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Effects of both extremes of environments on galaxy properties

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ABSTRACT

Aims. We investigate the dependence of galaxy properties on the local environment.
Methods. Member galaxies of compact groups (CGs) and isolated galaxies are located at both extremes of density, which are identified from the volume-limited Main galaxy sample of the Sixth Data Release of the Sloan Digital Sky Survey(SDSS DR6), while the volume-limited Main galaxy sample represents the mean density. We perform comparative studies of distributions of various physical properties among member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample.
Results. We find that physical properties of galaxies, such as luminosity, size, colors, concentration index, and morphology strongly depend on the local environment: luminous, red, and early-type galaxies exist preferentially in the densest regions of the universe (e.g., in groups), while faint, blue, and late-type galaxies are located preferentially in low-density regions.

Key words. Galaxy: general – galaxies: fundamental parameters

1. Introduction

Galaxy properties are strongly correlated with environment (e.g., Oemler 1974; Dressler 1980; Postman & Geller 1984; Whitmore et al. 1993; Dressler et al. 1997; Hashimoto & Oemler 1999; Fasano et al. 2000; Tran et al. 2001; Lewis et al. 2002; Gómez et al. 2003; Goto et al. 2003; Helsdon & Ponman 2003; Hogg et al. 2003; Treu et al. 2003; Tanaka et al. 2004; Balogh et al. 2004a,b; Hogg et al. 2004; Kauffmann et al. 2004; Berlind et al. 2005; Blanton et al. 2005; Kelm et al. 2005; Deng et al. 2007a–d; Park et al. 2007). It is widely accepted that luminous, red, and early-type galaxies exist preferentially in the densest regions of the universe, while faint, blue, and late-type galaxies are located preferentially in low-density regions. Compact groups of galaxies (CGs) are small and dense systems of several galaxies in the universe. Diaferio et al. (1994) showed that within a single rich collapsing group CGs continually form. Governato et al. (1996) proposed a model in which merging activity in CGs is accompanied by infall of galaxies from the environment. Hickson (1997) indicated that giant galaxies may be formed as the end product of compact-group evolution. Many authors studied CGs from different aspects (Zepf et al. 1991; Zepf & Whitmore 1991; Yun et al. 1997; Severgnini & Saracco 2001; Verdes-Montenegro et al. 2001; Johnson et al. 2007). Compact groups often are located at the centers of concentration in groups or clusters and actually represent the densest local environment. In contrast, isolated galaxies often reside in the most underdense regions and have no close companions. They may have experienced no major interactions in billions of years. Similarly, isolated galaxies also have been a very important issue of Astrophysics (Adams et al. 1980; Haynes & Giovanelli 1980; Haynes et al. 1984; Koopmann & Kenney 1998; Reda et al. 2004; Rojas et al. 2004; Croton et al. 2005; Hoyle et al. 2005; Rojas et al. 2005; Hernández-Toledo et al. 2007; Nigoche-Netro et al. 2007). The comparison between properties of isolated galaxies and member galaxies of other galaxy systems (e.g., close pairs or groups) is a useful method to unveil the effects of interactions or environment on the galaxy properties. In this study, we intend to perform comparative studies of distributions of various physical properties among member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample of the Sloan Digital Sky Survey (SDSS) Data Release 6 (Adelman-McCarthy et al. 2007). Member galaxies of CGs and isolated galaxies are located at both extremes of density, while the volume-limited Main galaxy sample represents the mean density. Undoubtedly, this research is beneficial to the understanding of the dependence of galaxy properties on the local environment.

Our paper is organized as follows. In Sect. 2, we describe the data used. The identification algorithms of CGs and isolated galaxies are discussed in Sect. 3. In Sect. 4, we perform comparative studies of distributions of various physical properties among member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample. Our main results and conclusions are summarized in Sect. 5.

2. Data

The Sloan Digital Sky Survey (SDSS) is one of the largest astronomical surveys to date. The completed survey will cover approximately 10 000 square degrees. Many of the survey properties were discussed in detail in the Early Data Release paper (Stoughton et al. 2002). Galaxy spectroscopic targets can be selected by two algorithms. The Main galaxy sample (Strauss et al. 2002) comprises galaxies brighter than $r_{\rm petro} < 17.77$ (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 $0.02 \leq z \leq 0.2$. The Luminous Red Galaxy (LRG) algorithm (Eisenstein et al. 2001) selects galaxies to $r_{\rm petro} < 19.5$, which are likely to be luminous early-types based on the observed colors. These LRGs are intrinsically red and at higher redshift.

