

Nearby early-type galaxies with ionized gas. Characterization of the underlying stellar population

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We present a preliminary analysis of the sample of early type galaxies of Rampazzo et al. (2005), selected to build a data-set of spectral properties of well studied early-type galaxies showing emission lines. Because of the presence of emission lines, the sample is biased toward objects that might be expected to have ongoing and recent star formation. We have compared the line-strength indices presented in Rampazzo et al. (2005) with Simple Stellar Populations (SSPs) in order to characterize the underlying stellar population of the galaxies. We have derived ages, metallicities and $[\alpha/Fe]$ ratios. The positive trend of the σ -metallicity and $\sigma - [\alpha/Fe]$ relations is reproduced. The bulk of the galaxies span a range in metallicity from \sim solar to \sim twice solar and a range in $[\alpha/Fe]$ from ~ 0.2 to ~ 0.4 . Furthermore the comparison of the derived parameters at different galactocentric distances shows the presence of negative metallicity gradients from the center outwards.

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1. Introduction

Although Early-Type galaxies (Es) appear as a homogeneous class, characterized by well defined scaling relations like the Fundamental Plane, the color-magnitude relation and the Mg2- σ relation, much evidence suggests that a secondary episode of star formation has occurred during their evolutionary history. Simulations indicate that galaxy collisions, accretion and merging episodes are important factors in the evolution of galaxy shapes (see e.g. Barnes (1996); Schweizer (1996)) and can interfere with their passive evolution. This understanding of early-type galaxy formation has been enhanced by the study of interstellar matter. This component and its relevance in secular galactic evolution was widely neglected in early studies of early-type galaxies since they were for a long time considered to be essentially devoid of interstellar gas. In the last two decades, however, multi-wavelength observations have changed this picture and have detected the presence of a multi-phase Inter Stellar Medium (ISM). For what concerns the “warm” ionized component of the ISM, the main ionization mechanism, which does not seem to be powered by star formation, remains still uncertain. With the aim of improving the understanding of the nature of the ionized gas in early-type galaxies, Rampazzo et al. (2005) (hereafter R05) have started a study of a sample of Es showing emission lines in their spectra. The adopted strategy is to investigate the physical conditions of the ionized gas, the possible ionization mechanisms and the connection to the stellar population of the host galaxy.

2. Observed properties of the Sample

The R05 sample contains 50 early-type galaxies. The sample is selected from a compilation of nearby galaxies ($z < 5500 \text{ km s}^{-1}$) showing ISM traces in at least one of the following bands: IRAS 100 μm , X-ray, radio, HI and CO, and should be biased towards objects that might be expected to have ongoing and recent star formation because of the presence of emission lines. The emission should come from a combination of active galactic nuclei and star formation regions within the galaxies. The spectra, taken along the major axis, are provided at different concentric regions (apertures) at radii of 1.5", 2.5", 10", $r_e/10$, $r_e/8$, $r_e/4$ and $r_e/2$, and in four adjacent regions (gradients) at $0 \leq r \leq r_e/16$ ("nuclear"), $r_e/16 \leq r \leq r_e/8$, $r_e/8 \leq r \leq r_e/4$ and $r_e/4 \leq r \leq r_e/2$. For all the apertures and gradients R05 measured the 21 line-strength indices of the original Lick-IDS system using the redefined passbands of Trager et al. (1998) (TR98) plus the higher order Balmer lines introduced by Worthey & Ottaviani (1997) (WO97). The measured indices have been conformed to the Lick-IDS System following the procedure described in WO97. The correction procedure include correction for possible hydrogen emission, correction for velocity dispersion and transformation to the Lick system. For details on the observations and reduction procedure we refer to R05.

The presence of emission lines affects the measure of some line-strength indices. In particular, the H β index measure of the underlying stellar population could be contaminated by a significant infilling due to presence of the H β emission component. R05 have measured H β emissions in their sample following two different approaches: 1) measuring the [OIII] emission and deriving the H β emission through the relation $EW(H\beta_{em})/EW([OIII]\lambda 5007) = 0.7$ found by Gonzalez et al. (1993) for his sample of early-type galaxies; 2) measuring the H α emitted flux and deriving the H β emitted flux according to the relation $F_{H\beta} = 1/2.86 F_{H\alpha}$ (see e.g. Osterbrock (1989)). In Figure 1

