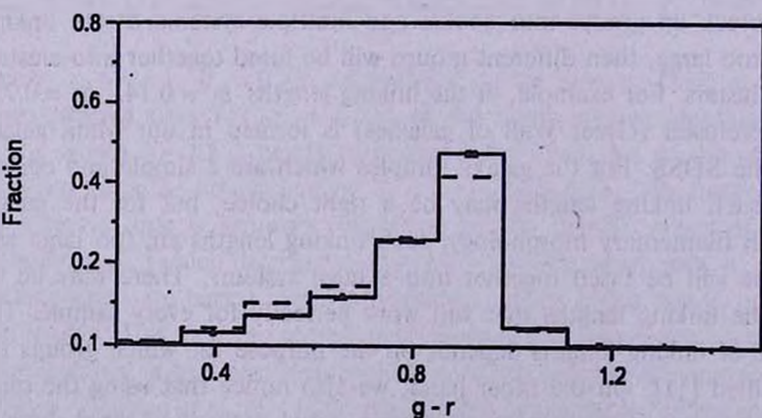

Fig.6. The $g-r$ color distribution of member galaxies of groups identified using the linking lengths $b_\perp = 0.14$, $b_\parallel = 0.75$ (dashed line) and using the linking length $b=0.2$ (solid line). The error bars are 1σ Poissonian errors for member galaxies of groups identified using the linking length $b=0.2$.

the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$, respectively. The luminosity distribution of member galaxies of groups identified by different algorithms is nearly the same. Fig.6 shows $g-r$ color distribution of member galaxies of groups identified using the linking length $b=0.2$ and the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$, respectively. As seen from this figure, member galaxies of groups identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$ have a higher proportion of blue galaxies and a lower proportion of red galaxies than member galaxies of groups identified using the linking length $b=0.2$. We also compute the early-type fraction of two samples. R_{50} and R_{90} are the radii enclosing 50% and 90% of the Petrosian flux, respectively. In this study, the concentration index $c_i = R_{90}/R_{50} = 2.86$ is used to separate early-type (E/S0) galaxies from late-type (Sa/b/c, Irr) galaxies [36-37]. The galaxy morphology is closely correlated with many other parameters, such as color and concentration index. These parameters can be used as the morphology classification tools [36, 38-41]. The concentration index is a simple morphological parameter. The early-type fraction of two samples are respectively: 44.19% for groups identified using the linking length $b=0.2$, 40.14% for groups identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$. Although $g-r$ color and morphology of galaxies apparently depend on compactness of groups, we do not observe as large statistical difference as Hickson [35] results for systems having different compactness.

5. *Summary.* From the volume-limited Main galaxy sample of SDSS DR6, we have identified groups by Berlind et al. [11] algorithm and Davis et al. [13] algorithm and compare the mean properties of groups with those of groups extracted by the same algorithms from the flux-limited Main galaxy sample of the SDSS Data Release 5. It is found that the mean velocity dispersion, virial radius and virial mass of the group catalogs identified in the volume-limited sample are much smaller than those of ones identified in the flux-limited sample. Our study shows that these properties of groups are heavily influenced by the relative values of the linking parameters and that there may be no values for the linking lengths that will work perfectly for every sample. We also compare the distributions of luminosity and $g-r$ color for member galaxies of groups identified using the linking length $b=0.2$ with those for member galaxies of groups identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$, in order to explore the dependence of galaxy properties on compactness of groups. The luminosity distribution of member galaxies of groups identified by different algorithms is nearly the same, but member galaxies of groups identified using the linking lengths $b_{\perp}=0.14$, $b_{\parallel}=0.75$ have a higher proportion of blue galaxies and a lower proportion of red galaxies than member galaxies of groups identified using the linking length $b=0.2$. In addition, the early-type fraction of member galaxies of groups identified using

the linking length $b = 0.2$ is higher than that of member galaxies of groups identified using the linking lengths $b_{\perp} = 0.14$, $b_{\parallel} = 0.75$. These are due to groups identified using the linking length $b = 0.2$ being denser systems than ones identified using the linking lengths $b_{\perp} = 0.14$, $b_{\parallel} = 0.75$.

