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, one of the main drivers in galaxy evolution, play a key role in their evolution at significant look-back time?

Due to the difficulty to identify these violent interactions between galaxies at high redshifts, the major merger fraction, involving two galaxies of similar masses, was constrained so far up to redshift $z = 3$ from previous studies of spectroscopic pair counts (e.g. Lopes-Sanjuan et al. 2012, Tasca et al. 2015). Thanks to its wide field-of-view and unprecedented sensitivity, MUSE allows us to perform spectroscopic deep fields, without any prior knowledge of galaxies, the main drawback of previous spectroscopic surveys. This new and powerful instrument is thus perfectly suited to identify close pairs of galaxies with secure spectroscopic redshift.

We provided, for the first time, robust observational constraints on the galaxy major merger fraction over the last 12 billion years, i.e., extending up to redshift $z = 6$, and over a large range of galaxy masses.

**Evolution of the galaxy major merger fraction since $z = 6$ in the MUSE Hubble Ultra Deep Field Survey**

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With T. Contini (IRAP) & the MUSE-GTO collaboration

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, one of the main drivers in galaxy evolution, play a key role in their evolution at significant look-back time?

2. **MUSE data set**
   - This analysis is based on MUSE observations over **two deep fields**, the UDF10 and HDF-S with an average exposure time of 30hr, and one medium deep (10 hr) mosaic covering the entire HUDF.

   The combined fields result in a **parent sample** of 1131 galaxies with spectroscopic redshift.

   The major merger fraction is constrained so far up to redshift $z = 3$ from previous studies of spectroscopic pair counts (e.g. Lopes-Sanjuan et al. 2012, Tasca et al. 2015). Thanks to its wide field-of-view and unprecedented sensitivity, MUSE allows us to perform spectroscopic deep fields, without any prior knowledge of galaxies, the main drawback of previous spectroscopic surveys. This new and powerful instrument is thus perfectly suited to identify close pairs of galaxies with secure spectroscopic redshift.

3. **Detection of close pairs of galaxies**
   - **Projected separation distance**: $5\sigma$, $z<6$
   - **Difference in relative velocity**: $D_z \leq 5000$ km/s

   We identified 113 secure close pairs of galaxies spread over a large redshift range ($0.2<z<6$) and stellar masses ($10^{-10}$ - $10^{11}$ Msun), see Fig 4. Stellar masses are estimated from SED fitting over the extensive UV-to-NIR HST photometry available, adding Spitzer IRAC bands to better constrain masses for high-redshift ($z>4$) galaxies.

   **Defining major mergers**: as having a mass ratio of $1:1-1:6$, we found 86 major close pairs, among this sample, 23 pairs are identified at high redshift ($z>3$) through their Lyα emission.

4. **First results**
   - The major merger fraction is estimated over 5 redshift bins from $z=0.2$ to $z=6$ and is defined (with correction from selection effect) as:

   $F_{MM}(z) = \frac{N_{M} - A}{N_{p}}$

   where $N_{M}$ and $N_{p}$ is the number of galaxies in the parent sample and the number of major close pairs, $A$ accounts for the missing/undetected pairs due to our limit in spatial resolution. We take into account that some galaxies are located on the border of the MUSE field-of-view, and finally $C_1$ is a correction term for the redshift incompleteness.

   The major merger fraction estimated in the MUSE fields are in good agreement with previous studies at similar redshifts, with a **constant increase** of the major merger fraction with look-back time up to $z = 3$ (Fig 4, Right). At higher redshift, we show for the first time that the fraction slowly decreases or flattens down to about 10% at $z = 6$.

   An attempt to separate our sample of close pairs in stellar masses is shown in Fig 5 (Bottom). We use the stellar mass of the primary galaxy to discriminate the pairs. The major merger fraction estimated for the massive sample is, within uncertainties, consistent with previous works, with an increase of the fraction up to 23% and 19% at $z = 3$ and $z = 3.5$. The major merger fraction evolution of the low-mass sample seems to follow the same trend, with a maximum increase up to $z = 3$ of 11%, and then **flattens** or slightly decreases to 8-9% between $3<z<6$.

5. **Comparison with simulations**
   - We can compare our merger fractions to predictions from hydrodynamic simulations which model the dark matter and baryonic components of a cosmological volume consistently. Fig 5 (Top) compares the predictions from HORIZON-AGN (Kaviraj et al.2015), EAGLE (Qu et al.2017) and ILLUSTRIS (Snyder et al.2017) simulations, to our major merger fraction estimates.

   The trend of our major merger fraction evolution is in good agreement with the trend of these simulations, with a slow increase of the merger fraction up to $z = 3$ and then a decrease toward higher redshift.

   We searched for **robust observational constraints** on the galaxy major merger fraction over the last 12 billion years, i.e., extending up to redshift $z = 6$, and over a large range of galaxy masses.

   Defining major mergers as having a mass ratio of $1:1-1:6$, we found 86 major close pairs, among this sample, 23 pairs are identified at high redshift ($z>3$) through their Lyα emission.

   The major merger fraction estimated in the MUSE fields are in good agreement with previous works at similar redshifts, with a constant increase of the major merger fraction with look-back time up to $z = 3$. At higher redshift, we show for the first time that the fraction slowly decreases or flattens down to about 10% at $z = 6$.

   An attempt to separate our sample of close pairs in stellar masses is shown in Fig 5 (Bottom). We use the stellar mass of the primary galaxy to discriminate the pairs. The major merger fraction estimated for the massive sample is, within uncertainties, consistent with previous works, with an increase of the fraction up to 23% and 19% at $z = 3$ and $z = 3.5$. The major merger fraction evolution of the low-mass sample seems to follow the same trend, with a maximum increase up to $z = 3$ of 11%, and then flattens or slightly decreases to 8-9% between $3<z<6$. 

   The most massive galaxy is circled in red and its companion in green.

   The major merger fraction is estimated over 5 redshift bins from $z=0,2$ to $z=6$ and is defined (with correction from selection effect) as:

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