THE EVOLUTION OF EARLY-TYPE GALAXIES IN DIFFERENT ENVIRONMENTS

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Abstract. We investigate the kinematic and chemical evolution of distant early-type (E+S0) galaxies in different environments between 0.2≤z≤0.4. To accomplish our goals, three large spectroscopic surveys have been carried out. The total sample consists of ∼100 E+S0 galaxies in two rich clusters, ∼80 E+S0s in six poor clusters and ∼25 field galaxies. Based on HST/WFPC2 or HST/ACS structural parameters for a sub-sample of E+S0s, the Fundamental Plane relations were constructed for the central cluster regions to reveal possible differences between the sub-populations of galaxies. Outside the HST field, the analysis concentrates on the Lick/IDS absorption line indices by comparing them to simple stellar population models with different [α/Fe] enhancements. Combining all data, age/metallicity variations and the mass evolution for densities from the field to rich cluster environments were derived.

1 Introduction

Current semi-analytic CDM simulations favour a hierarchical structure growth for galaxies through merging of subunits and an assembly of dark halo building blocks [1]. Only for the dense environments of rich clusters, galaxies experienced their last major merger at $z \sim$1–2. Therefore, the age distribution of early-type (E+S0) galaxies should be more diverse in lower density regions. For this reason, we analyse the kinematic and chemical evolution of distant E+S0 galaxies in various environments between 0.2≤z≤0.4. The studies span a broad range in luminosity (-20.0> M_r >-23.5) and in case of the clusters a wide $10' \times 10'$ FOV. We adopt a cosmology for a flat Universe with $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$ and $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

2 Rich Clusters

Since the galaxy samples of the two rich clusters, Abell 2218 [6] and Abell 2390 [3], are very similar, we combine them and explore a total number of 96 E+S0 galaxies at z∼0.2. From the Faber-Jackson relation (Fig. 1) and the Fundamental Plane (FP) we deduce on average only a mild evolution in the Gunn r-band of ∼0.30 mag with respect to the local Coma reference. Both scaling relations suggest a trend for a stronger luminosity evolution for lower-mass galaxies ($\sigma < 170\,\mathrm{km\ s^{-1}}$) than for more massive ones, providing support for the *downsizing* scenario [3]. There is also a small radial dependence with a larger relative brightening for galaxies in the outer regions. The E+S0 galaxies show a tight FP relation with a small scatter of 0.1 dex. Dividing our FP sample in terms of galaxy morphology, slight differences between the populations of ellipticals and S0 arise. Fig. 1 (*left*) illustrates the edge-on view of the FP for 34 E+S0 galaxies in A 2218 and A 2390 in rest-frame Gunn r-band. The FP of the distant clusters is compared to the FP for the local Coma sample [4]. On average, S0s experience a stronger evolution of $0.44{\pm}0.18^{\mathrm{m}}$ than Es with $0.02{\pm}0.21^{\mathrm{m}}$. The S0 galaxies are predominantly located below the local edge-on FP relation and thus may exhibit star formation histories different from the ellipticals [3].

3 Poor Clusters

This project is based on an extensive observational campaign studying the evolutionary status of galaxies in six poor clusters at redshifts of 0.2<z<0.3 selected to have very low X-ray luminosities ($L_X < 5 \times 10^{43}$ erg/s), 1.0 dex lower than rich clusters, and poor optical richness class. E+S0 cluster members were selected based on our low-resolution spectra and their HST morphology. For the FP study, we obtained high S/N MOSCA spectra of 5−7 galaxies lying within the HST fields and additional ∼10 spectra in the outskirts for a single MOS mask.

Analysis of the galaxy spectra for three clusters revealed that the overall spectral properties of these cluster galaxies are similar to those in more massive clusters at a look-back time of ∼3 Gyr. In particular, the 27 poor cluster galaxies exhibit a slightly stronger luminosity evolution of $\Delta M_r = 0.41 \pm 0.24^{\mathrm{m}}$ than the rich cluster galaxies (Fig. 1 *middle*). They mainly comprise passive galaxies with no or only little on-going star formation.