Acknowledgements. Our study is supported by the Program for Innovative Research Team of Nanchang University and also supported by the National Natural Science Foundation of China (10765004).

Funding for the creation and distribution of the SDSS Archive has been provided by the Alfred P.Sloan Foundation, the Participating Institutions, the National Aeronautics and Space Administration, the National Science Foundation, the U.S. Department of Energy, the Japanese Monbukagakusho and the Max Planck Society. The SDSS Web site is http://www.sdss.org/.

The SDSS is managed by the Astrophysical Research Consortium (ARC) for the Participating Institutions. The Participating Institutions are The University of Chicago, Fermilab, the Institute for Advanced Study, the Japan Participation Group, The Johns Hopkins University, Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, University of Pittsburgh, Princeton University, the United States Naval Observatory and the University of Washington.

School of Science, Nanchang University, Jiangxi,
China, e-mail: xinfadeng@yahoo.com.cn

ОСНОВНЫЕ ХАРАКТЕРИСТИКИ ГРУПП ГАЛАКТИК ПО ПРОСТРАНСТВЕННО-ОГРАНИЧЕННОЙ ВЫБОРКЕ SDSS DR6

ХИН-ФА ДЕНГ, ДЖИ-ЖУ ХЕ, ЦОНГ ДЖУН,
ЧЕНГ-ХОНГ ЛУО, ПИНГ ВИ

Используя алгоритмы Берлинда и др., а также Дейвиса и др., мы нашли, что средняя дисперсия скоростей, вириальный радиус и вириальная масса в каталогах групп, отождествленных в пространственно-ограниченной выборке, намного меньше, чем в тех случаях, когда они отождествлены в выборке, ограниченной - по потокам. Наше исследование показывает, что на эти характеристики групп оказывают сильное влияние относительные значения связывающих параметров и что нет каких-либо значений для

связывающих длин, которые были бы безупречны для любых выборок. К тому же, мы отмечаем, что распределения светимостей членов групп, отождествленных по разным алгоритмам, почти одинаковы. Однако члены групп, отождествленных с использованием связывающих длин $b_{\perp} = 0.14$, $b_{\parallel} = 0.75$, содержат большое количество голубых галактик и меньшее количество красных галактик, чем члены групп, отождествленных с использованием связывающей длины $b=0.2$. Соответственно, в последнем случае доля ранних типов галактик среди членов групп больше, чем в случае отождествления членов групп при $b_{\perp} = 0.14$ и $b_{\parallel} = 0.75$.

