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A morphological view of the Green Valley

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Abstract. In this work we study the population of the galaxies that lie in the transition region between the blue cloud and the red sequence, known as the Green Valley, and investigate which physical processes are responsible for quenching star formation in these objects. In particular, we measure the timescale in which this transition occurs and how it relates to the morphological type of the galaxies, in an attempt to determine whether the morphological transformation is associated with more violent processes. To do this, we use a sample of Sloan Digital Sky Survey (SDSS) galaxies combined with the morphological analysis performed by the Galaxy Zoo Project. Our methodology consists of analyzing spectra in order to measure a combination of photometric and spectroscopic indices — more specifically the 4000 Angstrom break and the H-delta absorption — and evaluate the age of the stellar population and recent star formation activity. Preliminary results indicate that, effectively, elliptical galaxies, which probably have undergone processes of interactions and merges, are quenching their star formation more rapidly. In the future, we will determine how this distinction depends on cosmological time, by comparing results from different redshifts.

Resumo. Nesse trabalho nós estudamos a população de galáxias que se encontra na região de transição entre a nuvem azul e a sequência vermelha, conhecida como vale verde, e investigamos quais processos físicos são responsáveis pela cessação de formação estelar destes objetos. Em particular, medimos a escala de tempo na qual essa transição ocorre e como ela está relacionada com o tipo morfológico das galáxias com o objetivo de tentar determinar se a transformação morfológica está associada a processos mais violentos. Para isso, utilizamos uma amostra de galáxias do Sloan Digital Sky Survey (SDSS) em conjunto com a análise morfológica realizada pelo Galaxy Zoo Project. Nossa metodologia consiste em analisar espectros para medir uma combinação de índices fotométricos e espectroscópicos - mais especificamente a ruptura de 4000 angstrom e a absorção de Hδ - e avaliar a idade da população estelar e a recente atividade de formação de estrelas. Resultados preliminares indicam que, efetivamente, galáxias elípticas, que provavelmente sofreram processos de interação e colisão, estão cessando sua formação estelar mais rapidamente. No futuro, determinaremos se esta diferença depende da época cosmológica, comparando resultados de redshifts diferentes.

Keywords. galaxies: evolution

1. Introduction

It has long been known that the bimodality in the color-magnitude diagram (CMD) separates two populations of galaxies (Figure 1): the blue cloud and the red sequence. The population of the former is mostly young, gas-rich, and with a high star formation rate (SFR), while the latter is characterized by a population of passive old gas-poor galaxies. In this work, we study the population of the galaxies that lie in the transition region between, known as the green valley (e.g. Martin et al., 2007; Wyder et al., 2007; Gonçalves et al. 2012) and investigate which physical processes are responsible for quenching star formation in these objects. More specifically, we ask: are quenching timescales related to galaxy morphology?

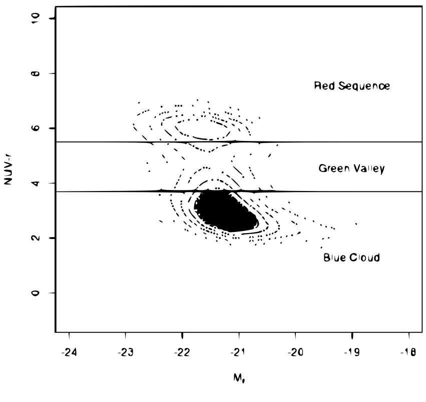

Figure 1. The color-magnitude diagram for a sample of approximately 59.000 galaxies, classified or as spirals or as ellipticals with 80% of confidence by the Galaxy Zoo Project. The lines indicate the empirical region of the green-valley for this work.

2. Metodology

We use a sample of Sloan Digital Sky Survey galaxies (Alam et al. 2015) of the local universe combined with the analysis performed by the Galaxy Zoo Project with 80% confidence of the morphological classification (Lintott et al. 2011), as can be seen in Figure 2. Our methodology consists of analyzing spectra in order to measure a combination of photometric and spectroscopic indices — more specifically the 4000 Angstrom break and the Hδ absorption — and evaluate the age of the stellar population and recent star formation activity (Martin et al., 2007, Gonçalves et al. 2012, Nogueira-Cavalcante et al, 2017).

