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Dependence of the bright end of galaxy luminosity function on cluster dynamical state

Z. L. Wen⋆ and J. L. Han
National Astronomical Observatories, Chinese Academy of Sciences, 20A Datun Road, Chaoyang District, Beijing 100012, China

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ABSTRACT

Luminosity function of cluster galaxies provides a fundamental constraint on galaxy evolution in cluster environments. By using the bright member galaxies of a large sample of rich clusters identified from Sloan Digital Sky Survey, we obtain the bright end of composite luminosity functions of cluster galaxies, and study their dependence on cluster dynamical state. After a redshift-evolution correction of absolute magnitude, the luminosity function of member galaxies can be well fitted by a Schechter function when the brightest cluster galaxies (BCGs) are excluded. The absolute magnitudes of BCGs follow a Gaussian function with a characteristic width of about 0.36 mag. We find that the luminosity function of galaxies in more relaxed clusters has a fainter characteristic absolute magnitude (M_*), and these clusters have fewer bright non-BCG member galaxies but a brighter BCG. Our results suggest the co-evolution of galaxy population with cluster dynamical state and somewhat support the hierarchical formation scenario of the BCGs.

Key words: galaxies: clusters: general — galaxies: luminosity function

1 INTRODUCTION

Clusters of galaxies are the most massive bound systems in the universe, which were formed hierarchically by accretion and merger of smaller sub-clusters and groups (e.g. Colberg et al. 1999). They are important laboratories to investigate the formation and evolution of galaxies in dense environment (Butcher & Oemler 1984; Goto et al. 2003; Gao et al. 2004; De Lucia & Blaizot 2007). The population of cluster galaxies in the local universe is dominated by red sequence galaxies. The hierarchical and the passive evolution models are two important scenarios on the evolution of cluster galaxies. The hierarchical model (e.g. De Lucia et al. 2006) predicts that more massive cluster galaxies have a history of earlier star formation and later stellar mass assembly. About the half of stellar mass in the most massive galaxies is assembled at a redshift of $z < 0.8$ through merger process. In contrast, the passive evolution model implies that cluster galaxies were formed in a rapid starburst at very early time of the universe, and evolved later without any star formation and merger (De Propris et al. 1999; De Propris et al. 2007). Luminosity function of cluster galaxies provides a fundamental constraint on galaxy evolution in cluster environments (e.g. Lin et al. 2006; Crawford et al. 2009; Ribeiro et al. 2013).

In general, the luminosity function of galaxies in clusters is defined as being the number density of galaxies per absolute magnitude as a function of luminosity, which can be fitted by a Schechter function (Schechter 1976):

$$\begin{aligned}\phi_s(M)dM &= 0.4\ln(10)\phi_* 10^{-0.4(M-M_*)(\alpha+1)} \\ &\times \exp\left[-10^{-0.4(M-M_*)}\right]dM, \qquad (1)\end{aligned}$$

where α is the faint-end slope, M_* is the characteristic absolute magnitude, and ϕ_* is the normalization factor. The luminosity of the brightest cluster galaxy (BCG) in each cluster is very different from other cluster galaxies. The luminosity distribution of a sample of BCGs follows a Gaussian function (Hansen et al. 2005, 2009; De Filippis et al. 2011).

To understand galaxy evolution in cluster environments, many efforts have been made to search for the changes of galaxy luminosity functions with the properties of whole clusters (e.g. redshift, cluster mass and dynamical state) or member galaxies. Clusters with a cD galaxy have a significantly different galaxy luminosity function from spiral-rich clusters (Oemler 1974). The luminosity function of galaxies in rich clusters has a brighter M_* and a steeper α than that in poor clusters (e.g. Lin et al. 2004; Hansen et al. 2005). Galaxy population and the luminosity function vary with distance to the cluster center (e.g. Hansen et al. 2005), and the value of α is steeper in the outer region than that in the central region (De Filippis et al. 2011). The luminosity function of early-type galaxies has a flatter α than that of late-type galaxies (Goto et al. 2002; Muzzin et al. 2007). The α value for red cluster galaxies at high redshifts may be (e.g. De Lucia et al. 2004; Toft et al. 2004; Stott et al. 2007; Rudnick et al. 2009), or may be not (e.g. Crawford et al. 2009; Mancone et al. 2012; De Propris et al. 2013),

⋆ E-mail: zhonglue@nao.cas.cn

smaller than that for local cluster galaxies. Simple pure passive evolution was claimed by comparing luminosity functions of galaxies in clusters up to redshift $z \sim 1$ (De Propris et al. 1999; De Propris et al. 2007; Lin et al. 2006; Crawford et al. 2009), which is inconsistent with the hierarchical model.

