Analysis of Lick Indices in early-type galaxies in the Virgo cluster

M.C. Scalia[1,2], A. Smith Castelli[1,2] & F. Faifer[1,2]

[1] *Instituto de Astrofísica de La Plata, CONICET–UNLP, Argentina*
[2] *Facultad de Ciencias Astronómicas y geofísicas, UNLP, Argentina*

Contact / mcscalia@fcaglp.unlp.edu.ar

Resumen / Los procesos involucrados en la formación y evolución de galaxias de tipo temprano están poco entendidos. El análisis de datos espectroscópicos homogéneos de una muestra de galaxias cercanas podría proporcionar pistas sobre dichos procesos, a través de la información relacionada con sus edades y contenido químico. En este trabajo presentamos un análisis preliminar del comportamiento de los índices de Lick en una muestra de 148 galaxias de tipo temprano, ubicadas en el Cúmulo de Virgo. Utilizamos datos espectroscópicos obtenidos del *Sloan Digital Sky Survey* (SDSS) DR14. A partir de este análisis, buscamos obtener edades e información química de estas galaxias que nos ayuden a trazar su trayectoria evolutiva. Este trabajo forma parte de la etapa inicial de la Tesis Doctoral de María Cecilia Scalia, desarrollada en la Facultad de Ciencias Astronómicas y Geofísicas de la Universidad Nacional de La Plata (Argentina)

Abstract / The processes involved in the formation and evolution of early-type galaxies are poorly understood. The analysis of homogeneous spectroscopic data of a sample of nearby galaxies might provide clues about such processes, via the information related to their ages and chemical content. In this work, we present a preliminary analysis of Lick Indices of a sample of 148 early-type galaxies located in the Virgo Cluster. We use spectroscopic data obtained from the Sloan Digital Sky Survey (SDSS) DR14. From this analysis we aim at obtaining age and chemical information of these galaxies that help us to trace their evolutionary path. This work is part of the ongoing doctoral studies of María Cecilia Scalia, developed at Facultad de Ciencias Astronómicas y Geofísicas of Universidad Nacional de La Plata (Argentina)

Keywords / Galaxies: abundances, Galaxies: clusters: individual: Virgo, Galaxies: elliptical and lenticular, cD

1. Introduction

The Virgo Cluster is the largest and extremely rich cluster in the neighborhood of the Local Group (Binggeli et al., 1985; Kim et al., 2014). For this reason, it offers a good opportunity to inquire into diverse properties. Early-type galaxies are good tracers of the design of the structures of the clusters and follow a color-magnitude relation (CMR) in which giant galaxies are redder than dwarfs (Bower et al., 1992; Smith Castelli et al., 2013; Roediger et al., 2017). Because of these characteristics, the exploration of age and chemical composition proves useful to find clues about the processes involved in the formation and evolution of this kind of galaxies. We will explore the behavior of Lick indices in a sample of early-type galaxies of the Virgo Cluster. Our aim is to determine if these indices can help to trace the age and chemical properties of the different substructures within this cluster.

2. The Virgo cluster

Following the works of Binggeli et al. (1987), hereafter B87, Davies et al. (2014), hereafter D14, review the current knowledge about Virgo sub-structures (see Fig. 1):

- *Sub-cluster A:* galaxies in this area are around but not exactly centered on NGC 4486 and have radial velocities of about 1300 km s^{-1}. B87 describes it as a rich sub-cluster in early-type galaxies and located at ∼17 Mpc (Gavazzi et al., 1999).
- *Sub-cluster B:* galaxies in this region are not exactly centered on M49, have radial velocities of about 1000 km s^{-1} and they are at ∼23 Mpc (Gavazzi et al., 1999). B87 describes this sub-cluster as rich in late-type galaxies and place it as falling into sub-cluster A from behind. D14 found no difference in the morphological mix of both sub-clusters.
- *W cloud:* galaxies here have a greater velocity (∼2200 km s^{-1}) than the sub-clusters. B87 states that W cloud is more distant than the sub-clusters and it is falling into them.
- *M cloud:* galaxies in this region are similar in distance and kinematic to those in the W cloud.
- *Southern extension:* it appears as a filamentary structure at the south of the cluster. Galaxies in this area are at about the same mean distance as the sub-clusters A and B, and B87 states that they are falling into these sub-clusters.

The W and M clouds are dominated by late-type galaxies, whereas the Southern extension lacks these galaxies (Kim et al., 2014) .

