АСТРОФИЗИКА

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DEPENDENCE OF SOME PROPERTIES OF GROUPS ON GROUP LOCAL NUMBER-DENSITY

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In this study we investigate the dependence of projected size $Size_{sky}$, rms deviation σ_R of projected distance in the sky from the group centre, rms velocities σ_V and virial radius R_{Vir} of groups on group local number-density. In the volume-limited group samples, it is found that groups in high density regions preferentially have larger $Size_{sky}$, σ_R, σ_V and R_{Vir} than ones in low density regions.

Key words: *cosmology: large-scale structure of universe - galaxies: fundamental parameters*

1. *Introduction.* Galaxy parameters are closely correlated with the environment of galaxies [1-25], which can be explained by the fact that there is a likely link between the halo properties and the galaxy properties [26]. When exploring such an issue, it is important to keep in mind that there often are tight correlations between galaxy properties [1,5,27-31]. This means that when knowing the correlation between a galaxy parameter and environment, one can anticipate the correlations between other galaxy parameters and environment. But many authors still devoted oneself to studies of the environmental dependence of various galaxy parameters. This can be traced to two facts. First, one often was not clear that which parameter is fundamental in correlations between galaxy parameters and environment. Second, correlations between physical properties of galaxies are not single and simple trends. For example, Strateva et al. [27] reported that the majority of blue galaxies is late-types (spirals), while the majority of red galaxies is early types (ellipticals). But some works showed that a significant fraction of red galaxies is not early-types [18,20]. Thus, it is rough to guess the correlations between some galaxy parameters and environment, only based on the correlations between other galaxy parameters and environment and correlations between physical properties of galaxies.

Galaxy groups or clusters can be defined as building blocks of the second-order clustering in the Universe. Some authors examined the correlations between parameters of galaxy groups or clusters and environment. Merch'an et al. [32] reported an increase of the amplitude of the correlation function of groups with the group masses. Giuricin et al. [33] demonstrated that groups with greater velocity dispersions, sizes, and virial masses cluster more strongly than groups with lower values of these parameters. Einasto et al. [34] showed that luminous clusters tend to reside in high-density regions, while low-luminosity clusters tend to reside in low-density regions. Einasto et al. [35] investigated clusters and superclusters in numerical simulations and found that simulated clusters in a high-density environment are also more massive than those in a low-density environment. Wang et al. [36] argued that the correlation amplitude of galaxy groups depends strongly on their masses and colors: more massive groups are more strongly clustered, and red groups also are more strongly clustered than blue groups. Their results are consistent with those obtained by Yang et al. [37].

Deng & Yu [38] studied the dependence of the total luminosity of groups on group local number-density, and demonstrated that groups with high luminosity tend to reside in high density regions, while groups with low luminosity tend to reside in low density regions. Considering likely correlations between group luminosity and other properties of groups [39-40], one can anticipate the correlations between group local number-density and other parameters of groups But, similar to the issues of galaxies, such studies still are necessary. Here, we attempt to further explore the correlation between group local number-density and other properties of groups.

The outline of our paper is as follows. Section 2 describes the data used. In Section 3, we present our results for the dependence of some properties of groups on group local number-density. Finally, Section 4 summarize our main results and conclusions.

2. *Data*. Following Deng & Yu [38], we use the group catalogs compiled by Tago et al. [41]. Section 2 of Deng & Yu [38] describes this data set. Here, we briefly summarise the key points. Tago et al. [41] extracted groups of galaxies with richness ≥ 2 as flux-limited and volume-limited samples from the Main galaxy sample [42] of the Sloan Digital Sky Survey Data Release 7 (SDSS DR7) [43] (http://www.sdss.org/dr7/). The Main galaxy sample used by Tago et al. [41] was limited in the redshift range $z = 0.009 - 0.2$, and contains 583362 galaxies. The group catalogs are available at the CDS. Table1 of Deng & Yu [38] lists some parameters of the group catalogs.

3. *Statistical results*.