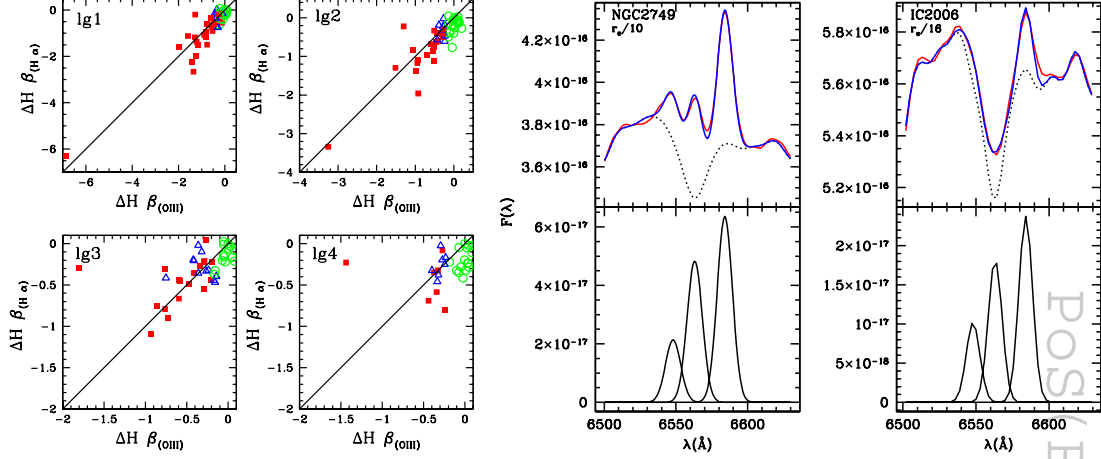


Figure 1: (left four panels) R05 sample: $H\beta$ emission estimate derived from $H\alpha$ against the emission derived from $[OIII]$ for the four gradients. The solid line is the one-to-one relation. Open green circles are for galaxies with $O[III]$ emission detected under 1σ level, blue triangles and red full squares between 1 and 2σ levels and above 2σ level respectively. (right four panels) Fitting of $N[II](\lambda 6548, 6584)$ and $H\alpha$ lines for two representative galaxies: one with $H\alpha$ in emission (NGC 2749) and the second with the $H\alpha$ infling (IC 2006). Lower panels show the residuals lines after the subtraction of the $H\alpha$ line of the template galaxy NGC 1426 (dotted lines in the upper panels).

it is shown the comparison between the two different $H\beta$ emission estimates computed in the four gradients.

3. Simple Stellar Population Indices

Following the procedure described in Bressan et al. (1996), to which we refer for details, we have derived line strength indices for SSPs. In brief all indices are constructed by means of a central band-pass and two pseudo-continuum band-passes on either side of the central band (see Worthey et al. (1994) (W94), TR98). The continuum flux is interpolated between the mid points of the pseudo-continuum band passes. The definition of the index in EW is

$$I_{EW} = (1 - F_R/F_C)\Delta\lambda \quad (3.1)$$

where F_R and F_C are the fluxes in the line and in the pseudocontinuum respectively and $\Delta\lambda$ is the width of the central band. The integrated indices for SSPs are calculated according to the following method. Given an isochrone in the HR diagram, we derive for each elementary bin $\Delta\log \frac{L}{L_\odot}$ and $\Delta\log T_{eff}$ the flux in the continuum F_C from libraries of stellar spectra and the index I from the fitting functions (FFs) of W94 and WO97. From F_C and I the flux in the central pass-band F_R is computed inverting (3.1). After having integrated F_C and F_R along the isochrone, the final SSP index I_{SSP} is computed from (3.1).

3.1 α – enhancement

Since the fitting functions are calibrated on Milky Way stars, they reflect, at solar metallicity, the solar element partitions. Nevertheless several studies have shown that elliptical galaxies are characterized by supersolar $[\alpha/Fe]$. Models accounting for α -enhanced chemical composition have been presented by Thomas et al. (2003, 2004) and Tantalo et al. (2004). The methods used are based on Response Functions (RFs), introduced for the first time by Tripicco & Bell (1995), that

describe the behavior of indices with elements variations. Similarly to Tantaló et al. (2004), we have derived RFs from model atmospheres computed with the code ATLAS9 for different Z/Z_{\odot} (1/50, 1/5, 3/5), T_{eff} (4250, 4500, 5000, 5750, 6250, 7000 K), $\log g$ (2, 4, 4.5, 5) and $[\alpha/Fe]$ (0.0 and 0.4), in order to construct SSP models with non-solar element partitions. For fixed T_{eff} , g and Z , and varying $[\alpha/Fe]$ from 0 to 0.4, the fractional variation of the i -th index is:

$$R_{i,0.4} = \frac{I_{(i,[\alpha/Fe]=0.4)} - I_{(i,[\alpha/Fe]=0)}}{I_{(i,[\alpha/Fe]=0)}} \quad (3.2)$$

where $I_{(i,[\alpha/Fe]=0.4)}$ and $I_{(i,[\alpha/Fe]=0)}$ are the indices computed on the synthetic stellar spectra for solar-scaled and α -enhanced compositions respectively. At metallicities higher than $Z/Z_{\odot} = 3/5$, the responses have been derived through linear extrapolation. At this point we computed α -enhanced SSPs with $[\alpha/Fe] = 0.4$ in the following way. For each elementary bin ($\Delta \log \frac{L}{L_{\odot}}$, $\Delta \log T_{eff}$) along the isochrone, we applied a correction ΔI to the index I derived from the FFs. The i -th index corrected for the effect of α -enhancement is:

