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# FABER-JACKSON RELATION FOR DWARF E/S0 GALAXIES

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RESUMEN

Presentamos observaciones espectroscópicas de 72 galaxias de tipo temprano en el núcleo de cúmulo de Coma. Nuestra muestra incluye 36 galaxias enanas (dE/dS0) para las cuales hemos medido la dispersión de velocidad e índices de fuerza de líneas. Confirmamos que la relación de Faber-Jackson se mantiene para las galaxias luminosas de tipo temprano. Sin embargo, galaxias de tipos más tempranos de luminosidad más baja siguen una relación diferente: $L \propto \sigma^2$. Mostramos que la rotación por sí sola no puede ser responsable de este cambio en la inclinación. También derivamos edades, metalicidades, y proporciones [$\alpha$/Fe] de esta muestra de galaxias.

ABSTRACT

We present spectroscopic observations of 72 early-type galaxies in the core of the Coma cluster. Our sample includes 36 dwarf galaxies (dE/dS0) for which we measured velocity dispersion and line strength indices. We confirm that the Faber-Jackson relation holds for the luminous early-type galaxies. However, lower luminosity early-type galaxies follow a different relation: $L \propto \sigma^2$. We show that rotation alone cannot be responsible for this change of slope. We also derive ages, metallicities and [$\alpha$/Fe] ratios for this sample of galaxies.

*Key Words:* **GALAXIES: CLUSTERS: INDIVIDUAL (COMA) — GALAXIES: ELLIPTICAL AND LENTICULAR, CD — GALAXIES: DWARF — GALAXIES: KINEMATICS AND DYNAMICS**



## 1. INTRODUCTION

Although dwarf elliptical galaxies (dEs) are the most numerous galaxies in galaxy clusters, their kinematic properties are still not very well known due to their low effective surface brightness (Ferguson & Binggeli 1994), which makes them difficult to observe. However, more spectroscopic observations of these faint, quiescent galaxies have emerged in recent years (De Rijcke et al. 2005; Smith et al. 2004; Matković & Guzmán 2005, hereafter MG05, etc.).

For decades the Faber-Jackson relation (Faber & Jackson 1976, hereafter F-J) between the luminosity and velocity dispersion has been considered a fundamental relation for early-type galaxies. This relation, which states that the luminosity of a galaxy increases with velocity dispersion to a power of 4 ($L = \sigma^n$, where $n \approx 4$), has been confirmed observationally by many authors in the literature (for a full reference list, see MG05).

The Faber-Jackson relation was based on observations at the bright end of the luminosity function of elliptical galaxies, and a few authors have noted that the slope, $n$, is different for dwarf elliptical galaxies (dEs). Tonry (1981) suggested that $n \approx 3$, while Davies et al. (1983) and Held et al. (1992) found $n \approx 2.5$ for these faint objects. However, these authors only had about a dozen dwarf early-type galaxies in their samples and the $L$–$\sigma$ relation for these galaxies remained somewhat uncertain.

Using our sample of 72 homogeneous, statistically representative galaxies, combined with data from the literature, we can now firmly establish the $L$–$\sigma$ relation for dwarf early-type galaxies. In this proceeding, we present our sample of faint early-type galaxies in the center of the Coma cluster. We show that $L \propto \sigma^2$ which is consistent with De Rijcke et al. (2005), and we also derive ages, metallicities and abundance ratios for these galaxies. This result is a part of a larger study with the overall goal of characterizing dE/dS0 galaxies and other low luminosity early-type galaxies in terms of their kinematic properties, stellar populations and as a function of cluster environment.

## 2. DATA AND MEASUREMENTS

We observed early-type galaxies in two different environments in the Coma cluster: $20' \times 20'$ in the center of the cluster and another $45'$ diameter region just outside the cluster's virial core. (Note, we only discuss galaxies in the central part of the Coma cluster here). We used the HYDRA multi-fiber spectrograph on the 3.5-m WIYN telescope at the Kitt Peak National Observatory.

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Our sample consists of 69 'faint early-type' galaxies ($-15.8 \leq M_B \leq -20.5$), and 3 giant elliptical galaxies, gEs, ($M_B \leq -20.5$, from Graham & Guzmán 2003, hereafter GG03). In this dataset, 36 galaxies are dwarf early-type galaxies, with $M_B > -18$ (Ferguson & Binggeli 1994). Since we cannot determine morphology of these galaxies without resolved photometry, we refer to them as dEs/dS0s, assuming there is a mix of the two types in our sample.

