SPECTROSCOPIC GRADIENTS IN EARLY – TYPE GALAXIES AND IMPLICATIONS ON GALAXY FORMATION

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The Coma cluster is the ideal place to study galaxy structure as a function of environmental density in order to constrain theories of galaxy formation and evolution. Here we present the spectroscopy of 35 early type Coma galaxies, which shows that the age spread of early type galaxies in the Coma cluster is large (15 Gyrs). In contrast to the field, the dominant stellar population in all (massive) Coma Es is older than 8 Gyr, while only S0s, which possess extended disks, can be as young as 2 Gyr. The old, most massive Es show a strong light element enhancement, probably due to a rather short star formation time scale and hence to a SNII – dominated element enrichment. The lower mass S0s are much less enhanced in light elements, indicating a longer star formation time scale. The measured absorption line index gradients support the idea that early type galaxies formed in processes that include both stellar merging and gaseous dissipation.

1 The Project

We obtained long slit spectra for 35 E and S0 galaxies at the Calar Alto 3.5 m, the Michigan – Dartmouth – M.I.T. 2.4 m and the McDonald 2.7 m telescopes. Our sample is complete for galaxies brighter than $M_B = -21.6^{mag}$ (14 galaxies) and is 1/3 complete in the magnitude range $-21.6^{mag} < M_B < -20.2^{mag}$ (21 galaxies). The integrated exposure time per galaxy ranges from 2 – 5 h. Our sample spans 4 dex of the cluster density reaching 4 Mpc out of the center. We derived the *radial profiles* of the line indices Mg, Fe and H_β as well as of the stellar rotation and the velocity dispersion reaching out to 2 r_e for most of the galaxies.

2 Age and Metallicity distribution

We used Worthey's (1994) stellar population synthesis models to investigate the age and metallicity distribution of our sample. In Fig. 1a we plotted the grid of models for the age sensitive H_β index versus the metallicity sensitive combined index $[\mathrm{MgFe}] = (\mathrm{Mg}_b <\mathrm{Fe}>)^{1/2}$, where $<\mathrm{Fe}> = (\mathrm{Fe}_{5270} + \mathrm{Fe}_{5335})/2$. Overplotted are the mean (inside 0.5 r_e) indices we measured for our galaxies.

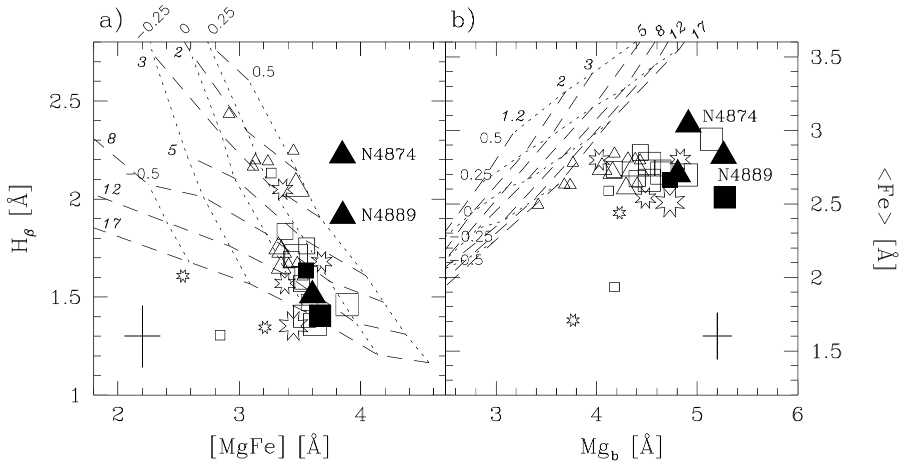

Figure 1: Mean absorption line indices inside 0.5 r_e for 35 Coma galaxies compared to the model grids of Worthey (1994); dashed lines - constant age t in Gyr; dotted lines - constant metallicity $\log(Z/Z_\odot)$. Open squares represent Es, open triangles S0 and open stars E/S0s, while black triangles represent the three CD galaxies (NGC 4874, NGC 4889, NGC 4839) and black squares two galaxies (NGC 4816 & IC 4051), which contain kinematically decoupled/peculiar cores (Mehlert et al. 1997). Different sizes refer to small, medium and large mean velocity dispersion σ - or mass - inside 0.5 r_e. **(a)** The age indicating index H_β versus the metallicity indicating [MgFe] combined index. The cross indicates the mean index errors for all galaxies. These translate into errors in metallicity $\Delta\log(Z/Z_\odot) \approx 0.25$ dex and errors in age $\Delta t \approx 2 - 9$ Gyr for young and old galaxies, respectively. **(b)** <Fe> versus the Mg_b index. The mean index errors for all galaxies are indicated by the cross.

