Outskirts of Galaxy Clusters: Intense Life in the Suburbs
Proceedings IAU Colloquium No. 195, 2004
A. Diaferio, ed.

DOI: 10.1017/S1743921304001085

A detailed view of the Fundamental Plane of early–type galaxies in clusters at z∼0.2

Alexander Fritz and Bodo L. Ziegler

Universitäts–Sternwarte Göttingen, Geismarlandstraße 11, 37083 Göttingen, Germany email: afritz@uni-sw.gwdg.de

Abstract. We present a spectroscopic sample of 48 early-type galaxies in the rich cluster Abell 2218 and 50 galaxies in Abell 2390. Since both samples are very similar, we combine them and investigate a total number of 98 early-type galaxies at $z \sim 0.2$. A subsample of 34 galaxies with *HST* structural properties is used to construct the Fundamental Plane. Elliptical and S0 galaxies show a zeropoint offset of $\overline{m}_r \sim 0.43$ mag with respect to the local Coma FP. Both sub-samples, ellipticals and lenticulars, exhibit a similar, mild evolution and small scatter. The moderate amount of luminosity evolution is consistent with stellar population models of passive evolution, if $z_f \geqslant 2$ is assumed.

1. Introduction

Clusters of galaxies are powerful laboratories in investigating the formation and evolution of galaxies. Rich clusters are dominated by early-type (E+S0) galaxies. A detailed study of the properties of these galaxies provides beneficial insights in their formation and evolution. In particular, the paradigm of hierarchical galaxy formation can be critically tested.

In the local Universe numerous investigations revealed that E+S0 form a very homogeneous galaxy population (e.g., Bower et al. 1992; Bender et al. 1993). Their structural parameters (effective surface brightness $\langle\mu\rangle_e$ and the size as described by the effective radius R_e) and kinematics (velocity dispersion σ) represent a tight correlation in three dimensional parameter space, the Fundamental Plane (Djorgovski & Davis 1987). Furthermore, they show a small scatter in their relations of colours (e.g., Mg–$(B-V)$), M/L ratios and absorption line indices with velocity dispersion (e.g., Mg–σ). However, the question arises whether E+S0s are truly one single family or rather a diverse group with different formation and evolutionary processes. Therefore, one aim of this work is to explore if there are differences between the properties of elliptical and S0 galaxies.

Previous spectroscopic studies were limited to a small number of the more luminous galaxies. To overcome bias and selection problems of small samples, we focus in this study of the clusters Abell 2218 (Ziegler et al. 2001) and Abell 2390 on a large number of objects ($N = 98$), spanning a wide range in luminosity, in case of A 2390 $21.4 < B < 23.3$, and a wide field-of-view (FOV) of $\sim 10' \times 10'$ ($1.56\ h_{70}^{-1} \times 1.56\ h_{70}^{-1}$ Mpc^2). We adopt a cosmology for a flat Universe with $\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$ and $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$.

The objects were selected on the basis of ground-based Gunn i-band images and a combination of defined colour regions using a similar selection procedure as described in Ziegler et al. (2001). In particular, in the selection procedure for the mask design special care was taken that galaxies cover the whole FOV. Additional imaging data obtained with the 200 inch Hale telescope is available in U and B and *HST* WFPC2 observations in the F555W and F814W filter.

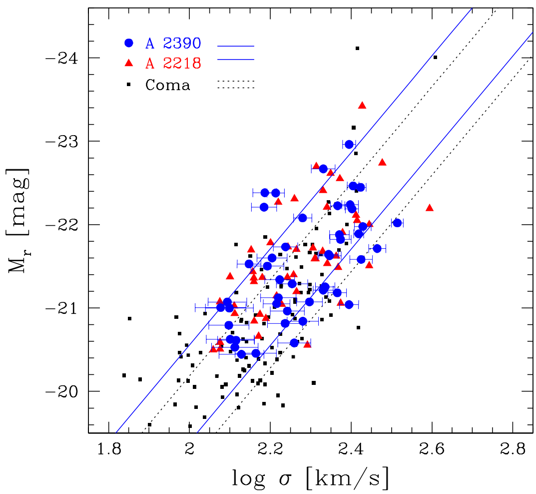

Figure 1. Gunn r Faber-Jackson relation for 94 early-type cluster galaxies in A 2390 and A 2218, compared to the Coma sample (JFK95). The Coma galaxies were restricted to $M_r < -19.5$ and log $\sigma > 2.0$. The area bounded by dotted lines indicates the mean ± 1 σ of the local FJ relation using a linear bisector fit, solid lines the respective fits to the distant sample within ± 1 σ.

2. Observations and data reduction for Abell 2390

During two observing runs (09/1999 and 07/2000) we observed three masks using the MOSCA spectrograph at the Calar Alto 3.5 m telescope with total exposure times between ∼8 and ∼12 hours each. In total, we obtained 63 high S/N spectra of 50 different early-type galaxies, out of which 15 are situated within the *HST* field. Only one object was revealed to be a background galaxy, which shows that our sample selection was highly efficient. The instrumental resolution in the spectral regime of Hβ and Mg b was 5.5 Å FWHM ($\sigma_{\rm inst} \sim 100$ km s^{-1}). The average S/N is ~ 41.

The reduction of the spectra was carried out using standard reduction techniques and velocity dispersions were calculated with the FCQ method (Bender 1990). Structural parameters were determined by fitting the surface brightness profile with either an $r^{1/4}$ or a combination of an $r^{1/4}$ plus an exponential law profile (Saglia et al. 1997). Further details concerning the reduction and analysis are outlined in Fritz et al. (2004).