The observed spectral range 4120–5600 Å was sampled at the instrumental resolution of FWHM=1.9 Å and a dispersion of $\sim 0.705$ Å pix$^{-1}$. With this instrumental setup we were able to measure velocity dispersions, $\sigma$, down to $\sim 30$ km s$^{-1}$ and some of the most prominent spectral features of early-type galaxies (H$\beta$, $Mg_2$, and different Fe-lines).

We reduced the spectra with the IRAF task 'dohydra', while we measured velocity dispersions and line strength indices with the REDUCEME software (Cardiel 1999). For uncertainty estimates, we used the boot-strapping method, which is included in the REDUCEME software.

## 3. FABER-JACKSON RELATION FOR DWARF E/S0 GALAXIES

We combine our Coma cluster sample with other data sets in the literature which have $\sigma$ measurements (Hudson et al. 2001; Moore et al. 2002; and the EFAR sample by Colless et al. 2001) and plot the $L$–$\sigma$ relation. The combined sample in Figure 1 consists of 167 galaxies out of which 143 are faint early-type galaxies.

The F-J relation clearly exhibits a change of slope in a way that the gE galaxies follow the traditional $L \propto \sigma^4$ (galaxies above the dotted line in Figure 1) and the fainter galaxies, including the dEs/dS0s, define a different relation $L \propto \sigma^2$. In fact, one can argue that giant elliptical galaxies, which follow the traditional F-J relation, are the exception and not the rule to the $L$–$\sigma^2$ relation which spans over 5 magnitudes.

We investigate what would cause this change of slope in the $L$–$\sigma$ relation. One possibility is 'contamination' by different morphological types. For this test we used B/T (bulge-to-total) ratios from Gutierréz et al. (2004) to distinguish between the different types. Although we find that $L$–$\sigma$ is steeper for galaxies with B/T = 1.0 than for galaxies with B/T < 0.5, the slope difference is still insignificant when compared to the change from $n \approx 4$ to $n \approx 2$. Furthermore, robust morphological classification is difficult without resolved photometry.

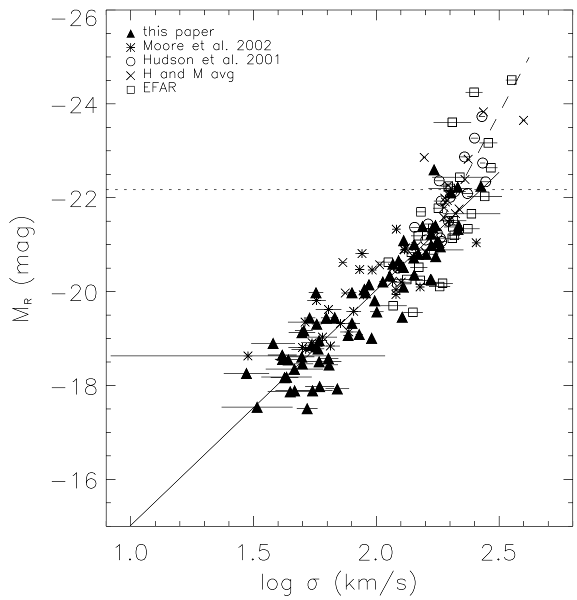


Fig. 1. The Faber-Jackson relation for Coma cluster galaxies. The *dotted* line corresponds to $M_B = -20.50$ mag (GG03) and separates gEs and all the other early-type galaxies. The *dashed* line is the traditional Faber-Jackson relation, $L \propto \sigma^4$, (Forbes & Ponman 1999), while the *solid* line, $L \propto \sigma^{2.01 \pm 0.36}$, is the least squares fit to all the faint early-type galaxies.

The possibility of rotation as the main driver for the departure of dE galaxies from the traditional F-J relation was already discussed by a few authors in the literature (Tonry 1981; Davies et al. 1983). However, at the time, no sufficient observations of rotational velocity nor $\sigma$ existed for dE galaxies. In MG05, we derive a relation which quantifies the amount of rotation dE/dS0 galaxies would need to have in order to follow the canonical F-J relation. We then compare this 'theoretical' curve with observations and conclude that rotation alone cannot explain the change of slope in the F-J relation for dE/dS0 galaxies.