Many clusters have experienced recent merger and show an unrelaxed dynamical state (e.g. Böhringer et al. 2010; Wen & Han 2013). Relaxed clusters may have fewer bright member galaxies than unrelaxed clusters (Dressler 1978; Barrena et al. 2012). However, there is no consensus on the possible relation between galaxy luminosity distributions and cluster dynamical states. Galaxy luminosity functions of some individual merging clusters can not be described by a single Schechter function but by a double Schechter function (e.g. A209 and A168, Mercurio et al. 2003; Yang et al. 2004) or by the superposition of a Schechter function and a Gaussian function (e.g. the Coma cluster, by Biviano et al. 1995). Barkhouse et al. (2007) found a weak correlation between M_* and the cluster Bautz-Morgan classification, and the later is related to cluster dynamical state (Wen & Han 2013). The luminosity function of galaxies in clusters with a Gaussian velocity distribution (i.e. in a relaxed state) has a brighter M_* and a steeper α than that in the non-Gaussian clusters (Ribeiro et al. 2013), which suggests again that the luminosity function of cluster galaxies is really related to cluster dynamical state. However, no significant difference was found between luminosity functions of galaxies in clusters with different Bautz-Morgan classifications (Colless 1989) or in clusters with and without substructures (De Propris et al. 2003, 2013). The discrepancy of these results may come from the limited number of galaxies of a small number of clusters in previous investigations.

To check if there is any dependence of galaxy luminosity function on cluster dynamical state, the member galaxy data of a large sample of clusters with quantified dynamical states are needed. Previously qualitative classifications for relaxed or unrelaxed (or X-ray cool/non-cool) clusters (Bauer et al. 2005; Vikhlinin et al. 2005; Chen et al. 2007) are too crude for such a study. Only a few clusters have their dynamical state carefully quantified by substructures in X-ray images (e.g. Buote & Tsai 1995; Böhringer et al. 2010; Weißmann et al. 2013). Recently, we used the photometric data of Sloan Digital Sky Survey (SDSS) to quantify the dynamical states for 2092 rich clusters (Wen & Han 2013), which is currently the largest cluster sample available with quantified dynamical state. In this paper, we use this cluster sample to investigate the dependence of the bright end of galaxy luminosity function on the cluster dynamical state. In Section 2, we introduce the cluster sample, the member galaxy data for composite luminosity function, and the quantified parameter for cluster dynamical state. In Section 3, we show the dependence of the bright end of galaxy luminosity function on cluster dynamical state. We present discussion and conclusion in Section 4.

Throughout this paper, we assume a ΛCDM cosmology, taking H_0 =100 h $\mathrm{km\,s^{-1}\,Mpc^{-1}}$, with $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$.

