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Spectral fitting of SDSS passive galaxies with α-enhanced single stellar populations

Jean Michel Gomes[1] **and Paula Coelho**[2]

[1]Centro de Astrofísica, Universidade do Porto, Rua das Estrelas, 4150-762 Porto, Portugal
[2]Núcleo de Astrofísica Teórica, Universidade Cruzeiro do Sul,
R. Galvão Bueno 868, Liberdade, 01506-000, São Paulo, Brasil

email: jean@astro.up.pt

Abstract. The power of population synthesis as a mean to estimate the star-formation and chemical histories of galaxies has been well established in the last decade. The major developments were due to a huge avalanche of methods, codes and high-quality galaxy data sets, such as the 2dF, 6dF and SDSS surveys. Semi-empirical spectral synthesis allows for the decomposition of a galaxy spectrum in terms of linear combinations of base elements, i.e. Single Stellar Populations (SSPs) of different ages and metallicities, which are computed from evolutionary synthesis codes (BPASS, GALEV, GALAXEV, MILES, PÉGASE, etc...), containing distinct ingredients like: stellar library, evolutionary tracks, metallicities and Initial Mass Function. In general, they have solar-scaled relative abundances, but this is about to change with the unfolding of new α-enhanced SSP models (Coelho *et al.* 2007). However, passive galaxies have some spectral features corresponding to "enhanced-ratios" ([E/Fe]), like O, Ne, Si, S, Mg, Na, C and N over Fe that are not well modeled using solar-scaled SSPs (Trager *et al.* 2000), leading to residuals between observed and modeled spectra, which also correlate with the velocity dispersion ($\sigma_\star$) and stellar mass ($M_\star$): Massive galaxies exhibit a larger [E/Fe] discrepancy than less massive ones. This result can be interpreted as a signature of distinct previous star-formation efficiencies in passive galaxies, leading to distinctive ratios of type Ia and II SNe.

We have applied the STARLIGHT spectral synthesis code (Cid Fernandes *et al.* 2005) to a sample of $\sim$ 1000 passive galaxies from the SDSS DR7 with a S/N at the continuum $\geqslant$ 20 to investigate possible enhancements in the derived [E/Fe] ratios. Three sets of SSPs based on Coelho *et al.* (2007) theoretical models and Walcher *et al.* (2009) prescriptions were computed for [α/Fe]=0.0, [α/Fe]=0.2 and [α/Fe]=0.4. Our aim is to determine: (1) the quality of the fits, (2) the mean stellar age and metallicity distributions, and (3) the star-formation history of passive galaxies.

Using [α/Fe]=0.0 SSPs, we have identified the strongest residuals in the CN (4142.125 − 4177.125 Å), Na D (5876.875 − 5909.375 Å) and Mg (5069.125 − 5196.625 Å) bands. On the other hand, [α/Fe]=0.2 and [α/Fe]=0.4 SSP models tend to reproduce better the Mg band, as compared to solar-scaled SSPs ([α/Fe]=0.0). The residuals are decreased by 1.77 Å ([α/Fe]=0.2) and 2.92 Å ([α/Fe]=0.4). However, as expected, these α–enhanced models lead to worse fits for the CN and Na D bands. These residuals may even reach up to 2.08 Å (CN) and 4.20 Å (Na D), using [α/Fe]=0.2 SSPs and 2.28 Å (CN) and 7.94 Å (Na D), using [α/Fe]=0.4 SSPs.

In terms of mean stellar ages and metallicities, we obtain non-negligible biases in both quantities when we compare the solar-scaled SSPs with α-enhanced ones, which tend to have mean stellar ages by 0.12 dex ([α/Fe]=0.2) and 0.14 dex ([α/Fe]=0.4) higher and mean stellar metallicities by 0.1 dex ([α/Fe]=0.2) and 0.2 dex ([α/Fe]=0.4) lower.

