Outskirts of Galaxy Clusters: intense life in the suburbs
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ESO Distant Cluster Survey: Spectroscopy†

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Abstract. We present first results for spectroscopic observations of galaxies in 4 clusters at $z = 0.7 - 0.8$ and one cluster at $z = 0.5$ observed by the ESO Distant Cluster Survey (EDisCS). Our spectroscopic catalogues contain 236 cluster members of our 5 clusters, and the number of members per cluster ranges from 30 to 67. Our cluster velocity dispersions are between ∼400 and over 1000 km s^{-1}. Galaxy redshift distributions are found to be non-Gaussian and we find evidence for significant substructure in two clusters, one at $z \sim 0.79$ and another at $z \sim 0.54$; both clusters have velocity dispersions exceeding 1000 km s^{-1}. These systems have clearly not yet virialised at these epochs in qualitative agreement with CDM scenarios and their cluster velocity dispersions should not be used in the measurement of cluster mass. Our clusters have a wide range of different cluster velocity dispersions, richnesses and substructuring, and our spectroscopic data set is allowing a comprehensive insight into cluster galaxy evolution as a function of redshift and environment.

1. Introduction

We present first spectroscopic results for the ESO Distant Cluster Survey (EDisCS). EDisCS (PI: White), is a photometric and spectroscopic survey of galaxies in 20 clusters at redshifts 0.4 to 0.8 selected from the Las Campanas Distant Cluster Survey (LCDCS) (Gonzalez et al. 2001). A first test of cluster reality for our EDisCS clusters was completed using imaging in two passbands (Gonzalez et al. 2002). The EDisCS project is investigating galaxy morphology, structure, masses, stellar populations and star formation histories as a function of both redshift and cluster environment, and study cluster mass and structure. Our programme involves deep optical photometry with the VLT (14 nights) (White *et al.* in preparation), near-IR photometry with the NTT (20 nights) (Aragón-Salamanca *et al.* in preparation), and multi-slit spectroscopy using the FORS2 spectrograph at the VLT (20 nights) (Halliday *et al.* submitted; Milvang-Jensen *et al.* in preparation). This ground-based data set has been complemented by 80 orbits of HST ACS imaging (PI: Dalcanton) for 10 EDisCS clusters (Desai *et al.* in preparation).

† Based on observations collected at the European Southern Observatory, Chile (166.A–0162)

Cluster name (1)	No. of members (2)	$z_{cluster}$ (3)	$\sigma_{cluster} \pm \delta\sigma_{cluster}$ (4)	P_{DS} (5)
Cl 1040	30	0.7043	$418\ ^{+55}_{-46}$	0.08
Cl 1054-11	49	0.6972	$589\ ^{+78}_{-70}$	0.64
Cl 1054-12	36	0.7498	$504\ ^{+113}_{-65}$	0.14
Cl 1216	67	0.7943	$1018\ ^{+73}_{-77}$	0.05
Cl 1232	54	0.5414	$1080\ ^{+119}_{-89}$	0.01

Table 1. Cluster members and velocity dispersions are presented for each EDisCS cluster indicated in column 1; column 2 - number of cluster members; column 3 - cluster redshift; column 4 - cluster velocity dispersions ($\sigma_{cluster}$) and errors in km s^{-1}; and column 5 - probability of cluster substructuring from a Dressler-Shectman analysis.

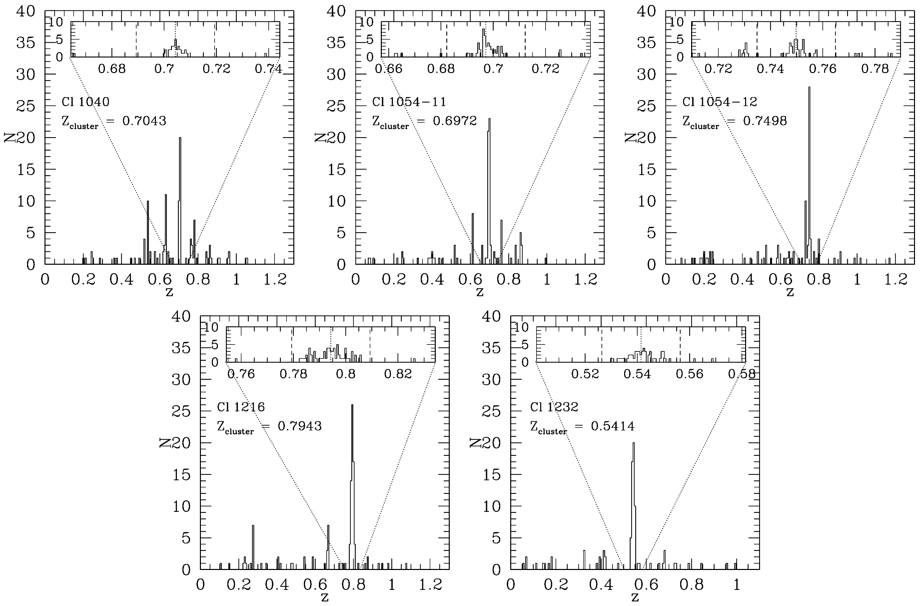

Figure 1. Redshift histograms for all 5 EDisCS clusters. Inset panel of each plot shows zoomed histogram for the redshift interval $z_{cluster} - 0.04 \leqslant z_{cluster} \leqslant z_{cluster} + 0.04$, where the cluster redshift $z_{cluster}$ is indicated by a dotted line. Dashed lines indicate the interval $z_{cluster} - 0.015 \leqslant z_{cluster} \leqslant z_{cluster} + 0.015$. Redshift bins are 0.00625 (1874 km s^{-1}) for main plot and in inset plot 0.000625 (187 km s^{-1}) (observed frame).