Ключевые слова: *галактики:основные параметры:широкомасштабная структура*

REFERENCES

1. *J.P.Huchra, M.J.Geller*, Astrophys. J., 257, 423, 1982.
2. *M.J.Geller, J.P.Huchra*, Astrophys. J. Suppl. Ser., 52, 61, 1982.
3. *M.E.Merch'an, M.A.G.Maia, D.G.Lambas*, Astrophys. J., 545, 26, 2000.
4. *G.Giuricin, C.Marinoni, L.Ceriani, A.Pisani*, Astrophys. J., 543, 178, 2000.
5. *D.L.Tucker, A.Jr.Oemler, Y.Hashimoto et al.*, Astrophys. J. Suppl. Ser., 130, 237, 2000.
6. *R.G.Carlberg, H.K.C.Yee, S.L.Morris et al.*, Astrophys. J., 552, 427, 2001.
7. *M.Ramella, M.J.Geller, A.Pisani, L.N. da Costa*, Astron. J., 123, 2976, 2002.
8. *M.E.Merch'an, A.Zandivarez*, Mon. Notic. Roy. Astron. Soc., 335, 216, 2002.
9. *V.R.Eke, C.M.Baugh, S.Cole et al.*, Mon. Notic. Roy. Astron. Soc., 348, 866, 2004.
10. *M.E.Merch'an, A.Zandivarez*, Astrophys. J., 630, 759, 2005.
11. *A.A.Berlind, J.Frieman, D.H.Weinberg et al.*, Astrophys. J. Suppl. Ser., 167, 1, 2006.
12. *X.F.Deng, J.Z.He, P.Jiang et al.*, Astron. Astrophys., 474, 783, 2007a.
13. *M.Davis, G.Efstathiou, C.S.Frenk, S.D.M.White*, Astrophys. J., 292, 371, 1985.
14. *A.Jenkins, C.S.Frenk, S.D.M.White et al.*, Mon. Notic. Roy. Astron. Soc., 321, 372, 2001.
15. *M.A.Strauss, D.H.Weinberg, R.H.Lupton et al.*, Astron. J., 124, 1810, 2002.
16. *J.K.Adelman-McCarthy, M.A.Agüeros, S.S.Allam et al.*, Astrophys. J. Suppl. Ser., 172, 634, 2007a.
17. *J.R.Gott, M.Juric, D.Schlegel et al.*, Astrophys. J., 624, 463, 2005.
18. *X.F.Deng, Y.Q.Chen, Q.Zhang et al.*, Chin. J. Astron. Astrophys., 6, 35, 2006.
19. *X.F.Deng, J.Z.He, C.G.He et al.*, Acta Physica Polonica B, 38, 219, 2007b.
20. *E.A.Praton, A.L.Melott, M.Q.Mckee*, Astrophys. J., 479, L15, 1997.

21. *J.K.Adelman-McCarthy, M.A.Agüeros, S.S.Allam et al.*, Astrophys. J. Suppl. Ser., in press (arXiv:0707.3413), 2007b.
22. *C.Stoughton, R.H.Lupton, M.Bernardi et al.*, Astron. J., **123**, 485, 2002.
23. *D.J.Eisenstein, J.Annis, J.E.Gunn et al.*, Astron. J., **122**, 2267, 2001.
24. *X.F.Deng, J.Z.He, P.Jiang*, Astrophys. J., **671**, L101, 2007c.
25. *C.Park, Y.Y.Choi, M.S.Vogeley et al.*, Astrophys. J., **633**, 11, 2005a.
26. *M.R.Blanton, J.Brinkmann, I.Csabai et al.*, Astron. J., **125**, 2348, 2003.
27. *E.L.Turner, W.L.W.Sargent*, Astrophys. J., **194**, 587, 1974.
28. *J.C.Jackson*, Mon. Notic. Roy. Astron. Soc., **173**, 41p, 1975.
29. *J.R.I.Gott, E.L.Turner*, Astrophys. J., **213**, 309, 1977.
30. *H.J.Rood, J.R.Dickel*, Astrophys. J., **224**, 724, 1978.
31. *A.Diaferio, M.Ramella, M.Geller et al.*, Astron. J., **105**, 2035, 1993.
32. *M.Girardi, G.Giuricin*, Astrophys. J., **540**, 45, 2000.
33. *G.Giuricin, S.Samurović, M.Girardi et al.*, Astrophys. J., **554**, 857, 2001.
34. *X.F.Deng, J.Z.He, X.S.Ma et al.*, Central European Journal of Physics, in press, 2008.
35. *P.Hickson*, Astrophys. J., **255**, 382, 1982.
36. *K.Shimasaku, M.Fukugita, M.Doi et al.*, Astron. J., **122**, 1238, 2001.
37. *O.Nakamura, M.Fukugita, N.Yasuda et al.*, Astron. J., **125**, 1682, 2003.
38. *C.Park, Y.Y.Choi*, Astrophys. J., **635**, L29, 2005b.
39. *C.Yamauchi, T.Goto*, Mon. Notic. Roy. Astron. Soc., **359**, 1557, 2005.
40. *R.G.Abraham, S. van den Bergh, P.A.Nair*, Astrophys. J., **588**, 218, 2003.
41. *I.Strateva, Z.Ivezic, G.R.Knapp et al.*, Astron. J., **122**, 1861, 2001.