Galaxy Evolution across the Hubble Time
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The Evolution of Galaxies and Groups in Cluster Environments at $0.3 < z < 0.6$

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We investigate the dependence of galaxy populations on environment. Our samples are selected from the follow-up of Red-Sequence Cluster Survey (RCS) catalogs using wide-field BVRz' imaging for 60 intermediate redshift ($0.3 < z < 0.6$) clusters. Galaxy redshifts are estimated using an empirical photometric redshift technique with a training set of 3996 galaxies to z 1.4. To obtain photometric redshift probability density for each galaxy, we bootstrap the training set galaxies to estimate the fitting uncertainties and apply Monte-Carlo method to simulate galaxy magnitudes errors. In order to find galaxy groups using photometric redshift, we develop a modified friends-of-friends algorithm, 'Probability Friends-of-Friends Algorithm (pFOF)', where photometric redshift redshift probability densities of individual galaxies are used to determine member galaxies of a group. We calculate the red galaxy fraction to infer the evolutionary status of cluster galaxies and also for galaxies in groups selected in the same redshift space as the clusters.

Dividing individual galaxies by cluster-centric radius, local projected galaxies density, and luminosity, we find that (1) at a given cluster-centric radius, the red population is more dominant in higher galaxy density regions, an indication of local environmental effects; and (2) in regions with fixed density, the red population diminishes significantly beyond the cluster central region, a demonstration of global cluster environmental effects. Separating cluster galaxies into group and non-group galaxies, we observe that (1) the Butcher-Oelmer effect is applicable to group galaxies; (2) cluster galaxies in groups have larger red population fractions in all environments than non-group cluster galaxies; and (3) group environment induces pre-processing effects on cluster galaxies. The key result of this work is that the properties of galaxies are influences by both local and global environments. The evolution is more prominent in bright galaxies in high density regions and galaxy groups; whereas the global cluster environment enhances their evolution, manifested by larger red galaxy fractions toward the cluster central region.

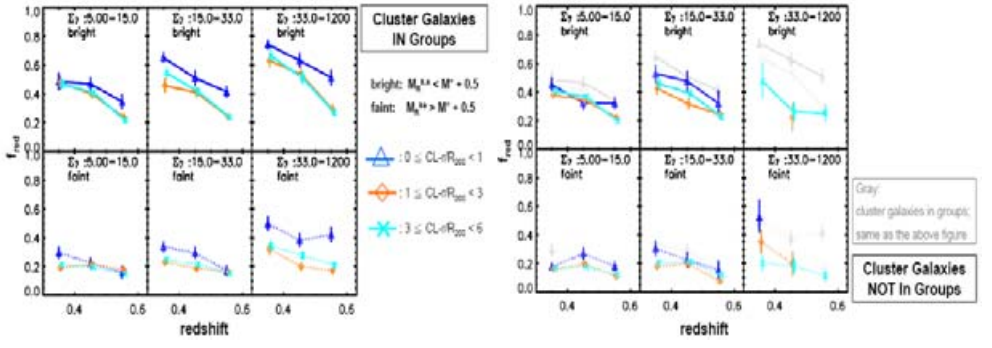

Fig. 1. Red galaxy fraction as a function of redshift in different environment as indicated in panels for both cluster galaxies in groups and not in groups.

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