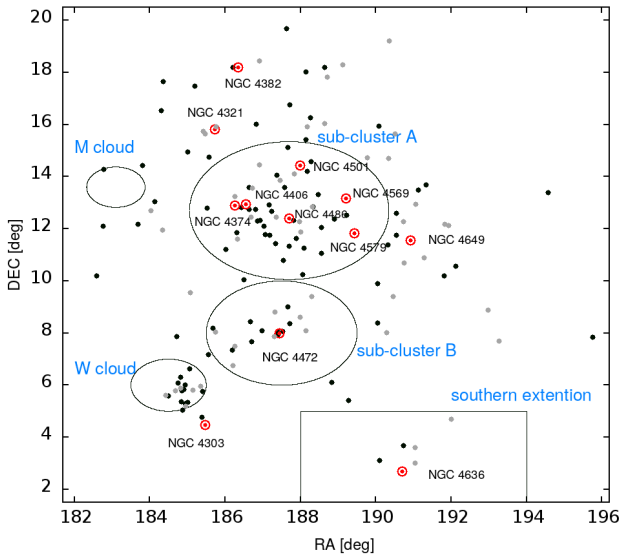

Figure 1: The projected spacial distribution of our sample. The black dots shows galaxies with S/N>20 and gray dots, those with 10<S/N<20. As a reference, we also add the brightest galaxies of Virgo (red dots). Black solid lines delineate the sub-structures identified in Virgo (B87).

3. The sample

The sample is composed of 125 early-type galaxies of the Virgo Cluster Catalogue (VCC, Binggeli et al., 1985) and 23 of the Extended Virgo Cluster Catalog (EVCC, Kim et al., 2014) that were not previously included in the VCC. They were selected because their spectra, obtained from the SDSS DR14, do not show perceptible emission lines and display a median signal-to-noise ratio S/N >10 (per Å). The spectrograph of SDSS uses optical fibers with a diameter of 3". Each fiber covers an equivalent physical region of ∼0.26 kpc diameter, considering the distance of 16.5 Mpc to the Virgo Cluster (Mei et al., 2007). This is the very central region of the galaxies.

4. The Lick indices

The Lick system (Worthey et al., 1994; Worthey & Ottaviani, 1997) defines absorption-line indices that can be used to derive the age and metallicity of stellar systems from low resolution spectra (∼9 Å), by comparing these indices with single stellar population models. In this work, these 25 indices were calculated using the LICK_EW code which is provided as part of the EZ_AGES package (Graves & Schiavon, 2008). The routine calculates errors of the indices following the equations given by Cardiel et al. (1998), and using the error spectra given by SDSS. The strength of absorption features in the spectra is measured in a bandpass centered on the feature of interest, flanked to the blue and red wavelengths by "pseudo-continuum" bandpasses. The average flux (in wavelength and magnitude units) is found for the flanking pseudo-continua, and a straight line is drawn between the centers of the pseudo-continua. The index is measured by integrating the ratio of the feature/continuum flux over the feature bandpass. We have calibrated these indices onto the commonly used Lick/IDS system, following the measurements obtained by Carson & Nichol (2010). In the near future, we will compare the values of the indices with those obtained from Simple Stellar Population (SSP) models. However, as a first step, it is interesting to explore their own intrinsic errors, if they trace structures within Virgo and if they can help to set, for example, the color scatter within the color-magnitude relation.

5. Results and future work

We compared the relative error of Lick indices with the S/N ratio in the spectroscopic data. Fig. 2 shows the sample of 148 galaxies with two indices: Hβ and Mgb. This is an important step before comparing the indices with models, to check how errors of absorption features translate into uncertainties in the derived mean age and metallicity of an old stellar population. The projected spacial distribution of our sample can be seen in Fig. 3, where the color is coded according to the index values, and shows the total variation of each index within the sample. There, triangles indicate galaxies with spectra with S/N<20. It can be seen how both indices seem to trace some of the sub-structures of the Virgo Cluster like, for example, the W cloud. The CMR defined by our sample is shown in Fig. 4. As a reference, we also show the Virgo sample of Chen et al. (2010) with black points. Colored points describe how Hβ and Mgb vary along the CMR. From this work in progress, we aim at obtaining the age, metallicity and α-enhancement ratio of these galaxies, which will help us trace their evolutionary path. To determine this parameters, we will compare several observed Lick indices with simple stellar populations models, that have a variable [α/Fe] abundance ratio (Thomas et al., 2003).

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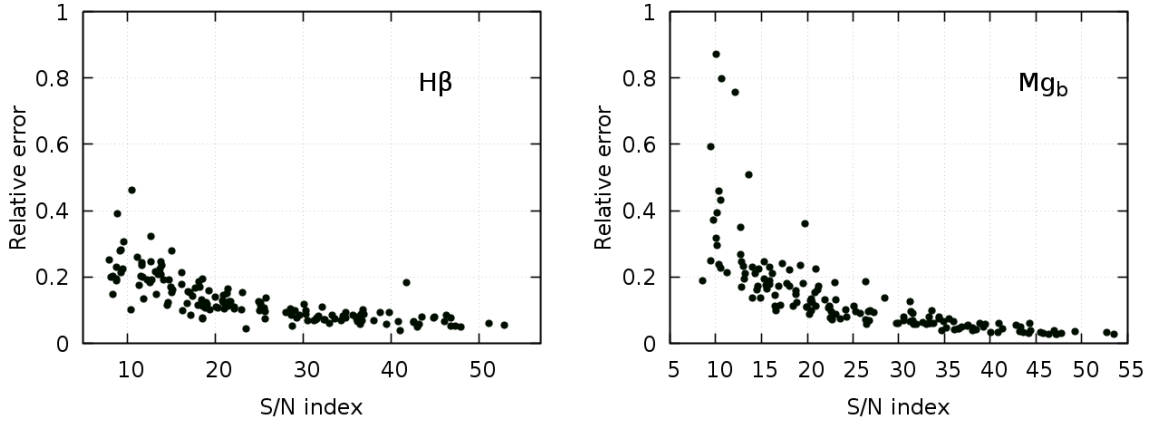

Figure 2: The relative error of Lick indices compared with the S/N ratio in the spectroscopic data of our sample.