3.1. *$Size_{sky}$, σ_R, σ_V and R_{Vir} of groups*. Section 2 of Tago et al. [41] describes the definition of the main properties of groups. Here, we briefly summarise the key points. Tago et al. [41] defined the size of a group $Size_{sky}$ (h^{-1} Mpc) as the largest projected distance between galaxies within the group. Tago et al. [41] also calculated rms deviation σ_R (h^{-1} Mpc) of projected distance in the sky from the group centre. The velocity dispersions σ_V^2 were computed with the standard formula

$$\sigma_V^2 = \frac{1}{(1+z_m)^2(n-1)}\sum_{i=1}^{n}(V_i - V_{mean})^2, \tag{1}$$

where V_{mean} and z_m are the mean group velocity and redshift, respectively, V_i is the velocity of an individual group member, and n is the number of galaxies with observed velocities in a group. σ_V (km s^{-1}) is rms radial velocities of galaxies in groups. The virial radii R_{Vir} (h^{-1} Mpc) of groups were calculated by the formula

$$\frac{1}{R_{Vir}} = \frac{2}{(1+z_m)n(n-1)}\sum_{i\neq j}^{n}\frac{1}{R_{ij}}. \tag{2}$$

where R_{ij} is the projected distance between galaxies in pairs in a group.

3.2. ***The dependence of $Size_{sky}$, σ_R, σ_V and R_{Vir} of groups on group local number-density.*** We proceed with the same approach as used by Deng & Yu [38]. Section 3 of Deng & Yu [38] describes this method in detail. Following Deng & Yu [38], we measure the three-dimensional local group density which is computed from the distance to the 5th nearest neighbor of each group in a comoving sphere, choose $\approx 5\%$ groups and construct two

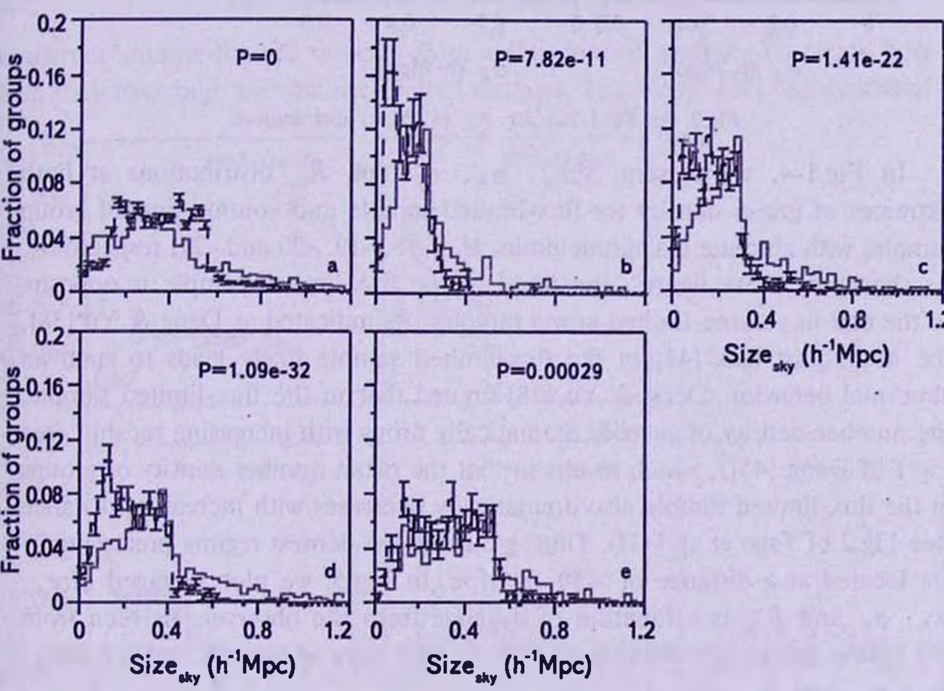

Fig.1. $Size_{sky}$ (h^{-1} Mpc) distribution at both extremes of group density for flux-limited group sample (a) and volume-limited group samples with absolute magnitude limits M_r = -18 (b), -19 (c), -20 (d), and -21 (e): solid line for the subsample at high density, dashed line for the subsample at low density. The error bars of dashed lines are 1σ Poissonian errors. Error-bars of solid lines are omitted for clarity.

subsamples at both extremes of density for each sample, to compare $Size_{sky}$, σ_R, σ_V and R_{Vir} distributions of groups in the lowest density regime with ones in the densest regime.