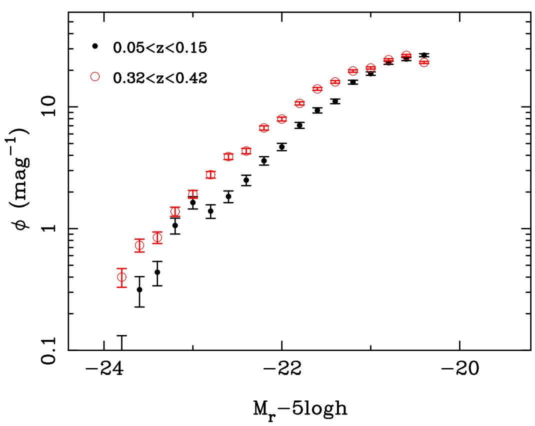
2 CLUSTER SAMPLE AND LUMINOSITY FUNCTION OF BRIGHT MEMBER GALAXIES

Using photometric redshifts of galaxies, we identified 132,684 galaxy clusters from the SDSS DR8 (Wen et al. 2012), which is an update of the previous catalog as made from SDSS DR6 (Wen et al. 2009). Clusters were identified if they have a richness of $R_{L*} \geqslant 12$ and the number of member galaxies $N_{200} \geqslant 8$ within a radius of r_{200}. Here, r_{200} is the radius within which the mean density of a cluster is 200 times of the critical density of the universe. The cluster richness is defined as $R_{L*} = L_{200}/L^*$, i.e., the r-band total luminosity of member galaxies of $M_r^e \leqslant -20.5$ within r_{200} in units of L^*, where M_r^e is r-band absolute magnitude after passive evolution being corrected (see below).

With these clusters, we need to know their dynamical state for this work. Three-dimensional distribution and motions of the member galaxies or hot intracluster gas are the most direct tracer of dynamical state of clusters, which show several observable effects, either the velocity distributions in the radial direction or the galaxy distribution or the gas distribution on the projected sky plane. The relaxed clusters of galaxies should show a Gaussian distribution of the radial velocities, and the unrelaxed clusters show non-Gaussian velocity peak in optical spectroscopic data for member galaxies (Colless & Dunn 1996; Halliday et al. 2004). However, spectroscopic observations usually are incomplete for cluster member galaxies and only available for a very limited sample of galaxy clusters. On the other hand, the unrelaxed or merger clusters usually show asymmetric distribution of member galaxies or hot gas. The dynamical state of galaxy clusters can be derived from the gas distribution by using substructures in X-ray images for small samples of galaxy clusters, e.g. quantitatively by using the power ratio (e.g. Buote & Tsai 1995; Böhringer et al. 2010), the centroid shift (e.g. Mohr et al. 1995; Maughan et al. 2008), the asymmetry and the concentration (e.g. Hashimoto et al. 2007; Santos et al. 2008). Currently, only a few hundred nearby clusters have their substructures quantified from X-ray image or optical spectrometry (e.g. Dressler & Shectman 1988; Buote & Tsai 1995; Weißmann et al. 2013).

Recently, we presented a method to diagnose the substructure and quantify the dynamical state of rich galaxy clusters by using photometric data of the SDSS (Wen & Han 2013). For each cluster, member galaxies were selected to have an evolution-corrected magnitude of $M_r^e \leqslant -20.5$ mag. We constructed an optical smoothed map by convolving the brightness distribution of member galaxies with a Gaussian kernel. The asymmetry factor α, the ridge flatness β, and the normalized deviation δ, were then calculated from the smoothed optical map. Based on these three parameters, a relaxation parameter Γ was defined to quantify dynamical state of clusters, which have been optimized by using a sample of 98 clusters with qualitatively known dynamical states of 'relaxed' and 'unrelaxed' in literature. A larger value of Γ indicates the more relaxed state of a cluster. The defined Γ can successfully separate 94% known 'relaxed' and 'unrelaxed' clusters, and has very tight correlations with substructure parameters obtained from X-ray data (e.g. Bauer et al. 2005; Cassano et al. 2010). With these tests and comparisons, we believe that our 'relaxation parameter' deduced in Wen & Han (2013) from photometric data can reliably quantify cluster dynamical state. Applying this method, we calculated the relaxation parameter Γ for 2092 clusters from Wen et al. (2012) with a richness $R_{L*} \geqslant 50$ in the redshift range of $0.05 < z < 0.42$. The redshift range is selected to make the cluster sample and also bright member galaxies to be approximately volume-limited complete (Wen et al. 2012). Above the richness of $R_{L*} = 50$, clusters have enough bright member galaxies to get a reliable relaxation parameter Γ. The values of Γ are continuously distributed in the range of $-2 \lesssim \Gamma < 0.6$ (Wen & Han 2013). The sample of 2092 clusters is the largest available with quantified dynamical state, and therefore is used in this paper to calculate the bright end of galaxy luminosity function.

