Stellar population synthesis

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ABSTRACT

We present a stellar population synthesis analysis of ten galaxies selected from the SDSS (Sloan Digital Sky Survey). We combined in different ways ten stellar spectra taken from the same archive in order to get integrated spectra similar to those of the galaxies. Finally, we tried to give an approximate morphological classification of our galaxies.

I. INTRODUCTION

Galaxy morphology is linked to many of the global characteristics of galaxies (e.g. stellar population, angular momentum, star formation rate, gas content). Referring to the Hubble sequence, we could notice, for instance, that ellipticals and spirals show considerable differences in their stellar population: the first ones are made up only of old stars, while the second ones present both a young and an old stellar population.
The spectroscopic characteristics of a galaxy are obviously due to the spectroscopic characteristics of the stars it is made up of, therefore the spectrum of a galaxy can be seen as the integrated spectrum of all the spectra of its stars. In this sense the stellar population synthesis consists in reproducing the integrated spectrum of a galaxy with a linear combination of individual stellar spectra of various types, in order to get an approximate idea of the composition of the galaxy.
Since the 1970's several stellar population synthesis models have been employed (see the "evolutionary population synthesis technique") and, even though modern models still suffer from serious limitations and intrinsic uncertainties, important progresses have been made.

II. OBSERVATIONAL DATA

We selected ten main sequence stars belonging to different spectral classes and ten galaxies at low redshift. The images we analyzed were taken from the Sloan Digital Sky Survey (SDSS) archives. We selected hot, intermediate and cold stars in order to make a comparison between the spectrum of each galaxy and the spectrum resulting from a proportioned combination of the various spectra of the stars. Coordinates, λ_{max} of the fitted black-body spectrum (Wien's law) and spectral type of the stars are reported in Tab.1, while coordinates and redshifts of the galaxies are reported in Tab.2.

Object	RA (deg)	Dec (deg)	λ_{max}	type
SDSS J002556.90-093231.1	6.48711	-9.54199	3857	A
SDSS J125417.89+003735.0	193.5746	0.62641	4047	A
SDSS J161138.47+523820.2	242.9103	52.63895	5581	F
SDSS J032731.34-063158.6	51.88061	6.53295	5579	F
SDSS J133116.70+020833.4	202.8196	2.14265	5580	F
SDSS J171710.76+585729.1	259.2949	58.95809	7605	K
SDSS J012647.06+141635.8	21.69614	14.27665	4038	A
SDSS J155335.88+001534.9	238.3995	0.25971	4796	F
SDSS J205029.53-052602.0	312.6231	-5.43391	5579	K
SDSS J205326.86-055301.2	313.3818	-5.88354	4897	F

Tab.1: Coordinates, λ_{max} and spectral type of the selectedstars.

Object	RA	Dec	Z
SDSS J105143.92+035951.9	162.93301	3.99777	0.0171
SDSS J151713.03+552640.4	229.30423	55.44444	0.0269
SDSS J113515.94+013819.3	173.8164	1.6387	0.0254
SDSS J214554.67+114041.8	326.4778	11.6783	0.0234
SDSS J140733.50+071040.3	211.88961	7.17786	0.0238
SDSS J111243.98+353356.8	168.18327	35.5658	0.0791
SDSS J150758.49+102053.6	226.99373	10.34822	0.0789
SDSS J112642.28-12732.3	173.74778	0.41924	0.0002
SDSS J141026.83-04956.5	212.6118	-0.83238	0.0255
SDSS J083737.87+441501.4	129.40784	44.25039	0.0269

Tab.2: Coordinates and redshifts of the galaxies.

In Fig.1 it is shown the spectrum of a star while in Fig.2 there is the picture of the spectrum of a galaxy.

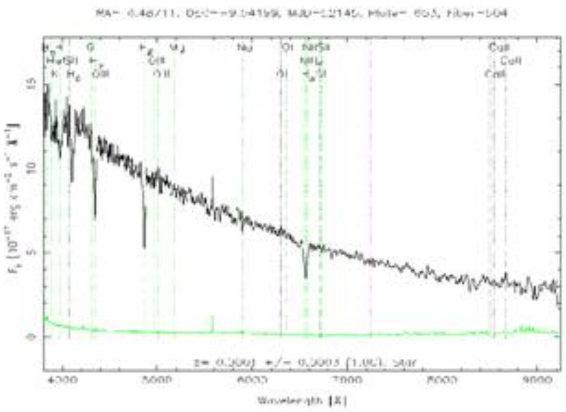

Fig.1: stellar spectrum.