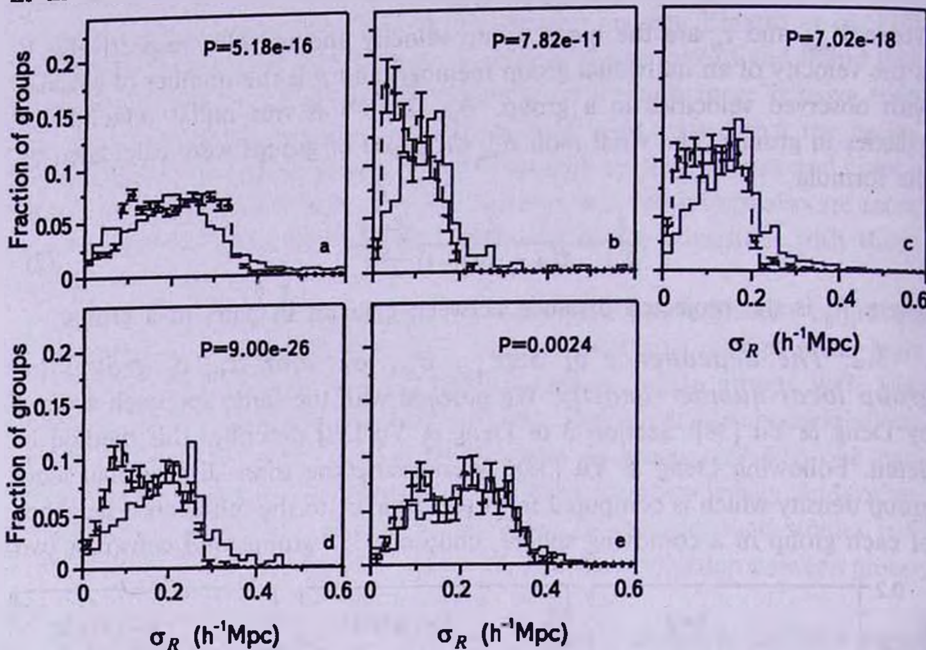

Fig.2. As Fig.1 but for σ_R (h^{-1} Mpc) distribution.

In Fig.1-4, we present $Size_{sky}$, σ_R, σ_V and R_{Vir} distributions at both extremes of group density for flux-limited sample and volume-limited group samples with absolute magnitude limits M_r=-18, -19, -20 and -21, respectively. As shown by these figures, the trend in the flux-limited sample is opposite to the one in volume-limited group samples. As indicated as Deng & Yu [38], the Malmquist bias [44] in the flux-limited sample likely leads to such an abnormal behavior. Deng & Yu [38] argued that in the flux-limited sample, the number-density of galaxies dramatically drops with increasing redshift (see Fig.1 of Deng [45]), which results in that the mean number density of groups in the flux-limited sample also dramatically decreases with increasing distance (see Fig.2 of Tago et al. [41]). Thus, groups in the densest regime preferentially are located at a distance of ≈ 50 h^{-1} Mpc. In Fig.5, we plot averaged $Size_{sky}$, σ_R, σ_V and R_{Vir} as a function of distance from the observer. As seen from this figure, groups at a distance of ≈ 50 h^{-1} Mpc have apparently smaller $Size_{sky}$, σ_R, σ_V and R_{Vir}.

Deng & Yu [38] argued that because selection effects of the group catalogs could affect the interpretation of statistical results, one should cautiously accept the conclusion obtained from the flux-limited sample. A good choice is to