We recognize the member galaxies of the 2092 rich clusters



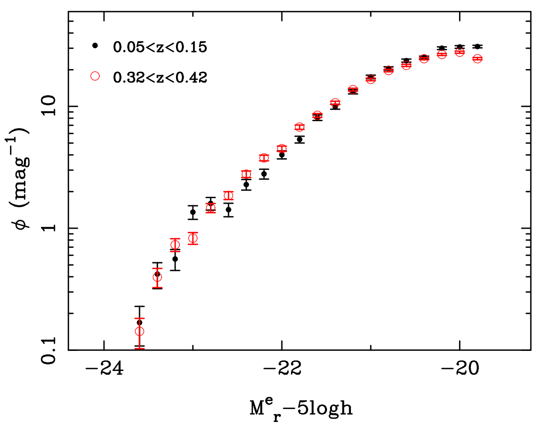


Figure 1. Luminosity function of member galaxies within r_{200} of rich clusters in two redshift ranges before (upper) and after (lower) evolution correction of the absolute magnitude for member galaxies via $M_r^e = M_r + 1.16\,z$.

by using photometric redshifts from the SDSS DR8. Because the star/galaxy separation is reliable to $r = 21.5$ mag for the SDSS photometric data (Lupton et al. 2001), the member galaxies are complete down to the limit $M_r = -20.3{+}5\log h$ within $z < 0.42$ (see Wen et al. 2012). For each cluster, the member galaxies are extracted if they have a photometric redshift within $0.04(1+z)$ from the cluster redshift. For such bright galaxies, this photometric redshift range was chosen to include $\sim 90\%$ member galaxies but with only ∼10%–15% contamination for rich clusters (see Wen et al. 2009). To further diminish the contamination of member galaxies and reduce the member incompleteness, we complement the photometric data with the spectroscopic redshifts of the SDSS DR10 (Ahn et al. 2013) for member galaxies. The galaxies are discarded from the member galaxy list if they have a velocity difference of $\Delta v > 2500$ km s^{-1} in the rest frame from the spectroscopic redshift of a cluster. We also include the missing member galaxies into the photometric redshift data if their spectroscopic redshifts are within a velocity difference of $\Delta v \leqslant 2500$ km s^{-1}. The galaxies within r_{200} are considered as member galaxy candidates of the cluster. For background subtraction, the galaxies between 2 and 4 Mpc from the cluster center and fainter than the second BCG are considered as being background galaxies, because the recognized BCG is always considered as member galaxy of a cluster.

We use these bright member galaxies to derive the bright end of a composite luminosity function following the method of Colless (1989). The number of galaxies in the jth bin of the composite luminosity function is

$$N_{cj} = \frac{N_{c0}}{m_j} \sum_i \frac{N_{ij}}{N_{i0}}, \tag{2}$$

where N_{ij} is the number in the jth bin of the ith cluster luminosity function after background subtraction, N_{i0} is the normalization of the ith cluster, and

$$N_{c0} = \sum_i N_{i0}, \tag{3}$$

m_j is the number of clusters contributing to the jth bin. We only consider the bright end of galaxy luminosity function in the absolute magnitude range where the member galaxies are approximately volume-limited complete, so that m_j is the total number of clusters. The error of the number in the jth bin is

$$\delta N_{cj} = \frac{N_{c0}}{m_j} \left[\sum_i \left(\frac{\delta N_{ij}}{N_{i0}} \right)^2 \right]^{1/2}, \tag{4}$$

where δN_{ij} is determined by the Poisson statistics. The faint galaxies with a lower luminosity are not considered here because many of them are late-type (spiral or irregular) and have a larger uncertainty on the estimated photometric redshift. The recognization of faint member galaxies is not as complete as bright galaxies, which may induce bias at the faint end of luminosity function. As pointed out by Driver et al. (2003) and Pracy et al. (2004), the clustering of background galaxies may induce uncertainty on galaxy number count. Nevertheless, clustering uncertainty is much smaller than the Poisson error at the bright-end though hence can be ignored.

