THE FUNDAMENTAL PROPERTIES OF EARLY-TYPE GALAXIES IN
THE COMA CLUSTER

STEPHEN A.W. MOORE*, J.R. LUCEY, H. KUNTSCHNER and R.L. DAVIES
Extragalactic Astronomy Group, University of Durham, UK

M. COLLESS
Mount Stromlo and Siding Spring Observatories, Australian National University, Australia

Abstract. We report the results of a high quality spectral study of early-type galaxies within the Coma Cluster core. Stellar population analysis using Lick/IDS indices to break the age/metallicity degeneracy are presented, probing their formation history and properties. A clear metallicity trend and a dominant single age population are found.

Keywords: Coma Cluster, stellar populations, early-type galaxies ages and metallicities

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1. Introduction

A complicated picture has emerged from studies of cluster early-type galaxies, with measurements of their stellar populations hampered by low quality data and by the age/metallicity degeneracy present in broad-band colours. In the core of the Coma Cluster, Caldwell et al. (1993) found evidence of a small dispersion in the ages of the large majority of early-type galaxies, whilst Jørgensen (1999) found evidence of a large spread in age and a small spread in metallicity. In the Fornax Cluster, a small age spread and a large metallicity spread was found (Kuntschner and Davies, 1998; Kuntschner, 2000). These differing results highlight an uncertain understanding of cluster early-type galaxy populations. This has important ramifications on studies of the evolutionary processes of galaxies in clusters, making it difficult to test hierarchical merging or early monolithic collapse models.

Here we present the results of a new study on the rich Coma Cluster which aims to accurately measure the ages and metallicities of the early-type galaxy population. Observations were made of the central 1 degree of the cluster with the WHT 4.2m telescope plus the WYFFOS/AUTOPIB2 multi-fibre spectroscopy instrument. A wide wavelength range 4000 → 5640 Å was studied at high resolution (2Å FHWM) and high signal-to-noise (mean of 50 per Å). Many repeat observations over 6 nights were taken to tie down the errors and create a homogeneous sample. The Lick/IDS indices HβG (a modified Hβ index proposed by Jorgensen, 1999 after González, 1993) and [MgFe] are used to break the age/metallicity degeneracy. The data set has a total of 135 galaxies (m_B = 12.6 – 18.0).

* Supported by a PPARC studentship. Author email address: s.a.w.moore@durham.ac.uk

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2. Data Reduction

Using any multi-fibre spectroscopy instrument introduces intra-fibre and fibre-to-fibre variations in resolution and throughput that necessarily have to be removed before accurate stellar population analysis can be undertaken. In this study these effects were mapped extensively and removed. Standard stars are then used to flux calibrate the spectra. Redshifts and velocity dispersions are measured using cross-correlation techniques. The data is then broadened to the Lick/IDS resolution and the Lick/IDS indices measured (see Trager et al., 1998 for details). Any offsets to the system were removed by comparing galaxies in common.

The Hβ index is emission corrected using a measurement of the OIII strength (calculated by subtracting a zero emission template from a galaxy spectrum and measuring the residual equivalent width) and multiplying it by 0.6 to compute the correction (Trager et al., 2000). A total of 50 galaxies had 1 sigma evidence of emission, with a median OIII emission of 0.228Å giving a median Hβ correction of 0.137Å (corrections are calculated individually for each galaxy).

The line index measurement errors were calculated by internal comparison during a night and between nights. With the large amount of multiple observations with different fibre configurations and high signal-to-noise data this allows accurate mapping of the random and systematic errors.

3. Comparison with Other Data

There are 44 galaxies in common with the Jørgensen (1999) study which covered a similar area and magnitude range, but at a lower signal-to-noise and with multiple data sets. The standard deviation between the two studies is 0.280Å in HβG and 0.265Å in [MgFe] — the principal stellar population analysis line indices used in this study. Mehler et al. (2000) have recently conducted a high signal-to-noise long slit study of bright early-type Coma Cluster galaxies. There are 18 galaxies in common with this study. The long slit data was summed up to match the aperture size of this study and compared giving a standard deviation of 0.255Å in Hβ (they did not measure the improved index HβG) and 0.103Å in [MgFe]. These comparisons and the internal analysis of the random and systematic errors indicate that the study data has a median precision of 0.138Å in HβG and 0.092Å in [MgFe].

4. Stellar Population Analysis

This study uses the HβG and [MgFe] indices as the principal probe of stellar populations. This combination provides the best compromise to non-solar abundance problems with maximal breaking of the age/metallicity degeneracy problem. These indices are superimposed onto a Worthey (1994) grid to measure the age and metallicities of the galaxies,
probing the intra-cluster trends. Figure 1 shows the data, which has been sifted to only include data with a minimum signal-to-noise of 35 per Å.

To test the presence or absence of age/metallicity trends in the cluster we used Monte Carlo simulations. These simulations assumed a constant age population and performed a density-weighted sampling along a given isochrone within the measurement errors. By comparison with the real distribution of ages and metallicities within the cluster we can see whether a constant age population is supported by the data within the measurement errors.

The results of these simulations are presented in Figure 2. This figure shows a plot of age vs metallicity for the real data (triangles) and Monte Carlo simulation data for a 9 Gyr isochrone (crosses) compared to a Worthey (1994) grid. To the right and at the bottom of the plot is a histogram of the real data. Overlaid on these histograms are lines showing the results from a number of simulations along different isochrones. Comparison of these lines to the real age and metallicity distributions shows clearly that a dominant luminosity-weighted single age population of approximately 9 Gyrs is supported within the measurement errors. A clear metallicity trend, from low to high metallicities, is also seen. This metallicity trend is unaffected by differing constant age hypotheses.

5. Conclusions

The early-type Coma Cluster data set in this study is homogeneous, self-consistent, has high signal-to-noise with well characterised errors. This has allowed a new unbiased assessment
of the Coma Cluster intrinsic properties, without any need to combine multiple data sets with systematic errors. A stellar population analysis using the indices H$\beta$$_G$ and [MgFe] overlaid on Worthey (1994) grids has shown:

- there is a clear metallicity trend;
- the data is consistent with a dominant luminosity-weighted single age early-type galaxy population.

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