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Possible Relations between Brightest Central Galaxies and Their Host Galaxies Clusters and Groups

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Abstract

The r -band of the Sloan Digital Sky Survey (SDSS) for 17,924 brightest cluster galaxies (BCGs) in clusters and groups within $0.02 \leq z \leq 0.20$ are used to study possible environmental relations affecting the nature of these galaxies. We find a correlation between BCGs physical properties (the effective radius (R_e), absolute magnitude and central velocity dispersion (σ_0)) and their host groups and clusters velocity dispersion (σ_{cl}). This type of relations suggests that the most massive groups or clusters host larger central galaxies. On the other hand, the σ_0/σ_{cl} ratio as a function of σ_{cl} is consistent with [10].

Keywords: brightest central galaxies; BCGs; galaxy clusters; galaxy groups.**AMS 2010 codes:** 85-08, 85A05, 85A15.

1 Introduction

Brightest cluster galaxies (BCGs) are considered as one from the interesting objects that can explain some unsolved problems in studying galaxies. They are large, bright early type galaxies lying at centers of most galaxies groups and clusters. There are several unanswered questions related to BCGs nature. The principal mechanism for BCGs evolution is feedback rather than merging [1]. BCGs properties may also be affected by their clusters halo masses at low redshift. In general, BCGs follow the same fundamental plane (FP) of elliptical galaxies [6], but they have different FP and other scaling relations than those of isolated galaxies and the FP is a waveband dependent [8].

Previous studies found correlations between BCGs and their clusters properties such as cluster mass, richness and X-ray luminosity [2, 11, 12]. Understanding BCGs nature needs to study well environmental effects which affect on their physical properties [6, 7, 9].

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In this work we present the sample and focus on investigating the relations between the physical properties of BCGs as the effective radii (R_e), absolute magnitude, central velocity dispersions (σ_o) and the velocity dispersions of their host clusters and groups (σ_{cl}).

This paper is organized as follows; Section 2 describes the selection of our BCGs sample, while in Section 3 we introduce and discuss our results and in Section 4 our main conclusions are summarized. In this paper we will adopt the cosmological parameters $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$, and Hubble constant $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$.

2 Galaxy Sample

BCGs and Brightest Groups Galaxies (BGGs) are selected using the catalog of [13] as it provides a huge list of galaxy clusters and groups in a broad redshift range. A sample of 17,924 elliptical galaxies in the r -band of the Sloan Digital Sky Survey (SDSS) in clusters and groups within $0.02 \leq z \leq 0.20$ are constructed. All parameters in our sample are obtained and updated from the SDSS-DR16. Physical properties of BCGs and BGGs (the effective radius (R_e), absolute magnitude and central velocity dispersion (σ_o)) are derived and corrected as in [8]. The velocity dispersion of host groups and clusters (σ_{cl}) are taken from [13].

3 Results and Discussions

3.1 Correlations between BCGs and environments

In this section, we explore the relations between physical properties of the BCGs and their host clusters and groups. We consider absolute magnitude and central velocity dispersion as mass representatives of BCGs and BGGs. To measure the mass of cluster and group, we use σ_{cl} . Figure 1 shows σ_{cl} of clusters and groups as a function of their redshifts (z). It is clear that most of clusters and groups have σ_{cl} higher than 300 km s^{-1} .

Fig. 1 σ_{cl} - redshift relation.

In Figure 2, we plot the distribution of BCGs with their spectroscopic redshifts in the r -band.

Figure 3(a) shows the r -band R_e of BCGs with respect to redshifts of their host clusters and groups. It is clear that galaxies are having larger R_e as the redshift of their host environment increases. Figure 3(b) shows R_e of BCGs as a function of σ_{cl} of their host clusters and groups. Error bars represent the average values of σ_{cl} in

Fig. 2 BCGs distribution with their spectroscopic redshifts.

every R_e bins with errors. There is a tight correlation between R_e of BCGs and σ_{cl} of their clusters and groups. As a result, the most massive clusters and groups host central galaxies with larger values of R_e .

Fig. 3 BCGs r -band effective radii (R_e) with (a) redshift and (b) σ_{cl} of host clusters and groups. Error bars represent the average values of σ_{cl} in every R_e bin with errors.

Figure 4(a) shows the r -band absolute magnitude of BCGs as a function of the redshift of their host clusters and groups. While BCGs are very bright ($M_r < -22$ mag) across redshift range, low redshift clusters and groups ($z \leq 0.04$) host less luminous BCGs. These low redshift systems have also lower values of σ_{cl} as clear in Figure 1. Figure 4(b) shows the r -band absolute magnitude of BCGs as a function of σ_{cl} . It is clear from this figure that clusters or groups with higher velocity dispersions host the brighter central galaxies which is consistent with previous studies [4, 14, 15].