According to Worthey's models the ages of our Coma galaxies range from 2 – 17 Gyr. However, all massive Es are older than 8 Gyr having a mean age of $\approx$ 12 Gyr. Interestingly the two cD galaxies of the main cluster (NGC 4874 & NGC 4889) are younger than the Es, but the most metal rich galaxies in Coma. Only the less massive S0s, which possess an extended disk component, can be as young as 2 Gyr, but also as old as 12 Gyrs. Similar results have been found by Kuntschner & Davies (1997, KD97) in the Fornax cluster, where the central number density of early – type galaxies is 6 times lower than in the Coma cluster. In contrast field Es are all younger than 10 Gyr and can also be as young as 2 Gyr (Faber et al. 1995). Similar differences between the effective age of the stellar populations in field and cluster Es have been found by Rose et al. (1994) as well as Guzman et al. (1992). We detect no dependence of a galaxy's age or metallicity on the density profile of the Coma cluster. The small metallicity spread (0.25 dex) of our Coma sample is probably only due to the lack of faint galaxies in our sample ($M_B >$ -20.2^{mag}). For example, KD97

found a metallicity spread of $\approx$ 0.75 dex for their complete sample of 22 Es and S0s in the Fornax cluster reaching M_B = -17^{mag}.
It is important to emphasize that the ages and metallicities we derived depend strongly on the stellar population model we used. An obvious problem is the Mg_b to <Fe> overabundance. Fig. 1b shows the mean <Fe> versus the Mg_b index measured for our galaxies and the grid of Worthey's models. Obviously, the models *do not* reproduce the data in the sense that the galaxies are highly overabundant in Mg_b relative to <Fe>. The most massive Es show abundances up to 0.5 dex super solar, while less massive S0s show solar element ratios or an enhancement up to 0.25 dex solar. These properties are also known for field Es (FFI95; G93). The supersolar light element enhancement of massive Es is probably due to a SN II dominated element enrichment. In a recent study Thomas et al. (1997) show that in addition to a top heavy initial mass function (IMF) a short star formation time scale is needed to produce a high SN II/SNIa ratio and hence the enhancement, which is detected in the most massive early type galaxies. As long as the available stellar population models cannot reproduce the observed abundances the determination of the ages and metallicities of stellar populations still remain problematic.

3 Line strength gradients

We computed index gradients grad(index) = Δlog(index)/Δlog(r/r_e) by applying a linear χ^2 fit to the index profiles out to r_e. In Fig. 2a & b we plotted the Mg_b and <Fe> gradients versus the central fit value at 0.01r_e. The most massive Es show the highest central indices and the strongest metallicity gradients, while the less massive S0s have lower central values and flatter gradients. The gradients of the age sensitive H_β index are in the range of grad(Hβ) = -0.18 to 0.07. Together, these considerations support the idea that early – type galaxies formed by a combination of merging and dissipative (gas involving) processes. Similar results have been found for field Es (Gonzales & Gorgas 1995; Carollo et al. 1993).
Once Fig. 2 is taken into account, the Mg_b gradient tends to be larger (on the 1 σ level) for galaxies at larger distances from the cluster's center. A larger sample is needed to investigate the reality of this possible environmental effect.

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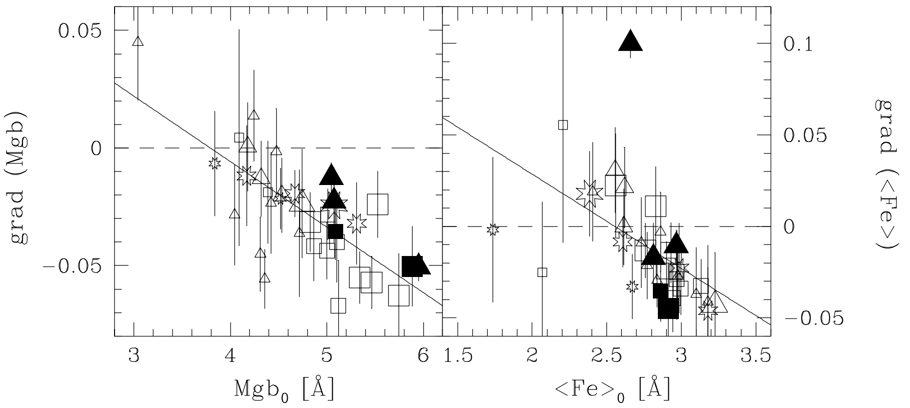

Figure 2: Fitted Mg_b **(a)** and <Fe> **(b)** gradients versus the central fit value at 0.01 r_e for 35 Coma early type galaxies (symbols and sizes as in Fig. 1). A linear χ^2 fit yields following correlations: grad(Mg_b) = 0.106 - 0.028 Mgb_0 with an RMS scatter of $\sigma = 0.0044$ in grad(Mg_b) and grad(<Fe>) = 0.132 - 0.052 $\langle\mathrm{Fe}\rangle_0$ with an RMS scatter of $\sigma = 0.0142$ in grad(<Fe>). The probability of having no correlation can be excluded at the 3 σ and 2.7 σ levels for the Mg_b and <Fe> gradients, respectively.

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