We used the Main galaxy sample. The data were downloaded from the Catalog Archive Server of the SDSS Data Release 6 (Adelman-McCarthy et al. 2007) by the SDSS SQL Search (with the SDSS flag: bestPrimtarget&64>0) with high-confidence redshifts (Zwarning ≠16 and Zstatus ≠0, 1 and redshift confidence level: zconf>0.95) (`http://www.sdss.org/dr6/`). From this sample, we select 469 199 Main galaxies in the redshift region $0.02 \leq z \leq 0.2$. The galaxy number of the SDSS DR6 is much larger than that of previous data release. We used the volume-limited Main galaxy sample constructed by Deng et al. (2008), which contains 112 889 galaxies, extends to $Z_{\max} = 0.089$, and is limited to the absolute magnitude region $-22.40 \leq M_r \leq -20.16$. The absolute magnitude M_r is calculated from the r-band apparent Petrosian magnitude, using a polynomial fit formula (Park et al. 2005), for the K-correction (Blanton et al. 2003a) within $0 < z < 0.3$:

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

The absolute magnitude limit $M_r = -20.16$ corresponds to 0.33 mag fainter than the value of M^* found for the overall Schechter fit to the galaxy luminosity function (Ball et al. 2006). As indicated by Norberg et al. (2001), the clustering amplitude increases strongly with absolute magnitude only for galaxies brighter than M^*. So, this volume-limited sample is appropriate for investigating the dependence of galaxy luminosity on the environment.

Many properties of galaxies depend strongly on luminosity (e.g., de Vaucouleurs 1961; Kormendy 1977; Bower et al. 1992; Blanton et al. 2003b; Shen et al. 2003; Baldry et al. 2004; Balogh et al. 2004b; Kelm et al. 2005), for example, more luminous galaxies are redder and preferentially early-type. The Main galaxy sample is an apparent magnitude-limited sample in which fainter galaxies progressively missed with increasing distance from the observer. In such a sample, the mean luminosity and many other properties of galaxies apparently change with redshift z. Due to the number-density of galaxies in an apparent magnitude-limited sample dropping dramatically with increasing redshift, there is a higher proportion of isolated galaxies in high redshift regions. This results in a higher proportion of luminous, red, and early-type galaxies in the isolated galaxy sample. To decrease the radial selection effect, a simple method is to use a volume-limited galaxy sample in which the radial selection function is approximately uniform, thus the only variation in the space density of galaxies with radial distance is due to clustering. But we also notice that in a volume-limited sample, fainter galaxies are excluded at all distances from the observer; a large fraction of the data is not used, and galaxies are restricted to smaller luminosity or color regions.

In calculating the co-moving distance, we use 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. Identification algorithms of CGs and isolated galaxies

3.1. Identification algorithm of CGs

The first large-scale, systematic search for CGs on the sky was made by Hickson (1982). Lee et al. (2004) slightly modified Hickson's criteria and extracted 175 CGs from the SDSS. Hickson (1982) and Lee et al. (2004) only considered the galaxy angular distribution and did not use redshifts to identify CGs. Thus, we believe that CGs identified by such criteria are seriously contaminated by background/foreground galaxies. Barton et al. (1996) used a different version of the friends-of-friends algorithm: galaxies having projected separation $r_\mathrm{p} \leq 50\,h^{-1}$ kpc and line-of-sight velocity difference $\triangle V \leq 1000\ \mathrm{km\,s^{-1}}$ (about 14.3 Mpc) are connected, and the sets of connected galaxies constitute the groups. Apparently, the velocity selection criterion will greatly decrease the contamination by background/foreground galaxies. By allowing a longer linking length in the radial direction, Barton et al. (1996) algorithm successfully accounted for the stretching of groups in redshift space along the radial direction-the redshift space distortion. But the criterion of radial distance used by Barton et al. (1996) is 286 times larger than that of the projected separation. This suggests that CGs identified by such a method still are seriously contaminated by background/foreground galaxies. In addition, we note that the projected separation criterion of CG identification developed by Barton et al. (1996) is even smaller than that of pair identification. For example, Lambas et al. (2003) selected galaxy pairs by radial velocity difference ($\triangle V \leq 350\ \mathrm{km\,s^{-1}}$) and projected separation ($r_\mathrm{p} \leq 100$ kpc) criteria. The only difference between two algorithms is that Barton et al. (1996) used a larger line-of-sight velocity difference criterion ($\triangle V \leq 1000\ \mathrm{km\,s^{-1}}$), which actually increases the projection effect.