The normalization of the composite luminosity function by the method of Colless (1989) depends on the total number of clusters. It is not obvious to show in a figure the difference of the composite luminosity functions between the subsamples of clusters with different redshifts or dynamical sates. In this paper, we define a normalized composite luminosity function by dividing the N_{cj} (and similarly for δN_{cj}) by the total number of clusters together with the width of absolute magnitude bin (ΔM_r)

$$\phi_j = \frac{N_{cj}}{m_j \Delta M_r}. \tag{5}$$

Some of previous studies showed that the evolution of member galaxy population can be described by a passive evolution model over a wide range of redshift (Lin et al. 2006; De Propris et al. 2007; Crawford et al. 2009), which means that galaxy population becomes older and fainter at lower redshifts. When taking member galaxies of a number of clusters over a wide range of redshift for a composite luminosity function, the evolution effect must be eliminated. As shown in Figure 1, member galaxies within r_{200} of clusters at higher redshifts ($0.32 < z < 0.42$) are systematically brighter than those at lower redshifts ($0.05 < z < 0.15$). Here we take a linear form of the redshift evolution, and define an evolution-corrected magnitude,

$$M_r^e = M_r + Q\,z, \tag{6}$$

where Q is the evolution slope. Assuming that the member galaxies were formed in a single burst at the epoch of about $z_f = 2$ (Lin et al. 2006; Crawford et al. 2009), we apply a stellar population synthesis model (Bruzual & Charlot 2003) with the initial mass function of Chabrier (2003) and solar metallicity, and we find the value of $Q = 1.16$. After the redshift-evolution correction of the absolute magnitude, the luminosity functions in different redshift ranges become roughly consistent (see lower panel of Figure 1). In the following analysis, we use M_r^e to calculate the composite galaxy luminosity function to the absolute magnitude

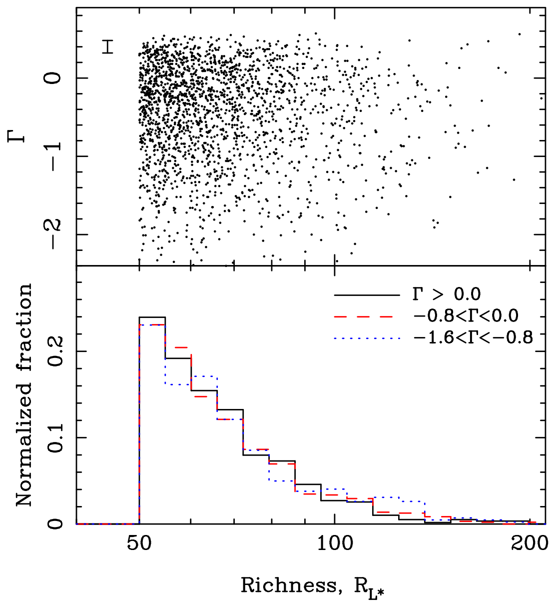


Figure 2. The richness distributions are almost the same for the three subsamples with different ranges of relaxation parameters.

limit of $M_r^e = -19.7 + 5\log h$ over a wide redshift range of $0.05 < z < 0.42$.

3 DEPENDENCE OF THE BRIGHT END OF GALAXY LUMINOSITY FUNCTION ON CLUSTER DYNAMICAL STATE

We use the sample of 2092 rich clusters of $R_{L*} > 50$ with known dynamical states quantified by Wen & Han (2013) to exam the dependence of galaxy luminosity function on cluster dynamical state. Here we emphasize that we only work at the bright end. Because the luminosity of a BCG is very distinct from non-BCG member galaxies (e.g. Hansen et al. 2005), we study their composite luminosity functions separately.

3.1 Luminosity function of non-BCGs in clusters

The sample of 2092 rich clusters of richness $R_{L*} \geqslant 50$ are divided into three subsamples according to their dynamical states quantified by relaxation parameter, Γ. The richness distributions of these subsamples are very similar (see Figure 2), so that there is no selection effect on richness in three subsamples.

