Study of the star formation history with STARLIGHT

Enrico Cescon, Luca Fardin, Eleonora Maset, Enrico Pandin, Carlo Maria Scandolo

Liceo Scientifico "Guglielmo Marconi", Conegliano (TV)

ABSTRACT

The aim of this work is to estimate the SFH (Star Formation History) of 50 galaxies through the analysis of their spectra. Comparing data of spiral and elliptical galaxies, it was possible to verify some aspects of the galactic evolution theory regarding star formation periods.

I. INTRODUCTION

Galaxies are large-scale aggregates of stars, gas, and dust kept together by gravitational forces. According to current theories, they started to form between 600 million and 1 billion years after the Big Bang. Hubble's morphological classification divides galaxies into elliptical, spiral and irregular ones. Elliptical galaxies show a quite uniform star distribution and their luminosity gradually decreases from the centre to the edge; they also present only little evidence of gas and dust.

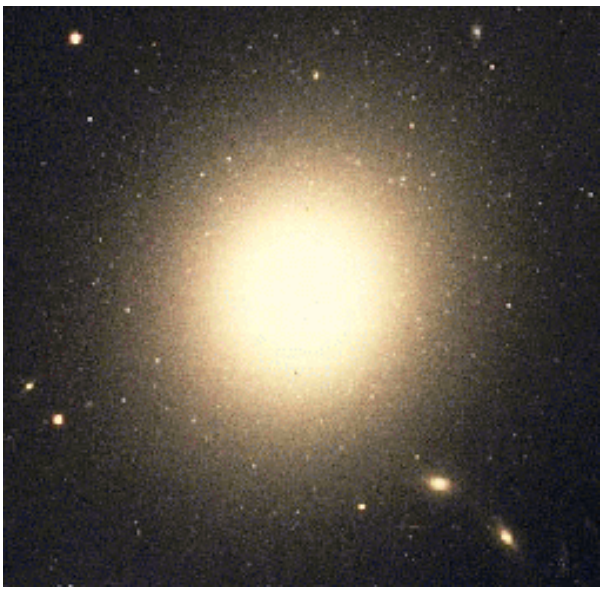

Fig. 1: Elliptical Galaxy M87. You can clearly see the uniform distribution of luminosity.

Spiral galaxies, instead, are characterized by the presence of an evident central bulge and of arms originating from the bulge. In this case there are large quantities of gas and interstellar dust in the arms.

Fig. 2: Spiral galaxy M81. You can clearly see the presence of the arms.

Irregular galaxies are called in this way because their unusual shape does not allow us to trace them to any category.

According to the classic theories, the shape of galaxies is influenced by two physical parameters, density and angular momentum, that play a fundamental role during formation. If the protogalaxy is very dense, gas condenses very quickly and it is completely transformed into stars, originating an elliptical galaxy. On the contrary, if the protogalaxy is not dense enough, cooling takes place more slowly; gas first condenses in the centre forming the stars of the bulge, then on a plane giving birth to the arms. Moreover, a high angular momentum favours the flattening of the cloud on a plane and the formation of the disc of a spiral. On the basis of galactic evolution theories, in elliptical

galaxies the star formation is concentrated in the first moments of their life. Spiral galaxies present instead many star formation events distributed along their whole existence.

II. OBSERVATIONAL DATA

The data were obtained from the DR6 (*Data Release 6*) archive of *Sloan Digital Sky Survey* (SDSS).
We analyzed the spectra of 50 galaxies with redshift lower than 0.1 and g – r colour index ranging between -0.6 and 1.3.

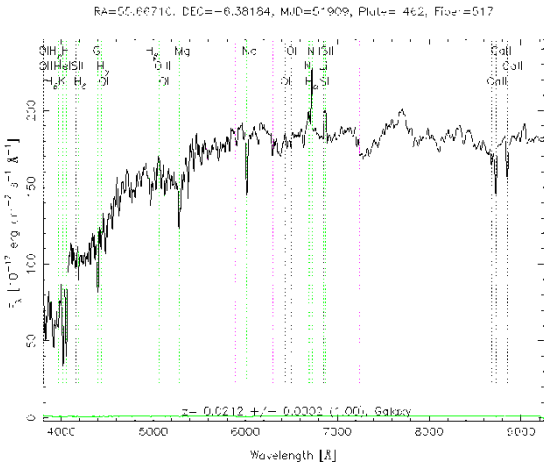

Fig. 3: Spectrum obtained from the observation of a spiral galaxy.