We use the catalog of CGs constructed by Deng et al. (2008). Deng et al. (2008) identified 1298 CGs with richness $4 \leq N < 10$ (N is the number of member galaxies in each system) from the volume-limited Main galaxy sample of the SDSS DR6. Deng et al. (2008) used the conventional three-dimensional cluster analysis (Einasto et al. 1984) by which the galaxy sample can be separated into individual systems at a given three-dimensional neighborhood radius R. At small radii, most systems are isolated single galaxies, the rest being close double and multiple galaxies. At larger radii, groups and clusters of galaxies and even superclusters will be formed. By selecting different neighborhood radii, we can probe the structures at different scales. As indicated by Deng et al. (2008), though Deng et al. (2008)'s algorithm is three dimensional and thus less subject to the projection effect, it is important to recognize that this algorithm did not take into account the redshift space distortion. But when we have no ability to correct the redshift-space distortion, we must face the choice between two effects: the projection effect or the redshift space distortion.

In fact, we do not have any a priori defined neighborhood radius to identify CGs. So far, there has been no widely accepted algorithm and criterion suitable for all galaxy samples. For different galaxy samples, many authors often developed different algorithms and criteria. Deng et al. (2008) analyzed the clustering properties of the galaxy sample in a certain range of neighborhood radii (see Fig. 2 of Deng et al. 2008), and intended to define the neighborhood radius to identify CGs. According to the study of Deng et al. (2008), at the neighborhood radii $R < 0.6$ Mpc, most systems are isolated single galaxies, close double, and multiple galaxies, the few being candidate CGs; at $R > 1.2$ Mpc, some CGs merge into loose groups and clusters. Because compact groups are often located within the bounds of loose groups and clusters (Vennik et al. 1993; Ramella et al. 1994; Rood & Struble 1994; Sakai et al. 1994; Garcia 1995; Barton et al. 1996); Deng et al. (2008), defined the neighborhood radius $R = 1.2$ Mpc for CG identification according to the following two factors: (1) most candidate CGs do not merge into loose groups and clusters; (2) to make ideal statistical analyses, the CG sample should be as large as possible.

3.2. Identification algorithm of isolated galaxies

The first systematic compilation of isolated galaxies was made by Karachentseva (1973). To date, this catalog still is a popular sample. For example, the AMIGA project (Analysis of the Interstellar Medium of Isolated Galaxies, see `http://www.iaa.es/AMIGA.html`) compiled a multiwavelength database of isolated galaxies and presented a complete refinement of properties for galaxies in this catalog (Verdes-Montenegro et al. 2005; Sulentic et al. 2006; Lisenfeld et al. 2007; Verley et al. 2007a,b). Karachentseva (1973) did not use redshifts to produce isolated galaxies, since at that time few of such data existed. Allam et al. (2005) slightly modified the original Karachentseva criteria to identify isolated galaxies from the SDSS. The main problem with these methods is that they completely ignore the projection effect.

Galaxies in groups or clusters and isolated galaxies are located at both extremes of density. Thus, the criteria used to identify isolated galaxies must ensure that isolated galaxies did not lie in groups or clusters. In the SDSS, R_{50} and R_{90} are the radii enclosing 50% and 90% of the Petrosian flux, respectively. If we use the r-band $R_{90}(R_{90,r})$ as the radius of galaxies, the mean projected galaxy diameter on the sky is ~20.8 kpc for our volume-limited Main galaxy sample. To ensure that isolated galaxies do not lie in groups or clusters, the criterion of the projected separation for the identification of isolated galaxies should at least be larger than the projected linking length used to identify groups (e.g., Berlind et al. 2006). But we note that the main criterion of Karachentseva (1973) and Allam et al. (2005) $x_{i,j} \geq 20 \times a_j \sim 0.42$ Mpc are much smaller than the projected linking length used by Berlind et al. (2006): $D_{\perp,ij} = 2\times\sin(\frac{\theta_{ij}}{2})\times D \leq 0.14\times\bar{n}^{-1/3} \sim 0.95$ Mpc. It results in that some isolated galaxies lie in groups or clusters.

