Evolution of the minor and major galaxy merger rate in MUSE deep fields

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1 Context

How do galaxies grow over cosmic time ? The processes that govern the evolution of baryons, and thus the mass assembly of galaxies in dark matter haloes, are still unclear. Do galaxy mergers, as observed in the nearby universe (see fig. 1), played a key role at significant look-back time ?

Previous studies have tried to quantify the evolution of galaxy merger rate. But due to the difficulty to detect close (spectroscopic) pairs of galaxies, the major merger rate was constrained so far up to redshift z~2-3 (eg. Lopez-Sanjuan et al. 2012, Tasca et al.2015). Moreover, the minor merger rate of galaxies is almost unconstrained, with one attempt only so far (Lopez-Sanjuan et al. 2011).

The purpose of this study is to provide new constraints on the growth of galaxies over the last 12 billion years, by studying the evolution of the galaxy merger rate.

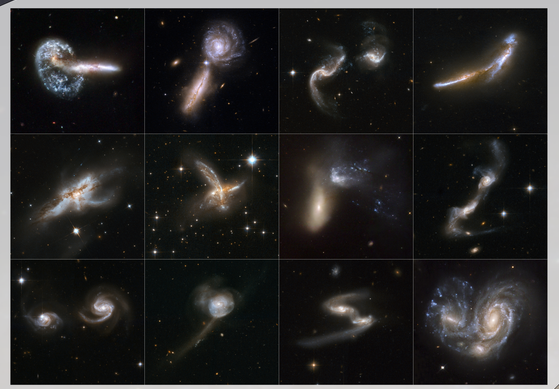


Figure 1: Hubble images of galaxies in the merging process.

2 Observational data

This work focus on the analysis of MUSE data.

The Multi Unit Spectroscopic Explorer (MUSE) is a new generation instrument installed at the Very Large Telescope in the Atacama desert in Chile.
Thanks to its 24 integral-field spectrographs, MUSE allow to probe the deep universe in 3D in a 1 arcmin² field of view.

This instrument is perfectly suited to identify close pairs of galaxies at very high redshift (z>3) and small satellites orbiting around big galaxies up to z~1.

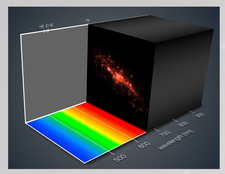
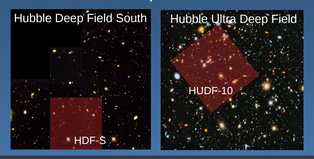


Figure 2: The 3D spectroscopy of MUSE allow us to study galactic objects over a large spectral range.

3 MUSE data set

This study is based on the two deepest fields (~ 30h exposure time) observed so far with MUSE in the Hubble Deep Field South (HDF-S) and the Hubble Ultra Deep Field (HUDF-10).



HST images

4 Detection of close pairs of galaxies

To quantify the merger rate in the HDF-S and HUDF data cubes, we start by searching for close pairs of galaxies.

What we define by close pair is two galaxies within:

A limited projected separation distance, $5 < r_p \leq 30\,kpc$

A limited difference in relative velocity, $D_V \leq 500\,km\,s^{-1}$

With these criteria about 70% of the close pairs will become galaxy mergers. (Patton et Atfield, 2008 ; Lin et al., 2008 , 2010)

A detection tool was developed to explore the close environment of galaxies in the data cubes and highlight the presence of close pairs.

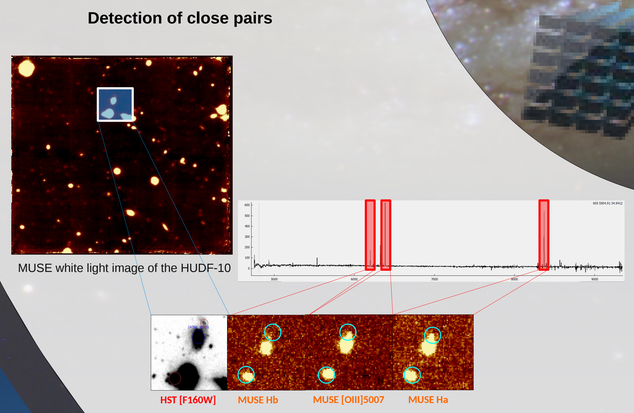
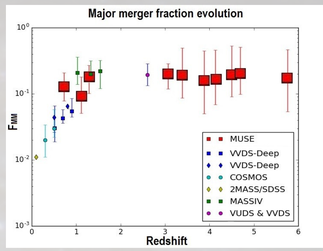


Figure 3: We probe the close environment of the centered galaxy in order to detect satellites galaxies around it.
Spectrum of our principal galaxy, and for different spectral lines, the narrow band images associated.
You can clearly see the presence of 2 satellites galaxies around the main one.
(circled in blue)



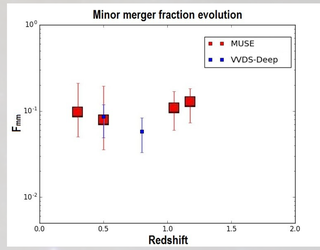


Figure 6: The major merger fraction evolution (top),and the minor merger fraction evolution (bottom) over cosmic time.

With a comparison between this work (MUSE points) and the last previous studies done on mergers from different surveys.

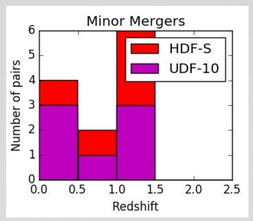


Figure 5: Histogram of the redshift distribution of minor (left) and major (right) mergers in the HUDF and the HDF-S .

5 Major and minor mergers

A major merger is the merging of two galaxies of a similar mass (with a mass ratio between 1 and 1/6).

For a minor merger the primary galaxy is much more massive than its companion (mass ratio between 1/6 and 1/100).

The first results show that there are about 10% of close pairs in the two fields and we could detect close pairs at high redshift (3<z<6).

About 68% of the close pairs will probably become major mergers and 32% minor mergers.

6 First Results

From our detection of close pairs (N_P), we estimate the major and minor galaxy merger fraction in the HDF-S and HUDF-10.
(to correct it from selection effects we compute for each galaxy two weights:
Wc that take into account the completeness and the confidence of the redshift measurement and W_A for galaxies located near the border of the field)

$$F_{MM} = \frac{\sum_{k=1}^{N_c} W_c^{k_1} * W_c^{k_2} * W_A}{\sum_{i=1}^{N_c} W_c^{i} * W_A}$$

Following de Ravel et al. (2009), we calculate the major and minor galaxy merger rate, defined as the number of mergers per galaxy and Gyr, as:

$$R_{MM} = F_{MM}\, T_{MM}^{-1}$$

(with F_{MM} the merger fraction and T_{MM} the typical merger timescale, from cosmological Simulations, *Kitzbichler & White,2008*)

We give the first estimate of the major merger rate for a redshift > 3.

And an estimate of the minor merger rate for a redshift range from 0.2 to 1.5.

Our first results tend to show that there is a flattening of the major merger rate evolution for high redshifts (with a major merger fraction of about **20**%).

Whereas the minor merger rate seems to be constant (~ **0,05** Gyr $^{-1}$ with a minor merger fraction of about **10**%) for the studied redshift range.

7 Next step

Extend such analysis to other MUSE fields, to obtain more statistically robust results. Since we explored just two fields of 1 arcmin², the uncertainties are dominated at high redshift by the cosmic variance.

Improve the merger rate estimate:
- New relation for the merger timescale, especially for close pairs of low-mass galaxies
- Better estimate the baryonic vs. dark matter halo mass fraction at different redshifts and in low-mass regime.

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