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PROGRESS REPORT: INVESTIGATION OF THE MORPHOLOGY OF CLUSTER GALAXIES

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ABSTRACT

We investigated the galaxy morphology of 6 Abell clusters at $z = 0.0784 - 0.145$ based on deep images obtained using MegaCam on the CFHT. For hundreds of galaxies in our data, we classified their morphology based on criteria related to secular or merger related evolution. We found that the morphological mixture of galaxies varies considerably from cluster to cluster. This article contains a general description of our deep imaging campaign and preliminary results for galaxy morphologies in cluster environments.

Key words: galaxies: cluster – galaxies: morphology

1. INTRODUCTION

Galaxy morphology is a final product of both secular and non-secular evolution of galaxies, and so it may contain clues about the processes that the galaxies undergo. Galaxy clusters are the sites where the most massive galaxies are found, and the most dramatic merger histories are seen. The morphologies of cluster galaxies in the nearby universe, e.g. the Virgo cluster, are well established (e.g. Janowiecki et al., 2010), but for clusters at z ∼ 0.1 work has been focussed on the bright galaxies to to observational constraints. Our optical deep imaging of 6 Abell clusters at $z = 0.0784 - 0.145$ using MegaCam on the 3.8-m CFHT allows us to investigate details of morphology even for faint galaxies. Our research on detailed morphological classification of cluster galaxies through deep imaging will give a general census of cluster galaxies and help the study of their evolution.

2. THE DEEP IMAGING SURVEY OF GALAXY CLUSTERS

Our cluster deep imaging survey ($\mu_r \sim 28$mag/arcsec^2) is aimed at the investigation of the evolution of cluster galaxies. We started with 4 rich Abell clusters at $z \sim 0.1$ using the CTIO 4-m Blanco telescope. With the MOSAIC 2 CCD and Hydra multi-object spectrograph on Blanco, we found abundant post-merger signatures in cluster early-type galaxies (Sheen et al., 2012; Yi et al., 2013). The survey continued, observing 6 additional Abell clusters with IMACS f/2 on the Magellan Baade 6.5-m telescope in 2012 and 10 Abell clusters at $0.04 < z < 0.145$ with MegaCam on the CFHT 3.6-m telescope. Follow-up spectroscopy for some clusters has been performed using CTIO, Magellan, and du Pont telescopes. We continue spectroscopic observations for our sample clusters to define robust memberships via spectroscopic redshifts and to analyze stellar populations from line measurements. Our cluster sample has been selected on the basis of GALEX UV data. The UV is sensitive to young stars, and so is often used as an indicator of recent star formation in galaxies (e.g., Jeong et al., 2007; Sheen et al., 2009). Our target clusters have extra-deep NUV and FUV data (exposure time ∼ 30000 second), which can provide good constraints for defining the stellar population of galaxies.

3. SAMPLE AND VISUAL CLASSIFICATION

As a preliminary test, we started our morphology classification with 6 Abell clusters observed using CFHT. We limited our sample to galaxies brighter than Mr = -19.5 within 2Mpc of the cluster center to facilitate direct comparison. The member galaxies of each cluster are selected using spectroscopic and photometric redshifts provided by the SDSS pipeline, and 80 - 200 galaxies were determined to be members for each cluster (Table 1). We visually classified galaxy morphologies into several subgroups based on features related to secular (Hubble types, bar, ring, etc.) and non-secular (merger, tidal features, etc.) evolution (Figure 1).

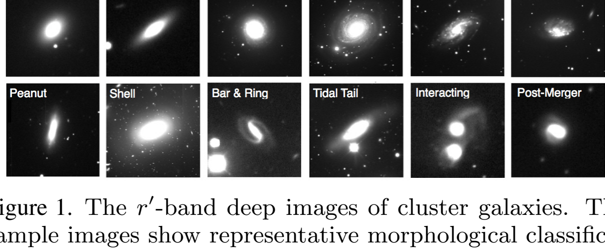

Figure 1. The r'-band deep images of cluster galaxies. The sample images show representative morphological classification in this study. Our images obtained using CFHT are deep enough to show low surface brightness structures.

Table 1
SUMMARY OF SAMPLE CLUSTERS

Cluster ID	z	RA(J2000) hh:mm:ss	Dec(J2000) dd:mm:ss	Filter	$t_{\rm exp}$ sec	$M_r <$ -19.5 $r_c < 2$ Mpc	Members
Abell 667	0.1450	08:28:10.00	44:48:38.2	u', g', r'	2940	285	127
Abell 1126	0.0846	10:53:50.90	16:57:01.7	u', g', r'	2940	230	81
Abell 1278	0.1290	11:30:31.60	20:41:40.9	u', g', r'	2940	386	139
Abell 655	0.1265	08:24:50.00	46:51:40.1	u', g', r'	2940	416	243
Abell 690	0.0788	08:39:16.12	28:57:02.7	u' , g', r'	2940	172	78
Abell 2061	0.0784	15:21:18.87	30:36:15.5	u', g', r'	2940	258	171

4. SUMMARY

We summarize what we learned from this preliminary study below. Our analysis is not based on the complete membership yet and therefore suffers from missing data and uncertainties in determining photometric redshifts.

• Most of the rich clusters are *Early-type dominant* systems, but the clusters with small numbers of members show much higher fractions of late-type galaxies, similar to the Virgo cluster. The galaxy morphology is tightly correlated with galaxy color or clustocentric distance for the rich clusters. The fraction of early-type galaxies is higher in the red regime for cluster centers, but this trend is only clear for rich clusters.

• Our results show the density-morphology relations within the clusters. Both early and late types are concentrated in the cluster center, however, the observed trends of density with clustocentric distance are quite different. The density of the early-type galaxies drops sharply from the cluster center to edge, but the late-type galaxies show a gradual decline.

• The ongoing-merger fraction is less than 10% in our sample, and does not depend on galaxy luminosity or location in the cluster. On the other hand, the post-merger features seem to be related to color or clustocentric distances, although this has a large error due to small-number statistics.

• The fraction of bars or rings in clusters is smaller than that in the field (Oh et al. 2012), and it varies from cluster to cluster. The bar fraction seems to depend on environment.

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