2.1. Star Formation Histories

We use the same simplifying hypotheses used by Gonçalves et al. 2012 and Martin et al., 2007 (Figure 3a):

1. Galaxies only move towards redder colors;
2. $\mathrm{SFR}(t) = \begin{cases} \mathrm{SFR}(t=0), & \text{if } t < t_0 \\ \mathrm{SFR}(t=0)e^{-\gamma t}, & \text{if } t > t_0 \end{cases}$

Kauffmann et al. (2003) showed that the $D_n(4000)$ and Hδ,A indices trace a well-defined region in a diagram, where the ex-

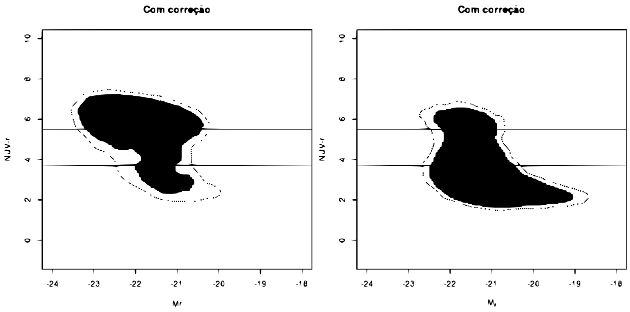

Figure 2. Left: The color-magnitude diagram for the sub-sample of ellipticals, with approximately 14.000 galaxies; Right: The color-magnitude diagram for the sub-sample of spirals, with approximately 45.000 galaxies.

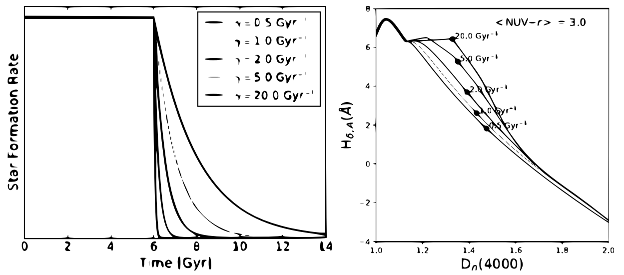

Figure 3. Left: Star formation rate as a function of time for five different SFHs with exponential decay. Hδ,A ×; Right: $D_n(4000)$ planes the same five SFH models. The black dots represent the Hδ,A and $D_n(4000)$ values for a given SFH model and NUV–r colour. Plots from Nogueira-Cavalcante et al. (2007)

act position of a galaxy depends strongly of its star formation history, as can be seen in the Figure 3b.

2.2. Spectral Parameters

We use the same definition used by Gonçalves et al. (2012) for the two indices (figura 4):

- $D_n(4000)$ is defined as the ratioof the average flux density Fν in the bands 3850–3950 and 4000–4100 Å, following the definition of Balogh et al. (1999);
- Hδ,A is the absorption equivalent width; the continuum is defined by fitting a straight line through the average flux density between 4041.60 and 4079.75 Å, on one end, and 4128.50 and 4161.00 Å, on the other:

$$H\delta, A = \sum_{\lambda=4083.5}^{4122.25} \left(1 - \frac{F_\nu}{F_{\nu,cont}}\right) \quad (1)$$

3. What is next

The next steps for our work will be the analysis of our sample at the plane Hδ,A × $D_n(4000)$ and compare with the models for different values for γ (as shown in the Figure 3). For this, we need to separate our sample in narrower color ranges (Figure 5).

Next, will be to determine gamma values according to morphology, in order to compare our results with previous works that measured quenching time-scaltes for local redshift (Schawinskiet al., 2014) and for higher redshifts (Nogueira-Cavalcante et al., 2017). Our final goal is to understand what processes may cause faster or slower quenching in each.

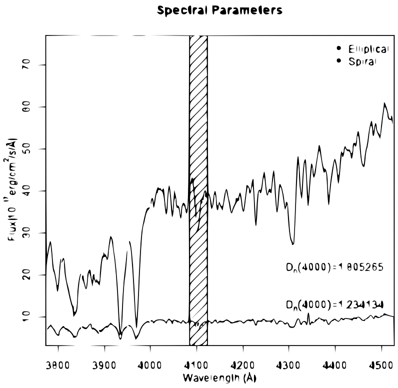

Figure 4. Two example spectra of galaxies in the sample, illustrating the determination of the aforementioned spectral indices: The gray-shaded areas indicates the bandpasses over which the Dn(4000) index is measured and the hatched area shows the Hδ,A bandpass

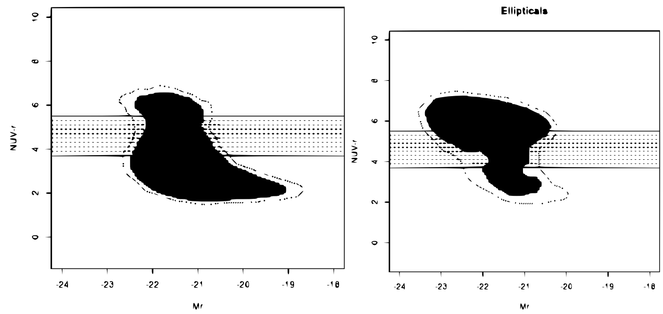

Figure 5. Green valley according to morfology: sample of ellipticals at left, and sample of spirals at right. The dashed lines indicate the bands of colours.

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