The spectra were taken from regions close to the galactic nucleus. In the spectrum of Fig. 3, the H_α emission line, which is found in spiral galaxies, is clearly visible. It is originated by the photoionization of interstellar gas due to young stars belonging to O and B spectral classes. In elliptical galaxies spectra this emission line is absent because stars are older and colder.

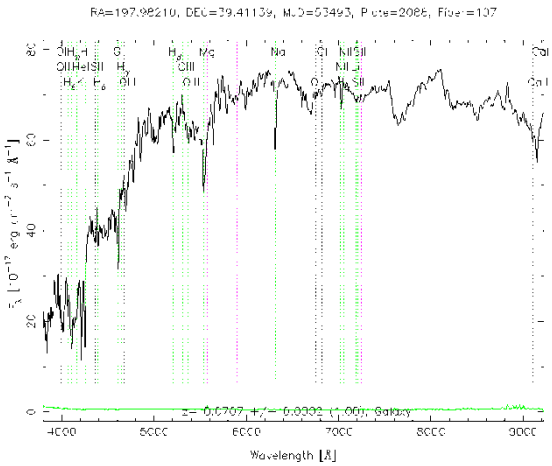

Fig. 4: Spectrum obtained from the observation of an elliptical galaxy.

III. WORK DESCRIPTION

On the basis of redshift and colour index parameters described in the previous paragraph, we downloaded data related to 5000 galaxies from www.sdss.org/dr6. We created a colour-colour diagram using a computer program called TOPCAT, which allowed us to distinguish between bluer and redder galaxies. Blue galaxies have a lower g-r colour index and spiral galaxies are more frequently found among them; red ones are instead generally elliptical. From this graph we selected 50 galaxies: 35 of them were spiral and 15 elliptical. We processed their spectra using the program IRAF (*Image Reduction and Analysis Facility*) in order to put them in the software STARLIGHT. First of all, we removed the effect due to the Galactic extinction, which is the partial light absorption by the dust/ISM of the Milky Way. To do this operation, we used data taken from *nasa/ipac extragalactic database* (NED). After that, we shifted spectra to redshift z=0. Measuring the wavelength of the Hα line, it is possible to calculate the redshift by means of the following formula:

$$z = \frac{\lambda - \lambda_0}{\lambda_0}$$

where λ_0 is the rest frame wavelength, 6563Å, whereas λ is the observed wavelength. Elliptical galaxies do not present the Hα emission line, so we considered the Na absorption line, whose rest frame wavelength is 5892Å. The so modified spectra were then put in STARLIGHT. This program, starting from the spectrum of a galaxy, is able to trace back its stellar composition. It combines the spectra of 45 different stellar types of the main sequence: 3 different metallicity classes (0.004 or 0.02 or 0.05) for each of the 15 age classes (from 1 million to 13 billion years). Metallicity indicates metal abundance in a star. A high metallicity might suggest that a star is old or that it is a second generation star, which contains metals produced by previous stars. The program makes a linear combination of sample-spectra at disposal to approximate the original spectrum as better as possible. It adopts the following procedure:

$$Sp = \sum_{i=1}^{45} a_i \cdot s_i = a_1 \cdot s_1 + a_2 \cdot s_2 + \ldots + a_{45} \cdot s_{45}$$

where *Sp* is the output spectrum, *s* is the spectrum of every stellar type and *a* is the number of stars of that particular type.
Since STARLIGHT uses only stellar spectra, which are exclusively absorption spectra, it cannot reproduce the emission lines we find in spiral galaxies spectra.
Since we were interested only in the different ages of stars, we added the results related to stars with the same age and different metallicity. STARLIGHT gave us tables with the fraction of light emitted by stars of the same age class.

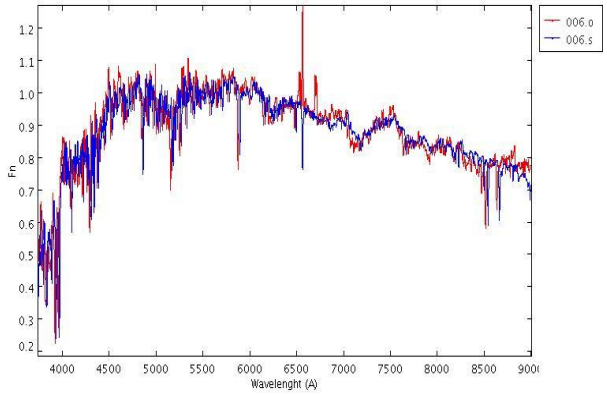

Fig. 5: The red spectrum is the one of fig.3 modified with IRAF. The blue one is the spectrum created by STARLIGHT. You can notice the good approximation, except for the absent rendering of the H_a emission line.