We first calculate the composite luminosity function of non-BCG member galaxies within the central region of $r_{500} = 2/3 r_{200}$ (Shimizu et al. 2003), and fit them with the Schechter function (see the upper panel of Figure 3). We only obtain the bright end of galaxy luminosity function, which is insensitive to the faint end slope α. Hence, we fix $\alpha = -1.0$ (e.g., Popesso et al. 2005; Lin et al. 2006; De Propris et al. 2013) in the fitting, and compare M_* for clusters in different range of Γ. The derived parameters, ϕ_* and M_* are given in Table 1. We find that the luminosity functions at $M_r^e - 5\log h > -21.0$ mag agree with each other for different ranges of Γ, but there is a significant excess for more unrelaxed (i.e., lower Γ) clusters at the bright end of $M_r^e - 5\log h < -21.0$ mag. Thus, more relaxed clusters have a fainter M_*. The value of M_* for relaxed clusters of $\Gamma > 0.0$ is 0.27 magnitude

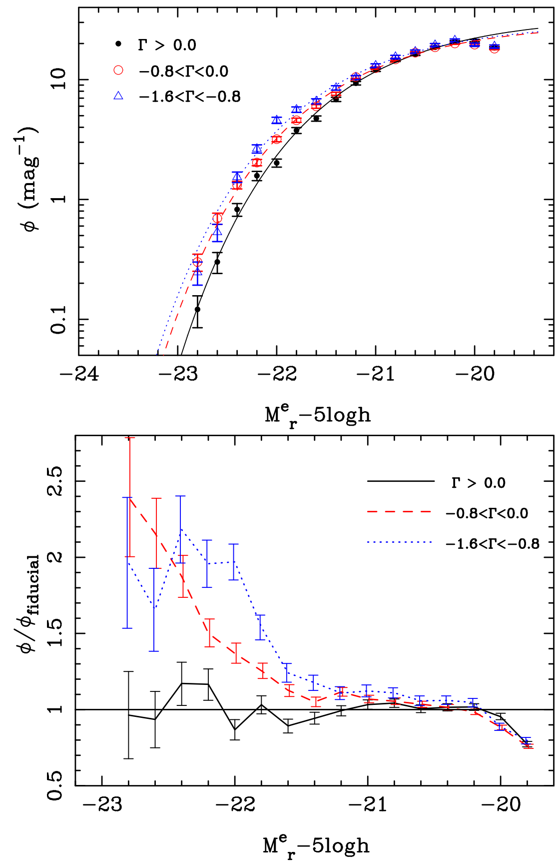


Figure 3. Composite luminosity functions and the best-fit Schechter functions (*Upper panel*) and the ratio to the fiducial line (*Lower panel*) for member galaxies within r_{500} of clusters in three ranges of Γ. The fiducial line is the best-fit Schechter function of member galaxies in relaxed clusters of $\Gamma > 0.0$.

fainter than that for the unrelaxed clusters of $-1.6 < \Gamma < -0.8$. To clearly show the excess of bright galaxies, we take the best-fit Schechter function of galaxies in relaxed clusters of $\Gamma > 0.0$ as a fiducial line, and compare the ratios of luminosity functions to this fiducial line (lower panel of Figure 3). Obviously, the ratio of luminosity function of galaxies in unrelaxed clusters significantly increases at $M_r^e - 5\log < -21.0$ mag, which means that there are more bright member galaxies in more unrelaxed clusters.

For a comparison, we also obtain the bright end of luminosity functions of galaxies in the outer cluster region between r_{500} and r_{200} for clusters in the three relaxation parameter ranges. As shown in Figure 4, the luminosity functions of these outer galaxies are very consistent for clusters with various dynamical states, even at the bright end of $M_r^e - 5\log h < -21.0$ mag. This is inconsistent with the result of Barrena et al. (2012) who found a larger difference of galaxy population in the outer cluster region at the bright end. We therefore can conclude that more relaxed clusters have fewer bright member galaxies within r_{500}, but in the outer cluster region ($> r_{500}$) the luminosity distribution of member galaxies is nearly independent of cluster dynamical state.