So, how can we explain the differing $L$–$\sigma$ relations for gE and dE/dS0 galaxies? De Rijcke et al. (2005) find the slope, $n \approx 2$, consistent with the semi-analytical models that include quiescent star formation, post-merger starbursts, and gas-loss triggered by supernovae winds. In other words, the gravitational potentials of dwarf galaxies are not strong enough to retain the gases ejected by supernovae of their respected stars, while this is not the case for gE galaxies whose gravitational potentials are much stronger.

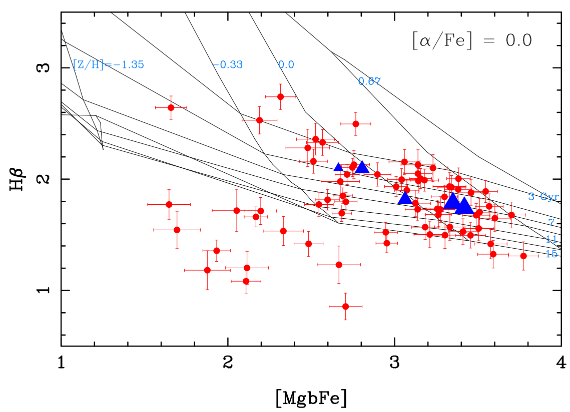


Fig. 2. Hβ vs. [Mg*b*Fe] plot overlayed with models from Thomas, Maraston, & Korn (2004). The filled circles are the faint early-type galaxies from our central Coma cluster sample. The *triangles* are index values when binned by velocity dispersion. The size of the triangles corresponds to the value of $\sigma$ i.e., larger triangles have larger velocity dispersion. The ages are displayed on the right hand side and are represented by the horizontal lines, while the metallicity values in units of solar metallicity are displayed next to their representative model lines (the vertical lines). Note the wide range of both ages and metallicities for this sample of galaxies.

## 4. STELLAR POPULATIONS: AGES, METALLICITIES AND ABUNDANCES

We also measured Lick/IDS indices and determined the ages, metallicities and [$\alpha$/Fe] ratios for our sample of faint early-type galaxies. Since $\alpha$ elements are produced in SN type II and the Fe-peak elements in SN type Ia, the [$\alpha$/Fe] ratio carries information on the formation time-scale of stellar populations.

In Figure 2 we show an age dependent index, Hβ, and a metallicity dependent index [Mg*b*Fe] overlayed with stellar population synthesis models from Thomas, Maraston, & Korn (2004). The circles are index measurements of our galaxies, while the large triangles represent the data binned by velocity dispersion. The faint early-type galaxies seem to have wide range in both age (2-15 Gyr) and in metallicity ($-1.2 < [Z/H] < 0.67$). On average, it also seems that the metallicity and age increase with $\sigma$ i.e., mass, for these galaxies.

In the left-hand corner of this figure, there are 13 galaxies which are not fit by the models. These galaxies have $\sigma$ between 40 and 60 km s$^{-1}$ and are all dE/dS0 galaxies. Out of 13, 6 of these were observed with HST and they are nucleated dE galaxies (GG03). Galaxies in this region, thus, may be consistent with the position of nucleated dwarfs as discussed by Rakos & Schombert (2004).

We also find that [$\alpha$/Fe] increases with $\sigma$ and that [$\alpha$/Fe] $\approx$ 0.0 for dwarf galaxies, while for the more massive galaxies we confirm the well known value of [$\alpha$/Fe] $\approx$ 0.3. This indicates that dE/dS0 galaxies had more gradual chemical enrichment and history than the more massive early-type galaxies.

## 5. SUMMARY AND CONCLUSIONS

We present spectroscopic observations of 72 early-type galaxies, out of which 36 are dEs/dS0s, in the central part of the Coma cluster. We find that the Faber-Jackson relation ($L \propto \sigma^4$) changes to $L \propto \sigma^2$ for low mass galaxies. This relation **cannot be explained by rotation**. However, this result is consistent with semi-analytical models including quiescent enrichment and gas-loss due to supernovae winds (De Rijcke et al. 2005).

We find that faint early-type galaxies have a wide range of ages $\sim$ 2–15 Gyr, and a wide range in metallicity from $-1.2$ to 0.67 solar metallicity. Age decreases, while the metallicity, and the [$\alpha$/Fe] ratio increase with velocity dispersion, i.e., mass. We also confirm predictions that dEs have had a more gradual chemical enrichment history than gEs.

These results are a part of a larger study which aims to characterize dE/dS0 galaxies in terms of their kinematic properties, stellar populations and cluster environment. Here we only presented results for galaxies in the central part of the Coma cluster.

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