Deng et al. (2006) used three-dimensional cluster analysis (Einasto et al. 1984), for the identification of isolated galaxies and showed that isolated galaxies identified at dimensionless radius $r \geq 1.2$ (dimensionless radii $r = R/R_0$, $R_0 = (3/(4\pi\times\bar{n}))^{1/3}$ is the radius of the sphere with unit population) can be defined as genuinely isolated in three-dimensional space. We extract 4343 isolated galaxies at dimensionless radius $r = 1.4$ (R_0 for the volume-limited Main galaxy sample of the SDSS DR6 is 4.23 Mpc) from the volume-limited Main galaxy sample of the SDSS DR6. At this radius, the largest system contains 50 906 galaxies. The result $R = 1.4 \times R_0 = 5.92$ Mpc implies a density contrast $\delta\rho/\rho < -0.64$ around isolated galaxies, which is lower than the density contrast $\delta\rho/\rho < -0.6$ around void galaxies identified by Rojas et al. (2004). In addition, $R = 1.4 \times R_0 = 5.92$ Mpc is also much larger than the projected linking length used by Berlind et al. (2006).Therefore, isolated galaxies identified at $r = 1.4$ are located in particularly low-density environments.

4. Comparison of distributions of various physical properties among member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample

Figure 1 shows the luminosity distributions of member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample, respectively. The whole luminosity region (–22.40 $\leq M_r \leq -20.16$) is divided into 10 bins of width 0.224. The (1σ) error bars are Poissonian errors. As seen from this figure, the luminosity distribution of member galaxies of CGs is nearly the same as that of the volume-limited Main galaxy sample. This is actually consistent with the conclusion obtained by Deng et al. (2007b). Deng et al. (2007b) compared statistical properties of galaxy luminosity in the compact galaxy group sample with those in the random group sample, and found that the two samples have nearly the same statistical properties of luminosity. In Fig. 1, we also note that the luminosity distribution of member galaxies of CGs is different from that of isolated galaxies: isolated galaxies have a higher proportion of faint galaxies ($M_r \geq -20.61$) and a lower proportion of luminous galaxies ($M_r \leq -21.28$) than member galaxies of CGs. The level of significance is at least 5σ in most bins. This shows that luminous galaxies exist preferentially in the densest regions of the universe (e.g., in groups), but faint galaxies are located preferentially in low-density regions. It further confirms the dependence of galaxy luminosity on environment. Our results also show that the dependence of galaxy luminosity on the dense environment (e.g., in groups) is much weaker than that on the underdense environment (e.g., isolated galaxies).

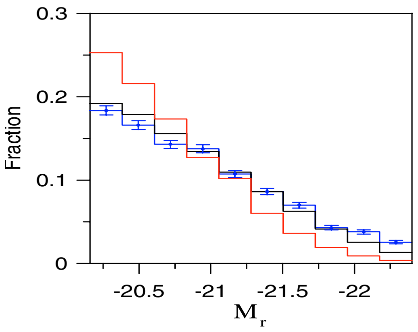

Fig. 1. The luminosity distributions of member galaxies of CGs (blue line), the volume-limited sample (black line) and isolated galaxies (red line), respectively. The error bars are 1 sigma Poissonian errors for member galaxies of CGs.

Using several typical algorithms to identify groups: the Berlind et al. (2006) algorithm, the Davis et al. (1985) algorithm, and the Barton et al. (1996) algorithm, Deng et al. (2007c) constructed different group catalogs from the volume-limited Main galaxy sample of SDSS DR6. These algorithms actually take into account projection effect or redshift space distortion. Deng et al. (2007c) found that the luminosity distributions of member galaxies of groups identified by different algorithms are almost the same, and are also the same as that of the volume-limited sample, but are different from that of isolated galaxies. Isolated galaxies have a higher proportion of faint galaxies ($M_r \geq -20.61$) and a lower proportion of luminous galaxies ($M_r \leq -21.28$) than member galaxies of groups. These conclusions agree with our results.