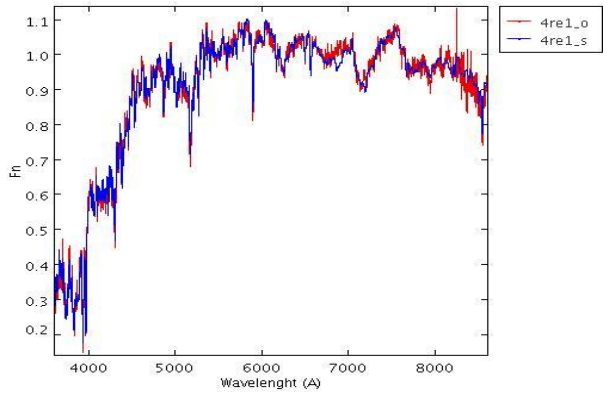

Fig. 6: The red spectrum is the one of fig.4 modified with IRAF. The blue one is the spectrum created by STARLIGHT. You can notice the good approximation.

Age class	Age (yr)	Light %
1	$1.0 \cdot 10^6$	2.78
2	$3.2 \cdot 10^6$	4.77
3	$5.0 \cdot 10^6$	0.00
4	$1.0 \cdot 10^7$	16.43
5	$2.5 \cdot 10^7$	9.82
6	$4.0 \cdot 10^7$	0.36
7	$1.0 \cdot 10^8$	1.35
8	$2.9 \cdot 10^8$	4.40
9	$6.4 \cdot 10^8$	0.00
10	$9.0 \cdot 10^8$	0.00
11	$1.4 \cdot 10^9$	6.02
12	$2.5 \cdot 10^9$	28.46
13	$5.0 \cdot 10^9$	3.12
14	$1.1 \cdot 10^{10}$	8.77
15	$1.3 \cdot 10^{10}$	15.24

Tab. 1: Example of output given by STARLIGHT from which we plotted the graph.

Using TOPCAT again, from these charts we obtained graphs showing stellar formation events during the life of the galaxy. We put the age of the stars in a logarithmic scale on the X axis, and the percentage of emitted light on the Y axis.

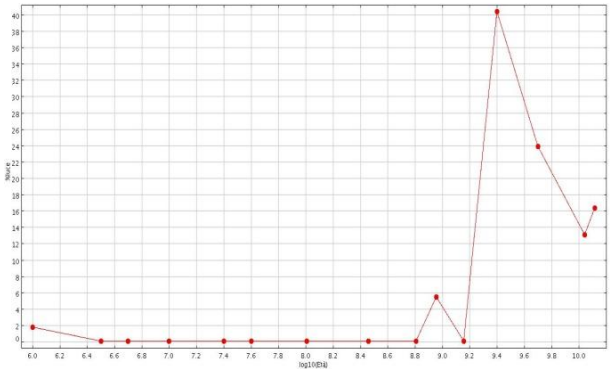

Fig. 7: Graph which represents the star formation history of the spiral galaxy in fig.3; each peak corresponds to a star formation event.

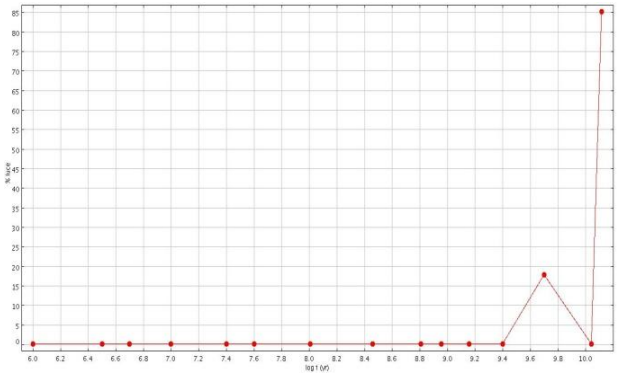

Fig. 8: Graph which represents the star formation history of the elliptical galaxy in fig.4.

IV. RESULTS

From the graphs we obtained, we made some statistical considerations:

- all spiral galaxies have at least 3 star formation events;
- 56% of blue spiral galaxies have at least 8 star formation events, while 90% of red spiral galaxies have less than 8 star formation events;

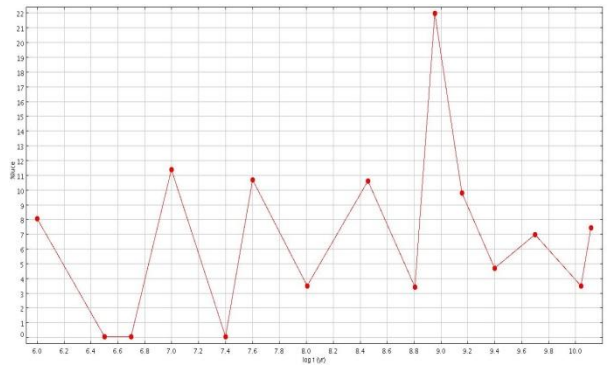

Fig. 9: Typical example of blue spiral galaxy with numerous star formation events.

