Cluster Galaxy Morphologies: The Relationship among Structural Parameters, Activity and the Environment

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Abstract.
We use an approach to estimate galaxy morphologies based on an ellipticity ($\varepsilon$) vs. Bulge-to-Total ratio (B/T) plane. We have calibrated this plane by comparing with Dressler’s classifications [5]. With the aid of our calibration, we have classified 635 galaxies in 18 Abell clusters ($0.02 < z < 0.08$). Our approach allowed us to recover the Kormendy’s relation [7]. We found that ellipticals and Spirals are slightly brighter than S0 in $R$ band. As S0 bulges are brighter than spirals bulges, we believe that ram pressure is not the main mechanism to generate S0s. In our sample, cluster radio galaxies morphologies cover the range S0-E-cD and their bulges have absolutes magnitudes distributed within $-21 M_R < -24.5$ mag. If we believe Ferrarese & Merrit’s relation [6], these radio sources have $10^8 - 10^9 M_\odot$ black hole mass.

Keywords: Cluster of Galaxies, galaxy morphologies, galaxy properties, S0 galaxies

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INTRODUCTION

There is strong evidence that cluster environments affect the morphology of galaxies [3]. Some of the processes that have been identified include, ram pressure, starvation, mergers, halo truncation, and galaxy harassment. While, these mechanisms could act simultaneously, we have neither identified which is the dominant one, nor its time scale. We are exploring the morphology and distribution of cluster galaxies searching for clues that can help us to identify the process that affects galaxy morphology more strongly. In this work, we have been able to separate E/S0/S galaxies comparing with Dressler morphologies [5] on the $\varepsilon$ vs B/T plane. We have fitted bulge and disk components for 635 galaxies in 18 Abell clusters. We have a trend between the magnitude of the bulge and the B/T. In addition we identified 12 cluster radio galaxies in our sample. In this work we have assumed $H_0 = 73$ km/s/Mpc, $\Omega_M = 0.27$ & $\Omega_\Lambda = 0.73$.

OBSERVATIONS AND CLUSTER SELECTION

We have used the LOCOS database (LOw-Redshift Cluster Optical Survey) [8]. The galaxy clusters were observed at KPNO with the 0.9 meters telescope in Kron-Cousins $R, I$ and $B$ bands. The images cover a range of 23.2’ x 23.2’ minutes and have a scale...
plate of 0.69”/pix [8]. For this study we have used R band images. Our sample overlaps with 8 clusters where galaxy types have been provided by Dressler [5]. Memberships have been determined for 11 clusters using spectra from the Sloan Digital Sky Survey (SDSS). Our final sample contains 18 clusters with redshifts between 0.02 < z < 0.08. In addition, we have cross-matched our sample with Faint Images of the Radio Sky at Twenty-centimeters (FIRST) data base, and we have found 12 radio galaxies (RS).

SURFACE BRIGHTNESS MODELING

We have used GALFIT package [4] in conjunction with DGCG (Driver for GALFIT on Cluster Galaxies) [1] to fit the surface brightness models. DGCG is a script that allows GALFIT to work automatically, that is, DGCG deblends or mask undesirable regions on the image, and drives GALFIT to work on uncontaminated images.

We have modeled the surface brightness distribution of galaxies using a two-component model based on a bulge component and a disk component. We assume that the bulges are Sérsics [9] and the disks are exponential. The Sérsic function have the following form: \( \Sigma(r) = \Sigma_e \exp[-k((r/e)^{1/n} - 1)] \), where \( r_e \), \( \Sigma_e \), \( n \) are effective radius, surface brightness at effective radius and Sérsic index respectively; the \( k \) parameter forces half to the light to be contained within \( r_e \). When \( n = 1 \), we have exponential function. And \( B/T = F_B / (F_B + F_D) \), where \( F_B \) and \( F_D \) are the total flux of bulge and disk respectively.

Using DGCG on LOCOS data base, we have fitted 635 galaxies in R band. From this sample, 172 galaxies are in the classification catalog of Dressler [5].

![FIGURE 1. \( \epsilon \) vs. B/T plane for 172 galaxies in Dressler’s catalog. Solid lines separate different morphological types. The following types are indicated, ellipticals galaxies (+), E/S0 galaxies (□), S0 galaxies (△), S0/S galaxies (×), Spirals galaxies (♦) and radio galaxies (•).](image-url)
RESULTS

Figure 1 shows ε vs. B/T plane, where Dressler morphologies are shown. We have defined the following regions: Elliptical galaxies occupy the region $0.3 < B/T < 1$ and $0 < \epsilon \leq 0.35$; S0s are in the region $0.3 < B/T < 1$ and $0.35 < \epsilon < 1$; and spirals are in the region $0 < B/T \leq 0.3$ and $0 < \epsilon < 1$. Adopting this scheme, we have classified the rest of the galaxies.

We have recovered the Kormendy relation [7]. Our fitting gives $< \mu >_e = 18.38 \pm 0.07 + (3.3 \pm 0.12) \log (r_e)$, which is similar to the result by Coenda et al. [2].

Figure 2 shows bulge magnitude vs. B/T for all the galaxies. There is a tendency that brighter bulges are found in galaxies with larger B/T. Since the mean of the total magnitudes of ellipticals, S0s and spirals are $-20.86$, $-20.69$ and $-20.82$ mag, respectively; and the mean of bulge magnitudes of ellipticals, S0s and Spirals are $-20.30$, $-20.01$ and $-19.2$ respectively. We suggest that S0 galaxies are the result of an internal process that transforms the bulges and the disks of spirals galaxies.

We have determined the morphology for the 12 radio sources ($\log P_{1.4\text{GHz}} > 23$) in our sample. Of these, 3 are cDs, 7 are ellipticals and 2 are S0 galaxies. Their bulge magnitudes are between $-21.03$ mag and $-24.36$ mag. Following Ferrarese & Merritt relation [6], we found that for a $-21.03$ mag bulge the associated black hole mass is $1.47 \times 10^8 M_\odot$; while, cD galaxies have the most massive black holes reaching up to $4.45 \times 10^9 M_\odot$. 

![Figure 2. Bulge magnitude vs. B/T Total Luminosity ratio for all galaxies in our sample. Symbols are the same as Figure 1.](image_url)
SUMMARY

In this work we have proposed a new approach to quantify galaxy morphology for cluster galaxies. Since the effects of crowding are important in cluster environment we have developed DGCG, a script that masks and deblends galaxies, allowing GALFIT to work on uncontaminated regions. We propose that S0 galaxies are not formed by ram pressure alone. We have found that radio galaxies in clusters have the most massive black holes.

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