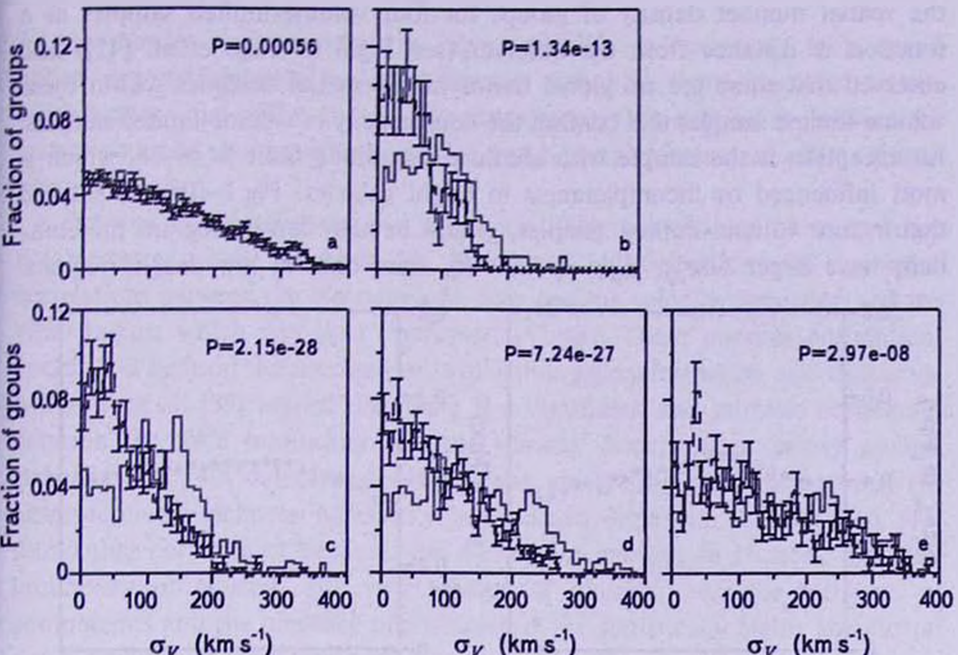

Fig.3 As Fig.1 but for σ_V (km s^{-1}) distribution.

construct volume-limited samples from a flux-limited sample. To check how well they have built the volume-limited samples, Tago et al. [41] demonstrated

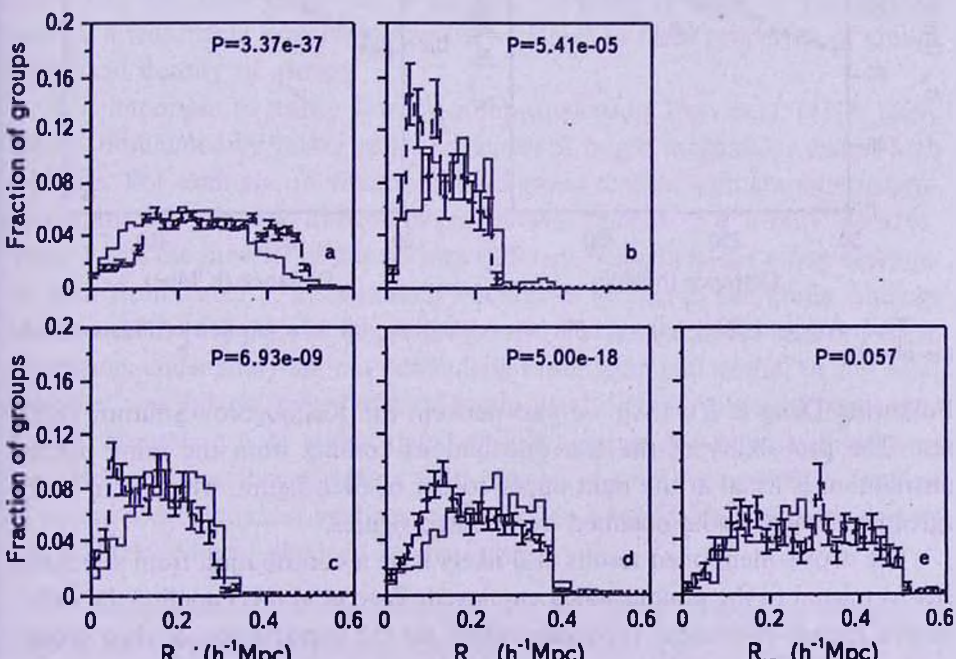

Fig.4. As Fig.1 but for R_{Vir} (h^{-1} Mpc) distribution.

the spatial number density of groups for four volume-limited samples as a function of distance from the observer (see Fig.6 of Tago et al. [41]) and observed that there are no global trends in the spatial densities within these volume-limited samples that confirm the homogeneity of volume-limited samples. An exception is the sample with absolute magnitude limit $M_r = -18$, which is most influenced by incompleteness in bright galaxies. Fig.1-4(b)-(e) showed that in four volume-limited samples, groups in high density regions preferentially have larger $Size_{sky}$, σ_R, σ_V and R_{Vir} than ones in low density regions.