To investigate the dependence of clustering properties on galaxy luminosity, many authors measured the two-point correlation function of galaxies and found that the clustering amplitude increases with absolute magnitude (e.g., Davis et al. 1988; Hamilton 1988; Willmer et al. 1998; Norberg et al. 2001, 2002; Zehavi et al. 2002). Zandivarez et al. (2006) computed the luminosity function of group galaxies and observed that the characteristic magnitude is ~0.5 mag brighter than that obtained for field galaxies. The studies of Blanton et al. (2003b) also showed that the local density is a strong function of luminosity, which is consistent with the results found by other authors (Hogg et al. 2003; Berlind et al. 2005; Blanton et al. 2005; Park et al. 2007). Park et al. (1994) noted that high-density regions preferentially include bright galaxies, but low-density regions tend to harbor

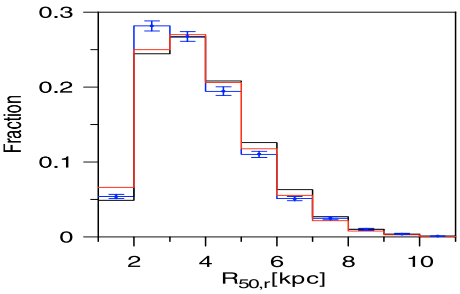

Fig. 2. The size distributions of member galaxies of CGs (blue line), the volume-limited sample (black line) and isolated galaxies (red line), respectively. The error bars are 1 sigma Poissonian errors for member galaxies of CGs.

only faint galaxies. Our studies show that low-density regions also harbor bright galaxies, but the fraction of bright galaxies is much smaller than that in the densest regions.

It is widely accepted that galaxy morphologies are strongly correlated with environments: dense regions are dominated by early-types and low-density environments by late-types. Thus, it is natural to find that in total galaxies in dense environments are more luminous, due to the correlation between luminosity and morphology. Sulentic et al. (2006) showed that isolated early-type galaxies are less luminous than early-types in denser environments. This suggest that such a trend still exists for the same morphological types.

But we also notice that some studies found no evidence of the environment dependence of galaxy luminosity. One possible explanation is that these studies used statistically incorrect methods or were affected by sampling fluctuations that are difficult to quantify. For example, Deng et al. (2007a) compared basic properties of member galaxies of groups with those of isolated galaxies in each redshift bin and found that luminosities of galaxies are nearly independent of environment. Deng et al. (2007a) used a flux-limited galaxy sample in which the mean luminosity of galaxies apparently change with redshift z. In each redshift bin, the galaxies are restricted to relative small luminosity bin, which may result in the lack of luminosity dependence on environment.

Figure 2 shows the size distributions of member galaxies of CGs, isolated galaxies and the volume-limited Main galaxy sample, respectively. We use the r-band R_{50} ($R_{50,r}$) as the parameter of galaxy size. The whole size region (1 kpc $\leq R_{50,r} \leq$ 11 kpc) is divided into 10 bins of width 1 kpc. In the region 1 kpc $\leq R_{50,r} <$ 2 kpc, the fraction of isolated galaxies is larger than that of member galaxies of CGs, while in the region 2 kpc $\leq R_{50,r} <$ 3 kpc, the fraction of isolated galaxies is much smaller than that of member galaxies of CGs. It is well-known that the galaxy sizes are correlated with luminosity (Kormendy 1977; Shen et al. 2003). Because we used the volume-limited sample where the galaxies are restricted to a narrow luminosity region, the dependence of galaxy size on environment is not very strong.

Brown et al. (2000) and Zehavi et al. (2002) showed that clustering of galaxies strongly depends on color. Blanton et al. (2003b) found that local density is a strong function of all colors. It is widely accepted that red galaxies exist preferentially in the densest regions of the universe (groups and clusters). Deng et al. (2007e) compared statistical properties of galaxy colors in the compact galaxy group sample with those in the random group sample, and found that mean colors of galaxies in CGs are redder than those of galaxies in the random groups. Figure 3 shows the color distributions of member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample, respectively. As seen from this figure, isolated galaxies have a higher proportion of blue galaxies and a lower proportion of red galaxies than member galaxies of CGs. This shows that red galaxies exist preferentially in the densest regions of the universe (e.g., in groups), while blue galaxies are located preferentially in low-density regions. It further confirms strong dependence of all colors on environment.