$$I_{i,0.4} = I_{i,0} + \Delta I_{i,0.4} = I_{i,0} + R_{(i,0.4,T,g,Z)} \times I_{i,0} \quad (3.3)$$

where $I_{i,0}$ is the value from the FFs and $R_{i,0.4,T,g,Z}$ is obtained by linearly interpolating the $R_{i,0.4}$ values of (3.2) at the gravity, temperature and metallicity of the bin. Once computed the corrected index I , the procedure to obtain the final SSP index is the same as described at the beginning of the section for solar-scaled models. More details can be found in Annibali et al. (2005) in prep.

4. Results

We have analyzed a sample of early-type galaxies showing emission lines in their spectra (R05) by means of new SSP indices that account also for the enhancement of the α -elements. It is known that narrow band indices constitute a powerful tool to disentangle age, metallicity and enhancement effects (see e.g. Worthey (1994), WO97). We have devised a simple but robust algorithm to derive these parameters from the analysis of the Mgb, [MgFe] and H β (or H γ) indices (Annibali et al. (2005) in prep.). The results of this preliminary investigation are shown in Figure 2. From top to bottom we plot the derived ages, metallicities and $[\alpha/Fe]$ ratios as function of central velocity dispersion σ_0 . Black dots, red squares and green triangles correspond respectively to the nuclear region ($r \leq r_e/16$), to $r_e/16 \leq r \leq r_e/8$ and to $r_e/8 \leq r \leq r_e/4$. Same colors are used for lines which indicate the fits to the data. The positive trend of the σ - Z and σ - $[\alpha/Fe]$ relations of early-type galaxies is reproduced for our sample. The galaxies span a range in metallicity from \sim solar ($Z \sim 0.02$) to \sim twice solar. The $[\alpha/Fe]$ ratios are supersolar and go from ~ 0.2 to ~ 0.4 from the smallest to the largest systems. The shift between the metallicity relations for the plotted regions indicates negative Z gradients from the center outwards. The broad range of ages derived from this analysis is at variance with the quite tight relations obtained for the global metallicity and α -enhancement. This could suggest that the reliability of the whole process of age determination by means of Hydrogen indices (possibly affected by emission contamination or by α -enhancement) is still far from being satisfactory. Indeed there are several data with too high ages. However the spectra are of high quality and the adopted lines are not heavily contaminated by emission, while effects of enhancement should include a bias instead of dispersion. We thus conclude that this is an evidence that the formation process of the bulk of the galaxy follows a well defined path (and timescale), and that the broad range in age is caused by subsequent "rejuvenation" episodes

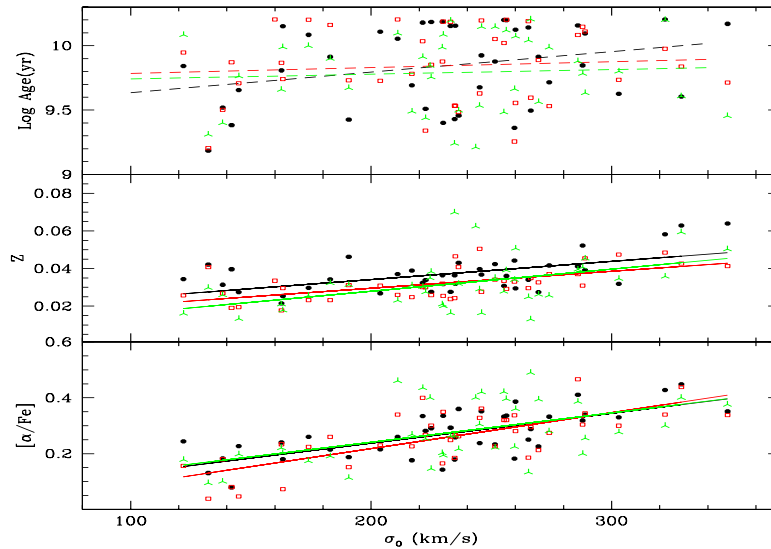


Figure 2: From top to bottom we plot the derived ages, Z and $[\alpha/Fe]$ as function of central velocity dispersion σ_0 . Black dots, red squares and green triangles correspond to the regions $0 \leq r \leq r_e/16$, $r_e/16 \leq r \leq r_e/8$ and $r_e/8 \leq r \leq r_e/4$. Same colors are used for lines which indicate the fits to the data.

involving only a tiny fraction of the galaxy mass (e.g. Bressan et al. (1996)). Thus the "indirect" signature left on the chemical enrichment path may be a more robust estimator of the formation timescales than the "direct" estimate based on H lines, marking the secular evolution of galaxies.

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