3.2 Luminosity function of BCGs

The BCG in a galaxy cluster is the most massive galaxy near the center of the cluster. The BCGs of many clusters have different statistical properties from the non-BCG member galaxies

Table 1. Best-fit parameters of luminosity functions of member galaxies in clusters with three ranges of relaxation parameters

Relaxation parameter (1)	No. of clusters (2)	ϕ_* (3)	$M_* - 5\log h$ (4)	ϕ_0 (5)	$M_0 - 5\log h$ (6)	σ_0 (7)
$\Gamma > 0.0$	589	36.8±0.9	-20.93 ± 0.02	2.8±0.3	-23.08 ± 0.04	0.39±0.02
$-0.8 < \Gamma < 0.0$	949	32.5±0.5	-21.13 ± 0.02	3.0±0.2	-22.66 ± 0.02	0.36±0.02
$-1.6 < \Gamma < -0.8$	421	32.7±0.8	-21.20 ± 0.02	3.2±0.3	-22.43 ± 0.02	0.35±0.01

Notes: Column (3) and (4) are the best-fit parameters of the Schechter function with a fixed faint-end slope of $\alpha = -1.0$ for the non-BCG member galaxies; Column (5)–(7) are the best-fit parameters of the Gaussian function for the BCGs.

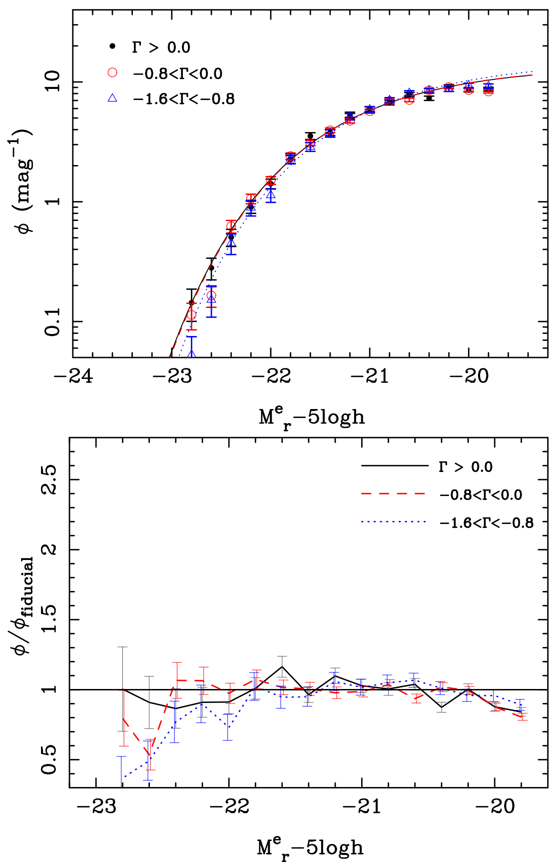


Figure 4. Similar with Figure 3, but for galaxies in the outer cluster region of r_{500}–r_{200}.

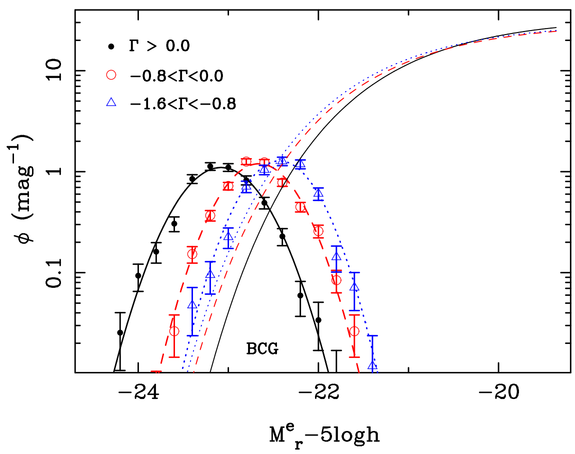


Figure 5. Composite luminosity functions of BCGs and the best-fit Schechter functions of non-BCG member galaxies (thin lines) for clusters in the three ranges of relaxation parameters.