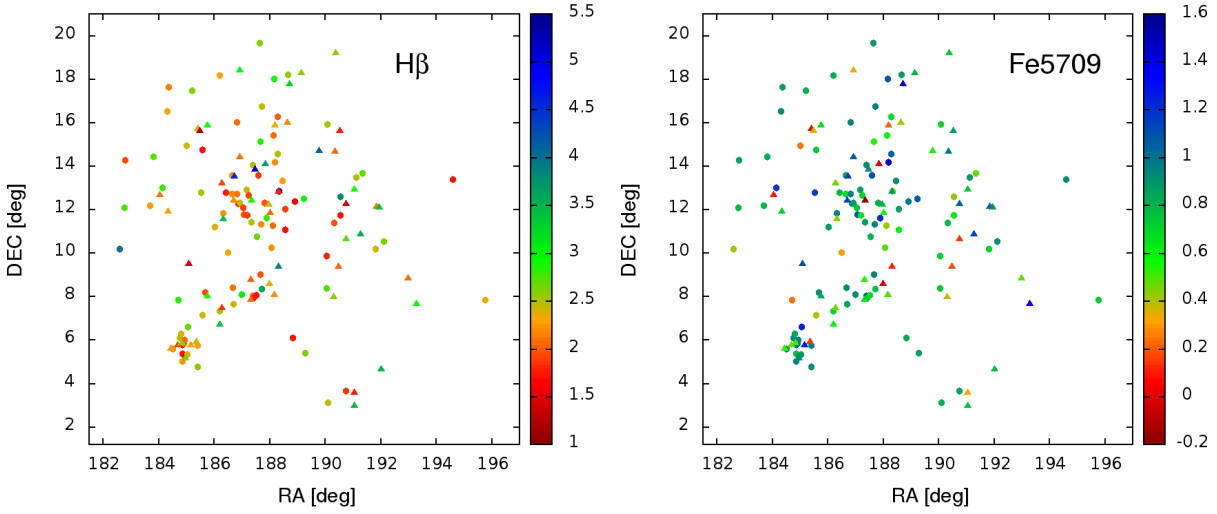

Figure 3: Projected spacial distribution of our sample, color coded according to the values of the Hβ and Mgb indices. The triangles indicate galaxies with spectra with S/N<20.

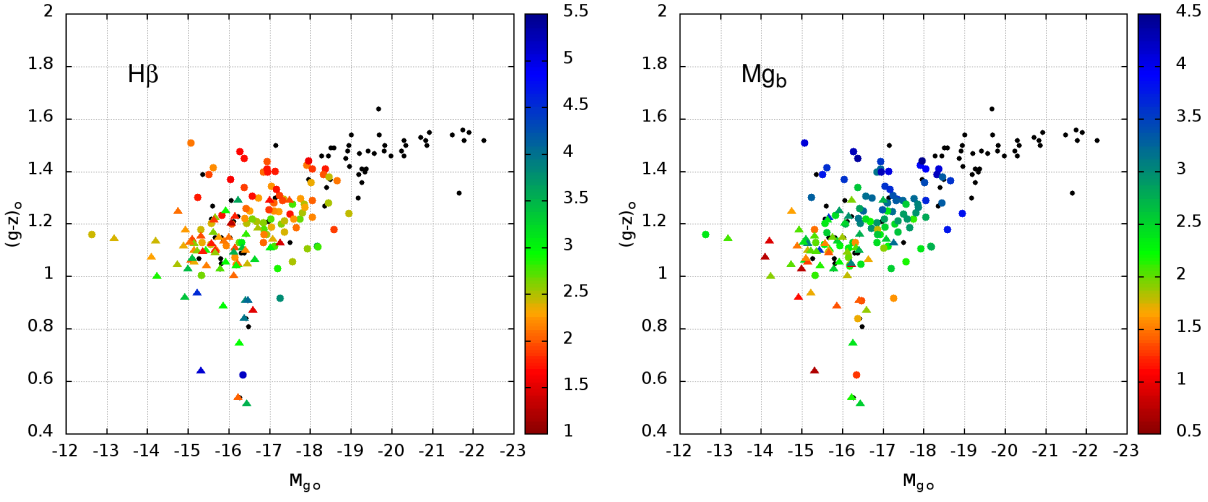

Figure 4: The color-magnitude relation (CMR) defined by our sample and the sample of Chen et al. (2010) (black points). Colored points show how Hβ and Mgb vary along the CMR. Triangles indicate galaxies with spectra that have S/N<20.