

“Downsizing” from the fossil record: Ages and metallicities of red galaxies and their dependence on mass and on environment

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1. Introduction

Red-sequence galaxies are known to obey well-defined scaling relations, such as the Fundamental Plane and the colour-magnitude relation, yet their star formation histories, which in part drive these relations, remain poorly understood. In this contribution, we summarize recent results from the NOAO Fundamental Plane Survey (NFPS). These results appear in more detail in Smith *et al.* (2006) and Nelan *et al.* (2005).

2. Data: The NOAO Fundamental Plane Survey

The NFPS is an all-sky survey of 93 galaxy clusters with $z < 0.07$. Based on *B*- and *R*-band imaging, 4000 red-sequence galaxies were selected for spectroscopic follow-up, with typical S/N per Å of ~ 25 . Full details are given in Smith *et al.* (2004).

For galaxies with no emission, we extract velocity dispersions, σ , and Lick linestrength indices, and find that all linestrengths obey well-defined scaling relations as a function of $\log \sigma$. We select 12 robust indices, including three Balmer lines, for comparison to the predictions of the stellar population models of Thomas *et al.* (2003, 2004).

3. Results

The linestrength scaling relations can only be reproduced with the following parameter scaling relations: $\text{age} \propto \sigma^{0.59 \pm 0.13}$; $Z \propto \sigma^{0.53 \pm 0.08}$; $\alpha/\text{Fe} \propto \sigma^{0.31 \pm 0.06}$ (where the errors reflect the range obtained using different subsets of indices). The results are shown in Fig. 1. Our conclusions are not strongly dependent on which Balmer lines are used as age indicators. The derived age- σ relation is such that if the largest ($\sigma \sim 400 \text{ km s}^{-1}$) galaxies formed their stars ~ 13 Gyr ago, then the mean age of low-mass ($\sigma \sim 50 \text{ km s}^{-1}$) objects is only ~ 4 Gyr. The data also suggest a large spread in age at the low-mass end of the red sequence, with 68% of the galaxies having ages between 2 and 8 Gyr. We conclude that although the stars in giant red galaxies in clusters formed early, most of the galaxies at the faint end joined the red sequence only at recent epochs. For full details, see Nelan *et al.* (2005).

In Smith *et al.* (2006), we then considered the effect of the cluster environment on the ages and metallicities of red galaxies. After subtracting off the dominant σ trend found above, we detect significant radial dependence of the linestrength residuals. The measured cluster-centric gradients for all 12 indices can be reproduced by a model in which red-sequence galaxies at the virial radius have on average younger ages (by $15 \pm 4\%$) and lower

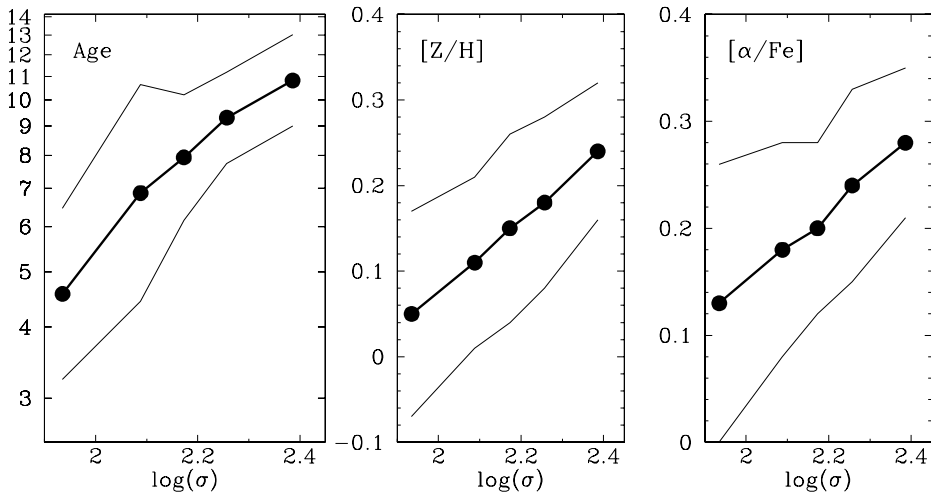


Figure 1. Fundamental scaling relations of the population parameters with σ . The thick line shows average age, metallicity and α/Fe determined in bins of velocity dispersion, using the grid-inversion method. The thin lines indicate an estimate of the 68% interval of the intrinsic scatter of the red-sequence galaxy population.

α -element abundance ratios (by $10 \pm 2\%$) than galaxies of the same velocity dispersion but located near the cluster centres. For the total metallicity, Z/H , no significant gradient is found ($2 \pm 3\%$ larger at R_{200} than in the cores).

4. Summary

We have detected “downsizing” in the sense that the luminosity-weighted ages of more massive red-sequence galaxies are older than those of smaller red galaxies. This downsizing trend is in good qualitative agreement with observations of the red sequence at higher redshifts (Smith 2005).

The sense of the downsizing trend is the same throughout the cluster, but the ages are slightly younger (at the same mass) for red galaxies at the virial radius. The age and $[\alpha/\text{Fe}]$ trends are in the sense expected if galaxies in the cluster core were accreted at an earlier epoch than those at larger radii, and if this earlier accretion contributed to an earlier cessation of star formation.

We are currently investigating to what degree the NFPS linestrength data can be reproduced with different assumed star formation histories (e.g. single age vs. exponential vs. quenched star formation), and, via colours, what constraints can be placed on the ages of discs vs. those of bulges.

References

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