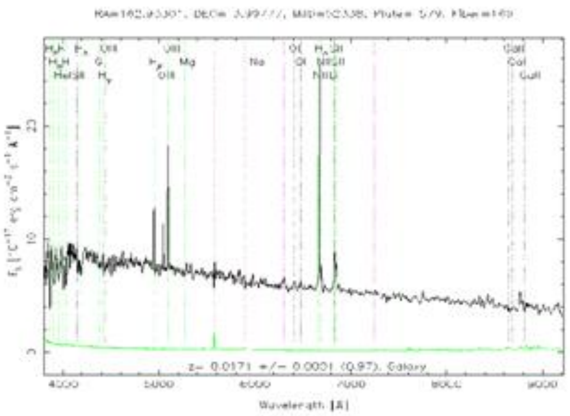

Fig.2: galactic spectrum.

III. WORK DESCRIPTION

We selected the galaxies having a colour index g – r between -1 and 2 and a redshift less than 0.1. Each spectrum extracted from SDSS is composed by four spectra. The first one is the spectrum of the object. Using IRAF we extracted only this spectrum and we made the extinction correction using the visual absorption A_V.

The next step was to calculate the redshift ($z = \Delta\lambda/ \lambda_0$) of every galaxy spectrum and then to deredshift it. We selected the Hα line for the emission line galaxies and the Na line for the absorption line galaxies. Computing the difference between the observed and the laboratory wavelengths, we derived the redshifts. In tab. 3 are reported the measured Hα or Na line wavelengths, the redshift and the Galactic extinction coefficient used for the correction of the spectrum for each galaxy.

Tab.3

Object	Wavelength	Redshift [z]	Extinction coefficient [A_V]
SDSS J105143.92+035951.9	Hα = 6676.5	0.017	0.141
SDSS J151713.03+552640.4	Hα = 6740.1	0.027	0.049
SDSS J113515.94+013819.3	Hα = 6729.9	0.025	0.091
SDSS J214554.67+114041.8	Hα = 6719.3	0.024	0.359
SDSS J140733.50+071040.3	Na = 6033.0	0.024	0.092
SDSS J111243.98+353356.8	Na = 6360.0	0.079	0.087
SDSS J150758.49+102053.6	Na = 6356.0	0.079	0.120
SDSS J112642.28-012732.3	Na = 6329.0	0.074	0.112
SDSS J141026.83-004956.5	Hα = 6730.4	0.025	0.161
SDSS J083737.87+441501.4	Hα = 6741.4	0.027	0.089

Then, we normalized the spectra of the stars and the galaxies dividing each of them for their flux at 6000Å. All these operations were performed with IRAF, while for the linear combinations of the stellar spectra we used Topcat. We first transformed the spectra in text files where every value of the wavelength was associated with the correspondent value of the flux. Then, we started to combine the stars' spectra to obtain the integrated spectra of the galaxies except for the emission lines. We combined different spectra in different proportions and the coefficients that appeared in front of each spectrum showed the presence in percentage of that kind of star in the galaxy.

Recognizing the spectral class of the stars, we were able to find approximately the percentage of old and young stars composing the galaxies. For example the spectrum of an a elliptical galaxy (Fig.3) was obtained adding the three spectra of F (Fig.4), K (Fig.5) and A (Fig.6) stars.

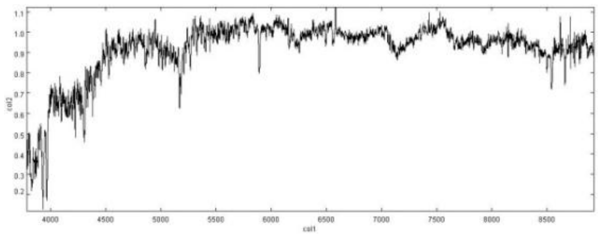

Fig.3: Example of spectrum of an elliptical galaxy.

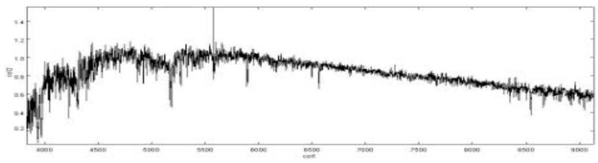

Fig.4: Spectrum of an F star.

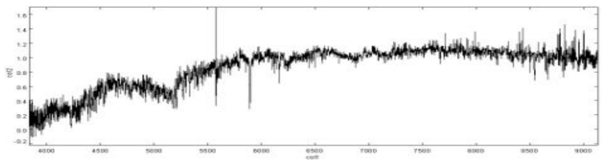

Fig.5: Spectrum of a K star.

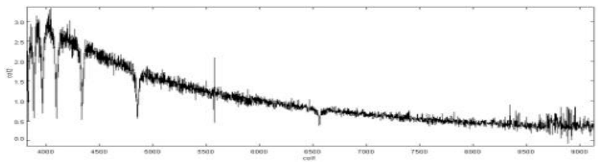

Fig.6: Spectrum of an A star.