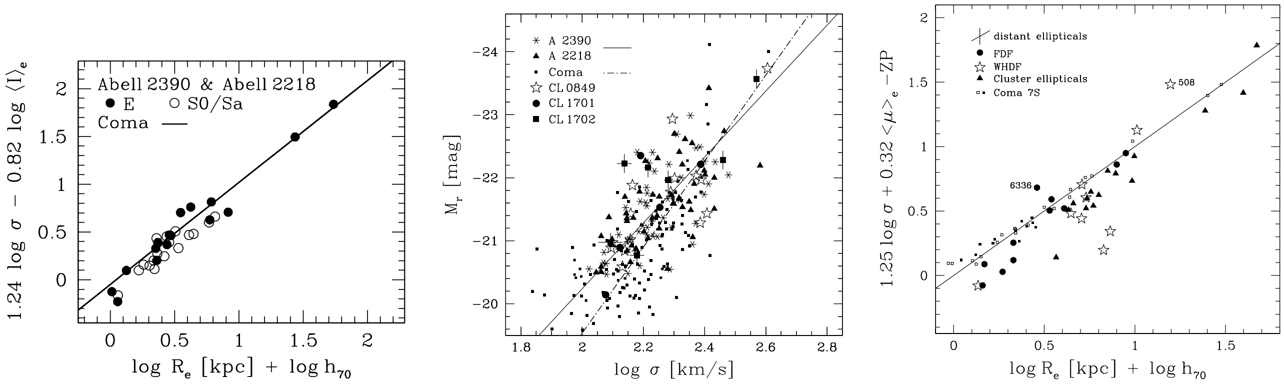

Figure 1: *Left:* Fundamental Plane in Gunn r for 34 E+S0 cluster galaxies in A 2218 and A 2390 divided according to morphology and compared to the local Coma sample [4], indicated by a bisector fit. *Middle:* Faber-Jackson relation in Gunn r for the rich clusters A 2218 and A 2390 (solid line) and three poor clusters CL 0849, CL 1701, CL 1702, compared to Coma (dashed line) [4]. On average, the 96 rich cluster members show a mild evolution of $\Delta M_r = 0.32{\pm}0.22^{\rm m}$, the 27 poor cluster galaxies a brightening of $\Delta M_r = 0.41{\pm}0.24^{\rm m}$. Typical errors are shown for one cluster only. *Right:* FP in rest-frame B-band for 20 FDF and WHDF field ellipticals, compared to the 7 Samurai data [2]. Both field samples indicate a modest evolution of $\Delta M_B = 0.42{\pm}0.20^{\rm m}$.

4 Field Galaxies

As a complement to the clusters, VLT/FORS spectroscopic observations of 42 field E+S0 candidates down to $R_{\rm lim} \leq 22.0^m$ with $\langle z \rangle = 0.4$ drawn from the FORS Deep Field (FDF) and William Herschel Deep Field (WHDF) have been performed using a resolution of R=1200 and exposure times of $t_{\rm tot}{\sim}5$ hrs. For a total of 24 out of 28 isolated field galaxies (14 are members of a cluster) velocity dispersions (σ) were derived using the FCQ method. HST/ACS structural parameters were analysed for 21 galaxies using the GALFIT package.

Scaling relations of the Faber-Jackson and FP indicate a mild luminosity evolution in the rest-frame B-band for both field samples of $\Delta M_B = 0.42 \pm 0.20^{\rm m}$ (Fig. 1 *right*). This result is comparable to cluster ellipticals at similar look-back times (~5 Gyr), which are brighter by $\Delta M_B = 0.44 \pm 0.18^{\rm m}$ [7]. The two outliers, # 6336 (strong H$\delta_{\rm F}$ absorption, young age) and # 508 (possible merger), reveal on the ACS images a significant disk component and early spiral morphology. For both objects a low level of star formation (SF) cannot be ruled out. Lick/IDS absorption line indices were measured and compared to evolutionary stellar population models to deduce light-averaged ages, metallicities (Z/H) and non-solar element abundance ratios (Mg/Fe). These three stellar parameters of the distant E+S0 FDF sub-sample show a correlation with velocity dispersion (mass) which is consistent with that of local galaxies [7]. The increase of [α/Fe] enhancement with σ cannot be explained by recent semi-analytic ICM models [5]. In summary, the results are consistent with a passive evolution of the stellar populations with no sign of recent significant SF episodes and little chemical enrichment since $z \sim 0.5$.

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