Figure 5(a) presents σ_o of BCGs in r -band with respect to the redshift of their host clusters and groups. In general, values of σ_o increase along the entire redshift range. In Figure 5(b), we plot σ_o of BCGs as a function of

Fig. 4 BCGs r -band absolute magnitude with respect to (a) redshift and (b) σ_{cl} of host clusters and groups. Error bars represent the average values of σ_{cl} in every M_r bin with errors.

σ_{cl} of their host clusters and groups. This figure shows that there is a correlation between σ_o of BCGs and σ_{cl} of their host environment. We can say that σ_o of BCG depends on its host cluster or group mass. The observed relation between σ_o and σ_{cl} provides an important test for the formation models of galaxies and clusters.

Fig. 5 σ_o of BCGs in r -band with respect to (a) redshift and (b) σ_{cl} of host clusters and groups. Error bars represent the average values of $\log_{10} \sigma_{cl}$ for $\log_{10} \sigma_o$ bins with errors.

3.2 Comparison with simulations

We found that σ_o of BCG correlates with σ_{cl} , which represents a cluster and group halo mass proxy. Here we compare the observed relation with predictions from numerical simulations by [3] and [5]. [3] performed their simulation taking into account heating by a UV background, radiative cooling, star formation and feedback. With more than 20 satellite galaxies, they identified 44 clusters. Some star particles were identified which are not bound to any subhalo within the cluster potential. Those star particles are either a diffuse stellar component

Fig. 6 σ_o of BCGs in r -band with respect to σ_{cl} of host clusters and groups as a function of σ_{cl} . Error bars represent the average values of σ_o/σ_{cl} in different σ_{cl} bins with errors. The blue solid line shows the best exponential fit to our sample. The black solid and dashed lines show the predicted relation and the 1σ deviation from simulation done by [3], respectively. The green dotted line is the predicted relation from simulations done by [5].

(DSC) or the BCGs stellar component (cD galaxies). They separated those two components and calculated velocity dispersions for them .

Figure 6 shows that the relation between σ_o and σ_{cl} decreases as a function of σ_{cl} which is also consistent with previous result from [10]. They studied the relation between 227 BCGs and their host clusters in the redshift range $0.02 < z < 0.30$. They found a tight relation between BCG velocity dispersion and cluster velocity dispersion. They found that the ratio of BCG velocity dispersion and cluster velocity dispersion decreases as a function of velocity dispersion of the host cluster. On the other side, the simulation of [3] suggests a constant relation between σ_o and σ_{cl} along a wide range of σ_{cl} . Also numerical simulations of [5] represents the same constant relation. In Figure 6, error bars represent the average values of σ_o/σ_{cl} in different σ_{cl} bins with errors. The black solid and dashed lines represent the relation and the 1σ deviation from simulation. In that simulation of [3], the velocity dispersion of BCGs, DSC, and cluster galaxies are well correlated with virial mass of cluster halo. We can say that the observed σ_o/σ_{cl} ratio depends on cluster and group mass which suggests that the mass fraction associated with brightest central galaxies indicate the evolution of brightest central galaxies and their host halos.

4 Summary and Conclusions

The r -band of the SDSS for 17,924 BCGs in clusters and groups within $0.02 \leq z \leq 0.20$ are used to study possible environmental relations that influence the formation of these galaxies. All parameters in our sample are obtained and updated from the SDSS-DR16. We find a tight relation between effective radii of BCGs and velocity dispersions of their host clusters and groups. As a result, the most massive clusters and groups host larger central galaxies. Also the r -band absolute magnitude of BCGs correlate with σ_{cl} of their host clusters and groups. This indicates that clusters and groups with higher velocity dispersions host the more bright central galaxies, that is in agreement with previous studies [4, 14, 15]. We find that σ_o of BCGs depend on its host group or cluster mass and σ_o correlates tightly with σ_{cl} . This relation suggests that σ_o of BCGs can be used as a tracer for group or cluster mass, which is in agreement with [9]. On the other hand, the σ_o/σ_{cl} ratio decreases as σ_{cl} increases which is consistent with [10]. Also σ_o/σ_{cl} ratio is different than theoretical predictions of [3], which

suggests two different scenarios for BCGs growth in lower mass and massive host groups and clusters. More large scale simulating studies of σ_o and σ_{cl} is useful for studying the environmental dependence of BCGs.

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