The result is shown in Fig.7, in which are visible two different spectra; the galaxy's spectrum is the red one while the integrated spectrum is the blue one:

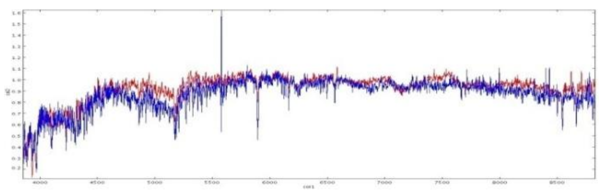

Fig.7: Comparison between the galactic spectrum and the spectrum obtained summing the different types of stars.

IV. RESULTS

We obtained ten different combinations made of 2 or 3 types of stars. However, in some cases, it was difficult to combine the stellar spectra to obtain a good integration, in particular the spectrum of elliptical galaxies was difficult to reproduce. Moreover, many spectra were similar because many galaxies belonged to the same type. For this reason we report only some graphs. From Fig.8 to Fig.10 there are the most representative galaxies' spectra (red) compared with the integrated spectra (blue).

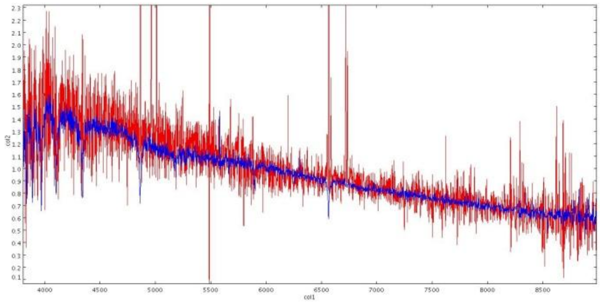

Fig.8: Example of a well reproduced spectrum.

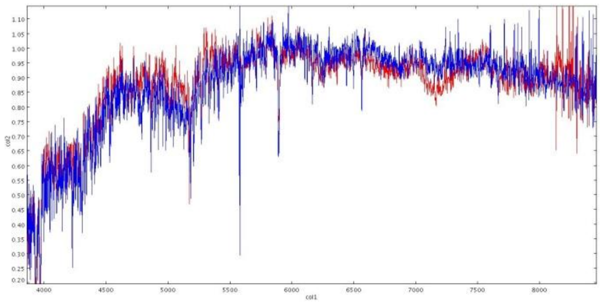

Fig.9: Example of a well reproduced spectrum.

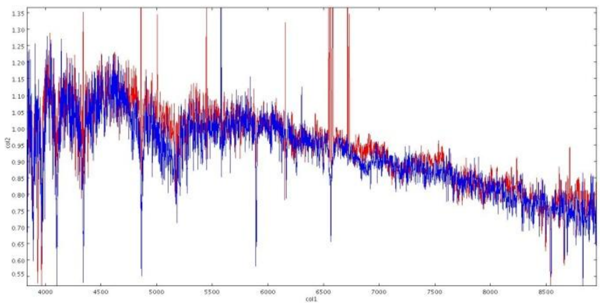

Fig.10: Example of a well reproduced spectrum.

In Tab. 4 we sum up our results: near each galaxy there are the linear combinations of the percentage of stellar types composing the galaxies.

Object	Stellar population synthesis
SDSS J105143.92+035951.9	40% A + 10% F + 20% K
SDSS J151713.03+552640.4	80% F + 20% A
SDSS J113515.94+013819.3	20% A + 30% F + 50% K
SDSS J214554.67+114041.8	50% A + 50% K
SDSS J140733.50+071040.3	30% F + 60% K + 10% A
SDSS J111243.98+353356.8	70% K + 20% F + 10% A
SDSS J150758.49+102053.6	50% F + 50% K
SDSS J112642.28-012732.3	70% K + 20% F + 10% A
SDSS J141026.83-004956.5	40% A + 60% K
SDSS J083737.87+441501.4	60% A + 40% K

Tab.4: table with results.

In conclusion, comparing our graphs with some typical spectra of elliptical, spiral and irregular galaxies and analyzing our stellar population synthesis, we made a catalogue of the objects (Tab.5). Sometimes it was not easy to catalogue the objects, like the last galaxy, which may be an Irregular or a Spiral galaxy.

Object	Type
SDSS J105143.92+035951.9	Spiral
SDSS J151713.03+552640.4	Spiral
SDSS J113515.94+013819.3	Spiral
SDSS J214554.67+114041.8	Spiral
SDSS J140733.50+071040.3	Elliptical
SDSS J111243.98+353356.8	Elliptical
SDSS J150758.49+102053.6	Elliptical
SDSS J112642.28-012732.3	Elliptical
SDSS J141026.83-004956.5	Spiral
SDSS J083737.87+441501.4	Irregular or Spiral

Tab.5: catalogue of the studied galaxies.