3. A detailed Fundamental Plane of E+S0 cluster galaxies at $z \sim 0.2$

In Fig. 1 the Faber-Jackson (FJ) relation for the complete sample of 94 E+S0 galaxies is shown. As a local reference we use the Coma sample of Jørgensen et al. 1995 (JFK95). Overall, the luminosity evolution is small ($\overline{m}_r \sim 0.32$ mag). The Fundamental Plane (FP) in rest frame Gunn r is shown in Fig. 2. The sub-sample with *HST* structural parameters comprises 34 E+S0 galaxies, splitted into 17 ellipticals, 2 E/S0, 8 S0, 3 SB0/a, 3 Sa and 1 Sab galaxy that enter the FP. With this large sample, possible differences of the galaxies' properties can be explored for various sub-populations. Both clusters have a similar behaviour within and along the FP, with no hint for a slope change. For the 34 cluster E+S0 galaxies we find a combined evolution of $\overline{m}_r \sim 0.43$ mag. Lenticular galaxies (E/S0, S0, SB0/a, Sa, Sab) have a zeropoint offset of 0.30 mag with respect to Coma and seem to inhabit a certain band within the FP (Fig. 2, right). Ellipticals exhibit a similar mild evolution of $\overline{m}_r \sim 0.46$. Both sub-samples have a small scatter (∼0.10 mag).

https://doi.org/10.1017/S1743921304001085 Published online by Cambridge University Press

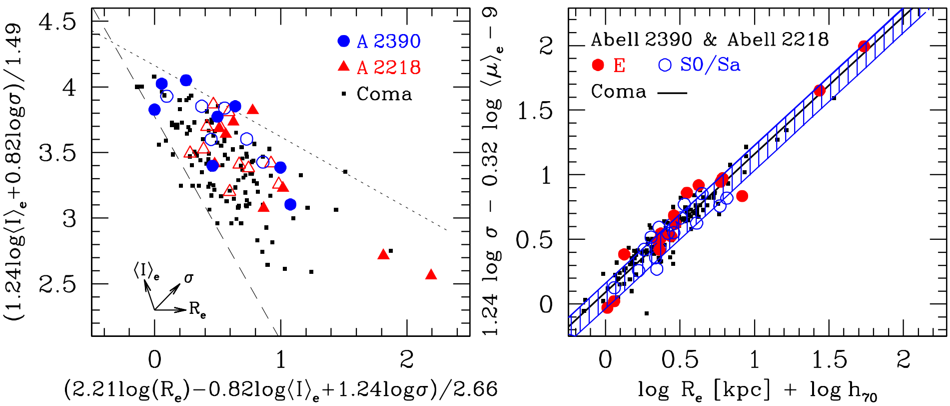

Figure 2. Fundamental Plane for A 2390 and A 2218 in Gunn r. *Left*: Face-on view. The dotted line indicates the exclusion zone for nearby galaxies, the dashed line the L limit for Coma. Filled symbols represent ellipticals, open symbols S0 galaxies. *Right*: Edge-on FP for the combined cluster sample, with a separation into morphologies. The solid line marks the Coma relation of JFK95. Fits along $1-\sigma$ errors for the S0 galaxies assuming a constant slope are indicated (hatched area).

4. Summary

We construct a spectroscopic sample of 48 E+S0 in the rich cluster Abell 2218 ($z = 0.18$) and 50 E+S0 in Abell 2390 ($z = 0.23$). Since both cluster samples are very similar, we combine them and analyse a total number of 98 E+S0 at $z \sim 0.2$. For a subsample of 34 galaxies we explore the evolution of the FP and study their M/L ratios. On average, all 34 cluster E+S0 galaxies show a mild evolution of $\Delta\log(M/L_r) = -0.17$. S0 galaxies show lower M/L ratios of $\Delta\log(M/L_r)_{\rm S0} = -0.12$ with respect to the local reference. For the ellipticals we again deduce a moderate evolution of $\Delta\log(M/L_r)_{\rm E} = -0.18$. Elliptical and S0 galaxies seem to comprise similar sub-populations with no significant differences. An analysis based on the M/L ratios revealed a mean formation redshift of $z_f \sim 3$, which is consistent with stellar population models of passive evolution.

Acknowledgements

This project is a collaboration with R. G. Bower and I. Smail (Durham/UK) and R. L. Davies (Oxford/UK) who have contributed to these results. We thank the Calar Alto staff for efficient observational support. AF and BLZ acknowledge financial support by the Volkswagen Foundation (I/76 520) and the DFG (ZI 663/1-1, ZI 663/2-1).

References

Bender, R. 1990 *A&A* **229**, 441–451.
Bender, R., Burstein, D., Faber, S. M. 1993, *ApJ* **411**, 153–169.
Bower, R. G., Lucey, J. R., Ellis, R. S. 1992 *MNRAS* **254**, 601–613.
Djorgovski, S., Davis, M. 1987 *ApJ* **313**, 59–68.
Fritz, A., Ziegler, B. L., Bower, R. G. et al. 2004 *MNRAS*, submitted.
Jørgensen, I., Franx, M., Kjærgaard, P. 1995 *MNRAS* **273**, 1097–1128. (JFK95)
Saglia, R. P., Bertschinger, E., Baggley, G. et al. 1997 *ApJS* **109**, 79–102.
Ziegler, B. L., Bower, R. G., Smail, I. et al. 2001 *MNRAS* **325**, 1571–1590.