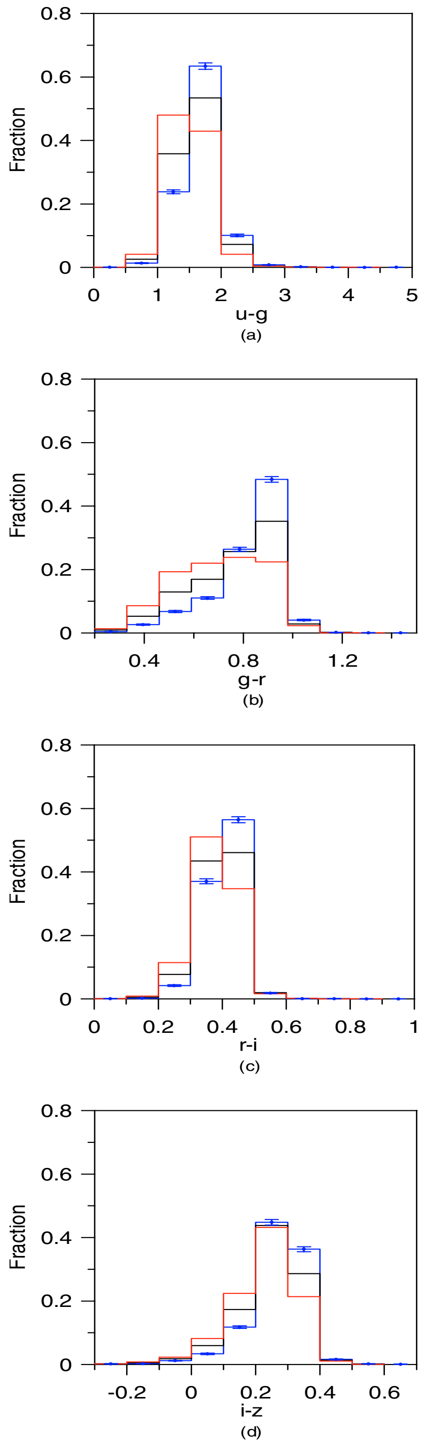

Fig. 3. The color distributions of member galaxies of CGs (blue line), the volume-limited sample (black line) and isolated galaxies (red line), respectively. The error bars are 1 sigma Poissonian errors for member galaxies of CGs **a)** $u–g$ color, **b)** $g–r$ color, **c)** r-i color, d) $i–z$ color.

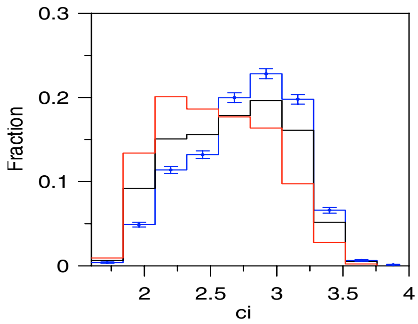

Fig. 4. The ci distributions of member galaxies of CGs (blue line), the volume-limited sample (black line) and isolated galaxies (red line), respectively. The error bars are 1 sigma Poissonian errors for member galaxies of CGs.

Lee et al. (2004) showed that the rest-frame colors of CG galaxies indeed differ from those of field galaxies, and concluded that CGs contain a relatively higher fraction of elliptical galaxies than does the field. N-body simulations pioneered by Toomre (1977) indicated that the end-product of merging spirals can be an elliptical galaxy. Due to the correlation between morphology and color (Strateva et al. 2001): redder galaxies are preferentially "early-type", our results can also be explained as the strong evidence of interactions and mergers within CGs. Rubin et al. (1991) observed 32 HCG spiral galaxies and found that two thirds of them have peculiar rotation curves, which show characteristic of strong gravitational interaction. In their study, 12 HCG elliptical galaxies were also observed. Rubin et al. (1991) detected nuclear emission in 11 of them. The high fraction suggests that interactions and mergers may be supplying gas to these galaxies.

However, the possible dependence of galaxy colors on environment has also sparked some controversies (e.g., Bernardi et al. 2003; Balogh et al. 2004b; Hogg et al. 2004). For example, Hogg et al. (2004) showed that red galaxy colors are independent of environment. Balogh et al. (2004b) found that at fixed luminosity the mean color of blue galaxies or red galaxies is nearly independent of environment. This may be due to the galaxy sample being restricted to a narrow color region. It is well-known that many properties of galaxies depend strongly on luminosity (e.g., de Vaucouleurs 1961; Kormendy 1977; Bower et al. 1992; Blanton et al. 2003b; Shen et al. 2003; Baldry et al. 2004; Balogh et al. 2004b; Kelm et al. 2005). For example, more luminous galaxies are redder. At fixed luminosity, galaxies are actually restricted to a narrow color region.