(von der Linden et al. 2007; Bernardi et al. 2007; Liu et al. 2012; Shen et al. 2014). It has been suggested that the BCGs were formed at redshift $z > 2$, and then evolved passively (e.g. Stott et al. 2008; Whiley et al. 2008). However, some simulation shows that the BCGs were formed by accretion and merger of satellite galaxies (e.g. De Lucia & Blaizot 2007). The BCGs are very bright, and have a similar absolute magnitude with a small dispersion of $\sim$0.3–0.45 mag (Sandage 1988; Aragon-Salamanca et al. 1998; Lin et al. 2004). The composite luminosity function of the BCGs can be described by a Gaussian function (Hansen et al. 2005):

$$\phi_g(M)dM = \frac{\phi_0}{\sqrt{2\pi}\sigma_0}\exp\left[-\frac{(M-M_0)^2}{2\sigma_0^2}\right]dM, \tag{7}$$

where ϕ_0 is the normalization, M_0 and σ_0 are the mean magnitude and the magnitude dispersion, respectively.

For clusters in the three ranges of Γ, we get three composite BCG luminosity functions (see Figure 5), and obtain the fitted parameters in Table 1. The dispersion of BCG absolute magnitude is $\sim$0.36. In contrast to the non-BCG member galaxies, we find that more relaxed clusters have a brighter BCG, e.g. $M_0 - 5\log h = -23.08 \pm 0.04$ for the relaxed clusters of $\Gamma > 0.0$, compared to $M_0 - 5\log h = -22.43 \pm 0.02$ for the very unrelaxed clusters of $-1.6 < \Gamma < -0.8$.

4 DISCUSSIONS AND CONCLUSIONS

The total composite luminosity function of member galaxies in clusters should be the summation of ϕ_s and ϕ_g, as

$$\phi_{\rm tot}(M)dM = [\phi_s(M) + \phi_g(M)]dM. \tag{8}$$

By using 2092 rich clusters, the largest sample of galaxy clusters with quantified dynamical state, we find different dependence of ϕ_s and ϕ_g for bright member galaxies on cluster dynamical state. This is a clear evidence for the co-evolution of bright member galaxies with cluster dynamical state. The mean absolute magnitude of BCGs in clusters varies about 0.65 mag for different dynamical states, while the characteristic magnitude M_* of the non-BCG member galaxies varies only about 0.27 mag. Note, however, that the above results are obtained for the bright galaxies in the inner region of clusters of $r < r_{500}$. The luminosity function of bright member galaxies in the outer region does not show dependence on cluster dynamical state, which is consistent with the conclusion given by De Propris et al. (2003) and De Propris et al. (2013) who found the independence of galaxy population on cluster dynamical state. Our conclusion is opposite to that given by Barrena et al. (2012) who showed the more significant dependence of galaxy luminosity function in the outer cluster region than that in the inner region.

How to explain the obvious difference of bright member galaxies in clusters with different dynamical states? During relaxation process of a cluster, many massive galaxies tend to sink to the center of a cluster due to dynamical friction, and may be merged into the BCG which produces a brighter BCG finally. This causes fewer bright non-BCG member galaxies in the inner region of clusters. Observations have showed that the BCGs in some clusters are experiencing major merger (McIntosh et al. 2008; Liu et al. 2009). More relaxed clusters have a larger magnitude gap between the first-rank and second-rank BCGs (Ramella et al. 2007; Smith et al. 2010; Wen & Han 2013). Our results indicate that the evolution of massive cluster galaxies deviates from a simple pure passive evolution model, and somewhat support the scenario of hierarchical formation of the BCGs (De Lucia & Blaizot 2007).

In summary, we study the dependence of the bright end of galaxy luminosity function on cluster dynamical state by using the bright member galaxies of a large sample of clusters. After a redshift-evolution correction for the absolute magnitude of galaxies, the composite luminosity function of non-BCG member galaxies can be well fitted by the Schechter function. The absolute magnitude of BCGs follows a Gaussian function with a dispersion of about 0.36 mag. Though in the outer cluster region ($> r_{500}$) the luminosity function of bright member galaxies is independent of cluster dynamical state, we find that in the cluster central region of r_{500}, luminosity function of more relaxed clusters has a fainter M_*. In these relaxed clusters, there are fewer bright member galaxies of $M_r^e < -21.0 + 5\log h$ but have a brighter BCG. Our results suggest the co-evolution of member galaxies with cluster dynamical state and somewhat support the hierarchical formation scenario of the BCGs.

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