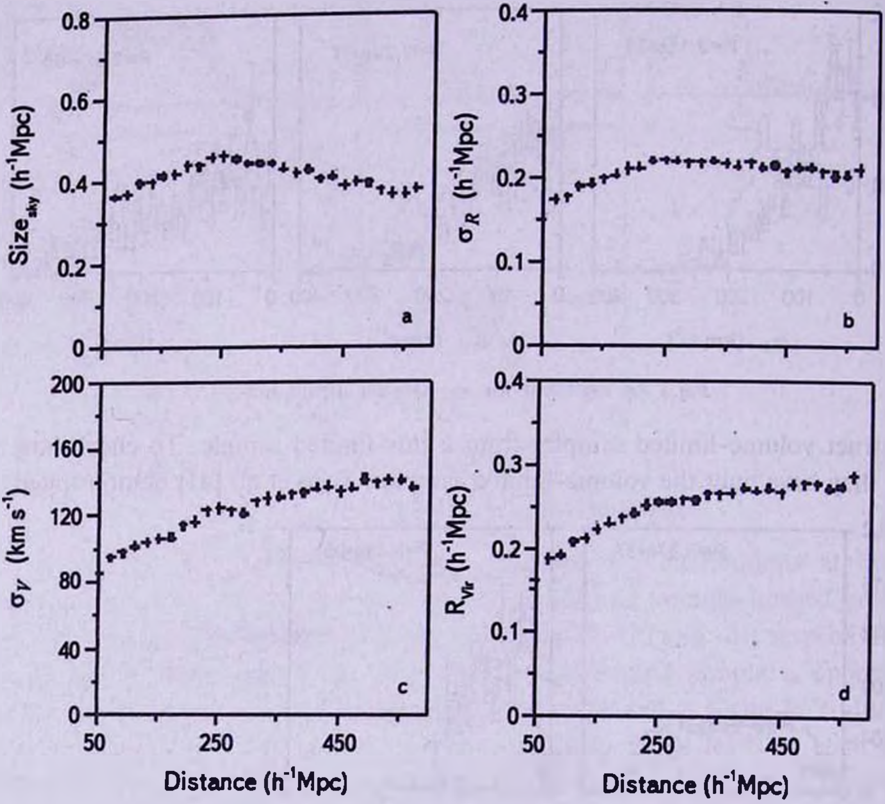

Fig.5. Averaged $Size_{sky}$ (a), σ_R (b), σ_V (c) and R_{Vir} (d) as a function of distance from the observer.

Following Deng & Yu [38], we also perform the Kolmogorov-Smirnov (KS) test. The probability of the two distributions coming from the same parent distribution is listed at the right upper corner of each figure, which is in good agreement with results obtained by the step figures.

The above-mentioned results also likely have a contribution from selection effects related to the group catalog employed. Tago et al. [41] applied the well-known"friends-of-friends" (FoF) algorithm for the construction of their group catalog. Such an algorithm may favor the detection of sparse low-mass groups in low-density environments. In higher-density environments, such sparse groups may preferentially be linked together with other more massive structures (with higher virial radius and velocity dispersion), thus helping to produce the results obtained. But in volume-limited group samples, selection effects should become smaller.

Previous studies showed that there are likely correlations between some parameters of groups [39-40,46-48]. Rood et al. [46] first discovered significant correlations between the mass-to-light ratio and the velocity dispersion and the virial radius, which was later confirmed [47-48]. These possible correlations could shed light on the mechanism involved in galaxy formation and clustering. Mezzetti et al. [39] argued that there is a significant and intrinsic correlation between the total luminosity and the velocity dispersion in galaxy groups. Bahcall et al. [40] demonstrated that there are scaling relations between the observed cluster richness, luminosity, and velocity dispersion. Einasto et al. [49] found that correlations between the number of galaxies in clusters, the total luminosity of clusters, the virial radius of clusters, and the numbers of components and the presence of substructure are statistically highly significant: richer, larger and more luminous clusters have a larger amount of substructure. Deng & Yu [38] observed that groups with high luminosity exist preferentially in high density regions, while groups with low luminosity are located preferentially in low density regions. Considering likely correlations between group luminosity and these properties of groups, the result of Deng & Yu [38] can provide a reasonable explanation for the variation in these properties of groups with local density of groups.