We also perform comparative studies of distributions of the concentration index $ci = R_{90}/R_{50}$ among member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample. As seen from Fig. 4, the distributions at both extremes of density differ significantly from that at the mean density. In dense regions, galaxies have preferentially greater concentration index. This does not agree with results found by other authors (Kauffmann et al. 2004; Blanton et al. 2005; Park et al. 2007). Kauffmann et al. (2004), showed that at fixed stellar mass structural parameters such as size and concentration are almost independent of the local density. When morphology and luminosity are fixed, Park et al. (2007) found that other physical properties, such as color, color-gradient, concentration, size, velocity dispersion, and star formation rate, are nearly independent of the local density. It has been known for a long time that there are correlations between galaxy properties. For example, the colors of galaxies depend strongly on luminosity (e.g., de Vaucouleurs 1961; Bower et al. 1992; Blanton et al. 2003b; Baldry et al. 2004). Thus, it is not surprising that there is no correlation between structural parameters and the local density at another fixed parameter.

The concentration index $ci = R_{90}/R_{50}$ often be used to separate early-type (E/S0) galaxies from late-type (Sa/b/c, Irr) galaxies (Shimasaku et al. 2001). 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 tool (e.g., Park & Choi 2005; Yamauchi & Goto 2005; Abraham et al. 2003; Strateva et al. 2001; Shimasaku et al. 2001). The concentration index is a simple morphological parameter. Nakamura et al. (2003) showed that $c_i = 2.86$ separates galaxies at S0/a with a completeness of about 0.82 for both late and early types. The early-type fraction of above three samples are respectively: 44.37% in CGs; 36.62% in the volume-limited Main galaxy sample; and 25.07% in isolated galaxies. We note that galaxy morphologies strongly depend on local environments: galaxies in dense environments have predominantly early-type morphologies, which were confirmed by many other studies. For example, Croton et al. (2005) showed that the galaxy populations at both extremes of density differ significantly from those at the mean density. The population in voids is dominated by late-types, in contrast, cluster regions have a relative excess of very bright early-type galaxies. This suggests that in dense environments there exists the transformation of galaxies from late to early-types. Many physical mechanisms, such as galaxy harassment (Moore et al. 1996), rampressure stripping (Gunn & Gott 1972), and galaxy-galaxy merging (Toomre & Toomre 1972), can explain such a process.

5. Summary

Member galaxies of CGs and isolated galaxies are located at both extremes of density. To investigate the dependence of galaxy properties on local environment, we perform comparative studies of distributions of various physical properties among member galaxies of CGs, isolated galaxies, and the volume-limited Main galaxy sample, which represents the mean density. We use the catalog of CGs constructed by Deng et al. (2008), which contains 1298 CGs with richness $4 \leq N < 10$ (N is the number of member galaxies in each system). Isolated galaxies are identified at dimensionless radius $r = 1.4$ (dimensionless radii $r = R/R_0$, $R_0 = (3/(4\pi \times \bar{n}))^{1/3}$ is the radius of the sphere with unit population. The radius R_0 for the volume-limited Main galaxy sample of the SDSS DR6 is 4.23 Mpc) from the volume-limited Main galaxy sample of the SDSS DR6. The main results can be summarized as follows:

1) As seen from Fig. 1, the luminosity distribution of member galaxies of CGs is nearly the same as that of the volume-limited Main galaxy sample, but is different from that of isolated galaxies: isolated galaxies have a higher proportion of faint galaxies ($M_r \geq -20.61$) and a lower proportion of luminous galaxies ($M_r \leq -21.28$) than member galaxies of CGs. This shows that luminous galaxies exist preferentially in the densest regions of the universe (e.g., in groups), but faint galaxies are located preferentially in low-density regions. Our results also show that the dependence of galaxy luminosity on the dense environment(e.g., in groups) is much weaker than the dependence on the underdense environment(e.g., isolated galaxies).

2) Because we used the volume-limited sample where the galaxies are restricted to a narrow luminosity region, the dependence of galaxy size on environment is not very strong.
3) Isolated galaxies have a higher proportion of blue galaxies and a lower proportion of red galaxies than member galaxies of CGs, which shows that red galaxies exist preferentially in the densest regions of the universe (e.g., in groups), while blue galaxies are located preferentially in low-density regions.
4) In dense regions, galaxies have preferentially greater concentration index and early-type morphologies.

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