- elliptical galaxies, which are all red, have at most 5 star formation events;

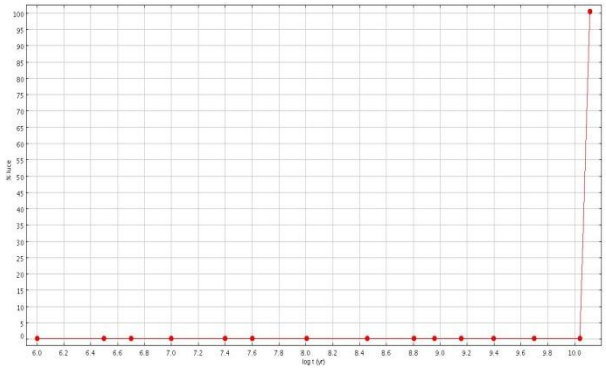

Fig. 10: Typical example of elliptical galaxy with only one star formation event dating to more than 10 billion years ago.

- all blue spiral galaxies have a star formation event more recent than 100 million years ago;

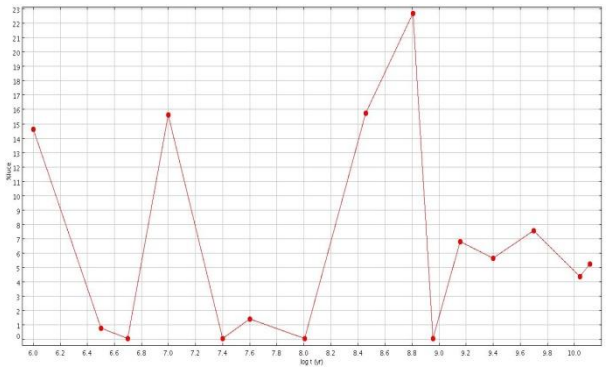

Fig. 11: Graph of a spiral galaxy with star formation events dating to 1 and 10 million years ago.

- 6 red galaxies out of 25 have a star formation event more recent than 100 million years ago; among them only one is elliptical;

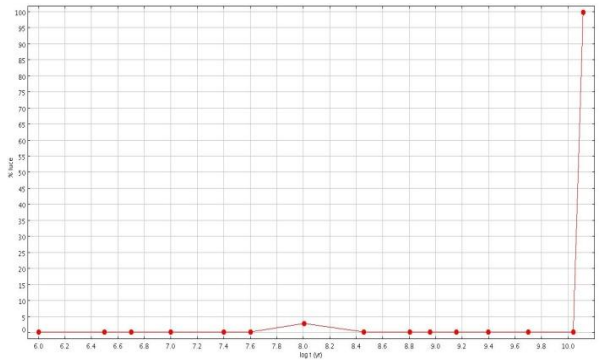

Fig. 12: Graph of the only analyzed elliptical galaxy which has a star formation event happened 100 million years ago.

As predicted by galactic evolution theories, obtained data show that in elliptical galaxies the initial collapse quickly converts all the gas into stars; in this way the star formation process does not last for the whole galaxy lifetime. Elliptical galaxies are, in this way, composed by red old stars.

In spiral galaxies the presence of gas and dust in the disk allows a more homogeneous star formation process. Therefore, they contain younger and hotter stars than elliptical galaxies, as already verified by Bano et al. [1].

From the fact that elliptical galaxies are only red and that the blue ones are spiral, and considering what we previously said, we can infer that the ellipticals are the oldest galaxies if the universe, as reported by Ralf Bender [2].

V. BIBLIOGRAPHY

[1] Studio della Popolazione Stellare nelle Galassie by M. Bano, A. Campa, M. Gusella, F. Righetti - "The sky as a laboratory 2006-2007", 2007.

[2] Galaxies Cosmology and Dark Matter by Bender R. – Lecture, 2000.

Star formation history in the Small Magellanic Cloud: the case of NGC 602 by M. Cignoni, E. Sabbi et al. – The Astrophysical Journal, 2009

Introduzione all'astronomia by H. L. Shipman – Zanichelli, 2000

http://www.sdss.org/dr6

http://nedwww.ipac.caltech.edu/