It is important to realize that the group catalogs of Tago et al. [41] is likely heavily dominated by galaxy pairs, especially at bright magnitudes and at high redshifts. For example, in volume-limited group sample with absolute magnitude limits $M_r = -21$, the fraction of groups with richness ≥ 4 is only $\approx 5.92\%$. Table 1 lists the number of groups with different richness in the group catalogs. As seen from Table 1, a substantial fraction of groups in the group catalogs of Tago et al. [41] may be spurious systems. For low-richness systems, these parameters under study are not particularly meaningful and would, in any case, represent very biased tracers of total group 'size" or other physical properties. A good suggestion is to repeat the statistical analysis of groups with richness ≥ 4. However, number of groups with richness ≥ 4 in the samples is too few to ensure ideal statistical analyses. Such studies need larger and more perfect group catalogs likely obtained in the future.

4. *Conclusions*. In this study, we use the group catalogs compiled by Tago et al. [41], and investigate the dependence of $Size_{sky}$, σ_R, σ_V and R_{Vir} of groups on group local number-density. The main results can be summarized as follows:

Table1

NUMBER OF GROUPS WITH DIFFERENT RICHNESS IN THE SAMPLES

Sample	N_{groups} (richness ≥ 4)	N_{groups} (richness ≥ 2)
Flux-limited groups	16564	78800
Volume-limited groups		
$M_r < -18$	996	5463
$M_r < -19$	2108	12590
$M_r < -20$	2771	18973
$M_r < -21$	541	9139

1) The trend in the flux-limited sample is opposite to the one in volume-limited group samples. This is likely due to the Malmquist bias [44] in the flux-limited sample, which suggests that one should cautiously accept the conclusion obtained from the flux-limited sample, and use volume-limited samples.

2) In the volume -limited group samples, it is found that groups in high density regions preferentially have larger $Size_{sky}$, σ_R, σ_V and R_{Vir} than ones in low density regions, which is likely due to the dependence of group luminosity on group local number-density [38] and correlations between group luminosity and these properties of groups.

3) Because some parameters of low-richness groups are not particularly meaningful, one wishes to see statistical results of groups with richness ≥ 4. However, number of groups with richness ≥ 4 in the samples is too few to ensure ideal statistical analyses. We expect that larger and more perfect group catalogs are available in the future.

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Japan Participation Group, Johns Hopkins University, the Joint Institute for Nuclear Astrophysics, the Kavli Institute for Particle Astrophysics and Cosmology, the Korean Scientist Group, the Chinese Academy of Sciences (LAMOST), Los Alamos National Laboratory, the Max Planck Institute for Astronomy (MPIA), the Max Planck Institute for Astrophysics (MPA), New Mexico State University, Ohio State University, University of Pittsburgh, University of Portsmouth, Princeton University, the US Naval Observatory and the University of Washington.

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ЗАВИСИМОСТЬ НЕКОТОРЫХ ОСОБЕННОСТЕЙ ГРУПП ОТ МЕСТНОЙ ЦИФРОВОЙ ПЛОТНОСТИ

ХИН-ФА ДЕНГ, ПИНГ ВУ

В этой статье мы исследуем зависимость проектированного размера $Size_{sky}$, rms отклонение σ_R проектированного расстояния в небе от группового центра, rms скорости σ_V и вириальный радиус R_{Vir} групп от групповой местной плотности.В образцах пространственно-ограниченных групп найдено, что группы с областями высокой плотности преимущественно имеют большие $Size_{sky}$, σ_R, σ_V и R_{Vir}, чем группы находящиеся в областях низкой плотности.

Ключевые слова: *космология: структура Вселенной большого масштаба: галактики: основные параметры*

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