Keywords. galaxies: evolution, galaxies: formation, galaxies: stellar content

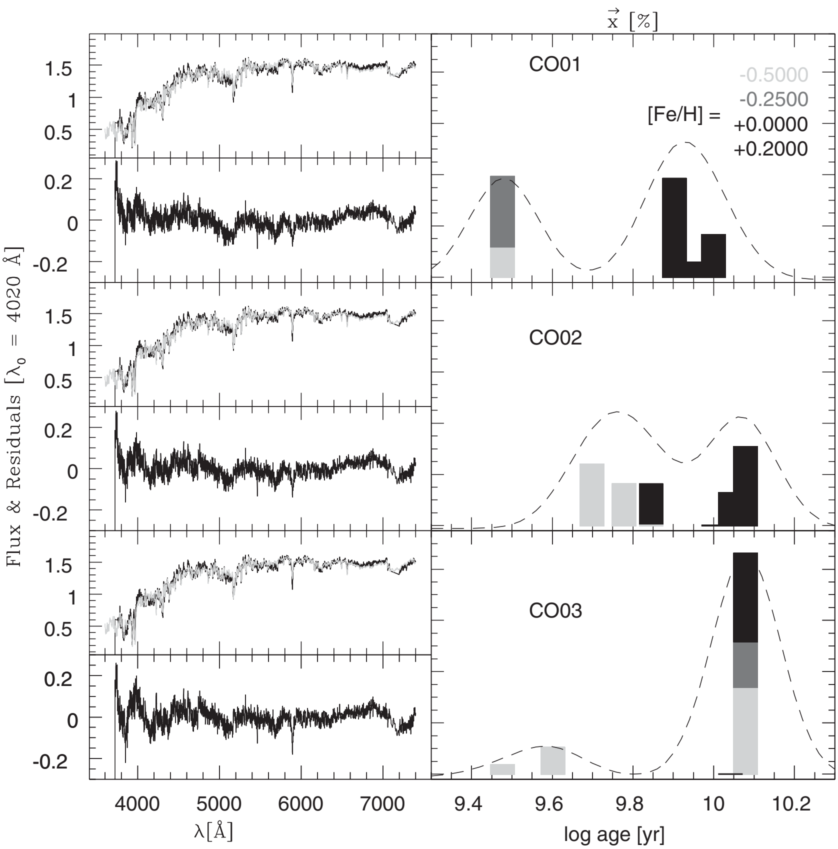

Figure 1. Spectral fit to the SDSS passive galaxy J100329.97+372734.6 using three different sets of SSPs with the following α-enhancement ratios: CO01 ([α/Fe]=0.0), CO02 ([α/Fe]=0.2) and CO03 ([α/Fe]=0.4), spanning 10 distinct ages from 3 to 12 Gyr and 4 different metallicities ([Fe/H]=-0.50, -0.25, +0.00 & +0.20). Left panels: Observed (black) and modeled (grey) spectrum with the corresponding residuals for CO01, CO02 and CO03 (from top to bottom). The fits are equally good in terms of their reduced χ^2. The corresponding Star Formation Histories (SFHs) are displayed in the right panels. The smoothed SFHs (re-scaled) are shown (black dashed line) with a Gaussian FWHM of 0.2 dex, further illustrating the tendency for higher mean stellar ages with increasing [α/Fe] SSP abundances.

1. Sample of passive galaxies

We have applied STARLIGHT to $\sim$ 1000 passive galaxies, lacking nebular emission, from the SDSS DR7, using three different libraries with distinct α-enhanced SSP models: CO01 ([α/Fe]=0.0), CO02 ([α/Fe]=0.2) and CO03 ([α/Fe]=0.4), spanning a range in ages from 3 to 12 Gyr, and 4 metallicities ([Fe/H]=-0.50, -0.25, +0.00 & +0.20). In Fig. 1 we show an example for the spectral fits and the corresponding Star Formation Histories (SFH) to the SDSS passive galaxy J100329.97+372734.6 using CO01, CO02 and CO03 SSPs.

2. Mean stellar age and metallicity

Fig. 2 shows the degeneracy diagram of age versus metallicity, showing a clear trend for a higher mean stellar age and a lower mean stellar metallicity with increasing α-element enhancement in model SSPs.

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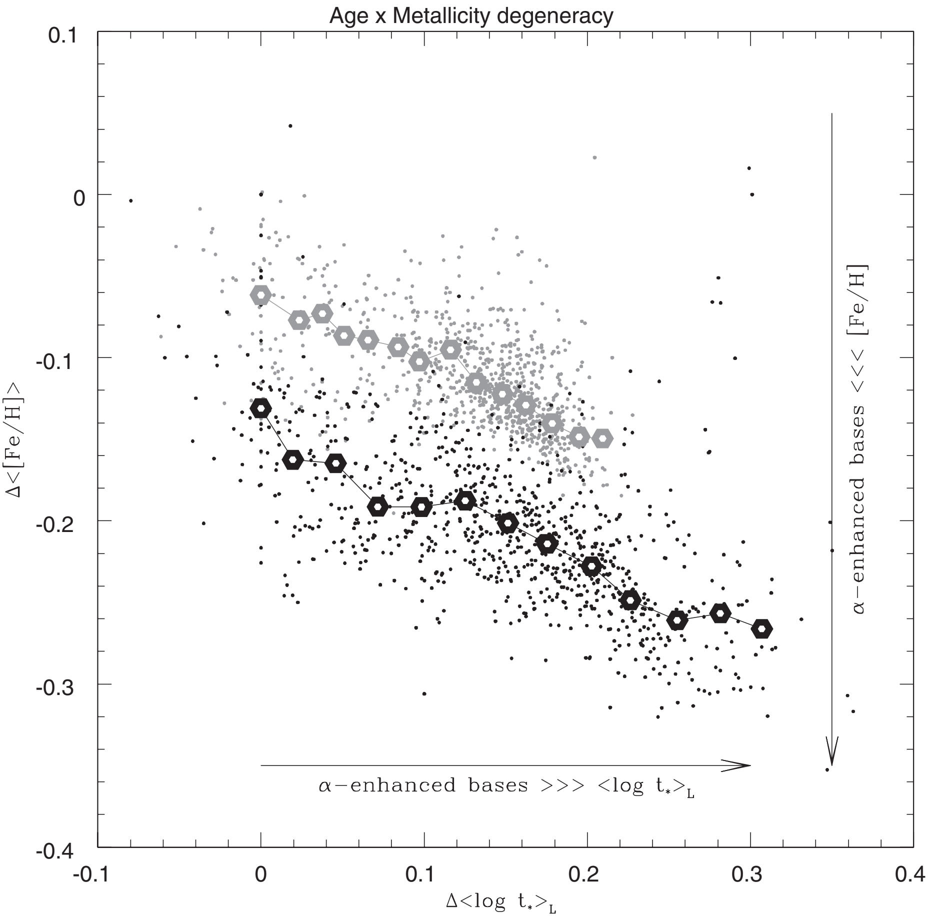

Figure 2. The degeneracy diagram of Age vs Metallicity. We show the difference in mean stellar age and mean stellar metallicity for CO02 [α/Fe=0.2] (grey) / CO03 [α/Fe=0.3] (black) compared to CO01 [α/Fe=0.0]. The hexagons correspond to the median values: top for CO02–CO01 and bottom for CO03–CO01. A clear trend for a higher mean stellar age and a lower mean stellar metallicity with increasing α-element enhancement is apparent.

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