2. Spectroscopy of EDisCS: first results

Deep spectroscopic exposures have been obtained to date for 9 of our high-z clusters and 4 of our low-redshift clusters. Galaxies were selected from our I-band photometric catalogues to have I magnitude < 22 for our low-z clusters, and I < 23 for our high-z clusters. Probabilities of cluster membership and star and galaxy classification were generated using our photometric redshift codes (Pelló, Rudnick *et al.* in preparation). Our spectroscopy has defined cluster membership and we are constraining the ages and metallicities of cluster absorption-line galaxies using evolutionary population synthesis models and studying early- and late-type galaxy evolution using emission line equivalent widths, the Fundamental Plane and Tully-Fisher scaling relations and interpretation

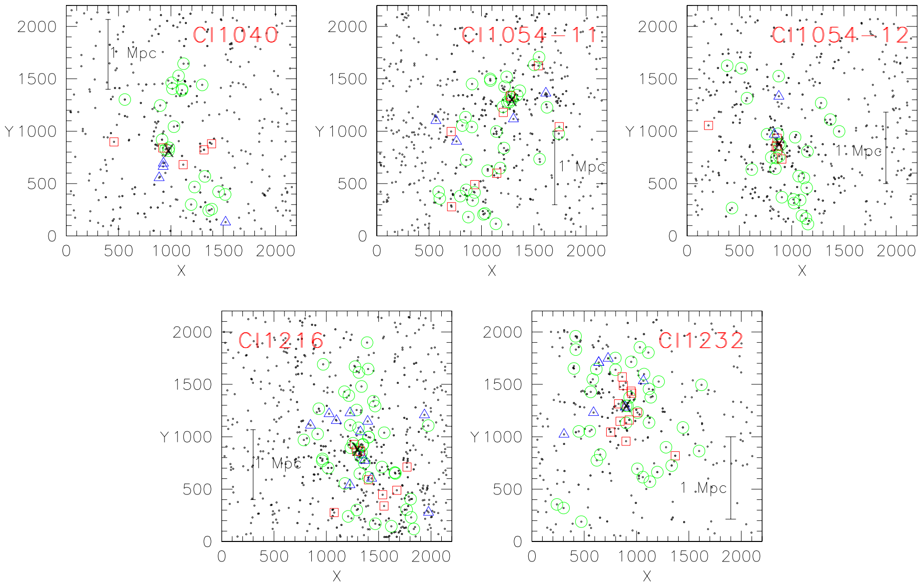

Figure 2. Plots of galaxy positions. Axis scales are in units of CCD pixels (0.2 arcsec/pixel). The cluster name is indicated at the top of each plot. Open symbols indicate the positions of cluster members: green open circles show galaxies within ± one z_σ from the cluster redshift $z_{\rm cluster}$, red open squares indicate galaxies whose redshift is more than one z_σ higher than $z_{\rm cluster}$, and blue open triangles represent galaxies whose redshift is lower than $z_{\rm cluster}$ by more than one z_σ, where z_σ is the redshift interval corresponding to the cluster velocity dispersion in the *observed* frame. Dots mark positions of galaxies selected from our I-band photometric catalogues as possible cluster members. The position of the brightest cluster galaxy (BCG) is given by a black cross symbol. A distance of 1 Mpc, calculated for a λCDM cosmology with $\Omega = 0.3$, $\Lambda = 0.7$ and $h = 0.7$, is provided in each plot.

with galaxy morphologies. We present first results for the VLT spectroscopy data of 5 clusters (4 high-z and 1 low-z) from Halliday *et al.*. Our redshift histograms in Figure 1 show that the cluster velocity distributions of the 5 EDisCS clusters are non-Gaussian. The XY positions of cluster members are given in Figure 2. For two clusters (Cl1232 and Cl1216), substructure is detected with more than 95% probability by a Dressler-Shectman (DS) analysis (Dressler & Shectman 1988) (see Column 5 of Table 1). In Cl1232 the red-shifted galaxies are mainly in projection towards the cluster centre. In Cl1216 blue-shifted galaxies are offset North-East of the cluster centre. For two clusters no significant substructure is detected (Cl1040 and Cl1054-12). No evidence for substructure in found for Cl1054-11. *In conclusion, the clusters of the highest cluster velocity dispersion exceeding 1000* km s^{-1} *(Cl1216 and Cl1232) display the most significant substructuring and are probably still undergoing collapse in qualitative agreement with CDM hierarchical scenarios. Their cluster velocity dispersions should not be used in the measurement of cluster mass.*

References

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