Building an unbiased sample of quiescent galaxies up to z=2.5 based on the Mg(UV) absorption index

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Abstract

Samples of **'red&dead' galaxies** selected through traditional colour-based techniques usually suffer from contamination by strongly dust-obscured sources. We are using **GTC/OSIRIS data from the SHARDS project** on the GOODS-N field to define **unbiased samples of really quiescent massive galaxies** at different redshifts up to z=2.5. By measuring the Mg(UV) absorption index in the pseudo-spectra of these galaxies, we intend to determine the redshift evolution of the characteristic age of their stellar populations. The current status of the project is summarized.

1 - Confusion of galaxy types in the Red Sequence

Studies focusing on red galaxies assume that rest-frame colours are a good way to identify **quiescent early-type galaxies** at all redshifts (e.g., Faber et al. 2007, Wuyts et al. 2007, Williams et al. 2009). However, **contamination by dust-reddened galaxies** becomes significant at high redshifts, reaching ~30% at z~0.8 and rising towards earlier epochs (Cimatti et al. 2002, Cirasuolo et al. 2007). This makes difficult to disentangle the evolution of quiescent galaxies from dust-reddened systems, even for the most advanced colour-based selection techniques (Brammer et al. 2009, Whitaker et al. 2012). The assembly epoch of *bona fide* quiescent galaxies is thus poorly constrained.

Spectral absorption features such as **the Mg(UV) absorption, the Balmer break, and the 4000 Å break** are known to be robust proxies of the characteristic age of stellar populations and distinctive of quiescent early-type galaxies at high redshifts (Balogh et al. 1999, Kauffmann et al. 2003, Daddi et al. 2005). It is thus possible to define unbiased samples of quiescent galaxies attending to them, but spectroscopic data are expensive for large samples. An alternative is obtaining low-resolution spectral energy distributions (SEDs) in the rest-frame NUV of red galaxy samples using deep medium-band data, as done in the SHARDS project.

2 – The ESO/GTC Programme SHARDS

The **Survey for High-z Absorption Red and Dead Sources (SHARDS)** is an ESO/GTC Large Programme, consisting in **GTC/OSIRIS imaging data** of the entire GOODS-North region in 25 medium-band different filters (FWHM ~ 17 nm), with a continuous coverage of the wavelength range between 500 and 950 nm. The depth of the survey is at least 26.5 mag at the 3σ level in all filters. A detailed description of SHARDs is provided in Pérez-González et al. (2013). **More information on SHARDS at**: http://http://guaix.fis.ucm.es/~pgperez/SHARDS/

Figure 1 illustrates the **main scientific goal of SHARDS**. The averaged spectrum of 13 GMASS early-type galaxies from Cimatti et al. (2008) is shown at four different redshifts, together with the profiles of the SHARDS filters. Using this filters set, it is possible to probe the Mg(UV) absorption feature (marked in red) at 1.0<z<2.5 in a pseudo-spectrum with a resolution R~50, as well as measure spectral indices such as D(4000) or the Balmer break absorption-line $H\delta_A$ for z<1.5 galaxies. **Figure 2** shows the SED of a quiescent galaxy at z=1.24 including its SHARDS data. It demonstrates that it is possible **to measure the Mg(UV) index** in quiescent galaxies at high redshifts **in a galaxy-by-galaxy basis** down to AB mag=26.5-27.0 with SHARDS.

Figure 1

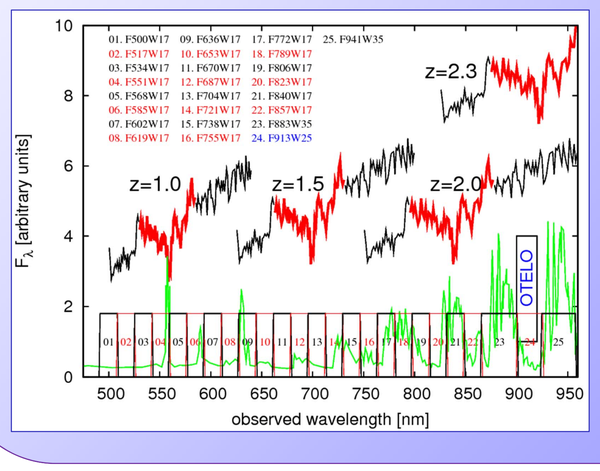
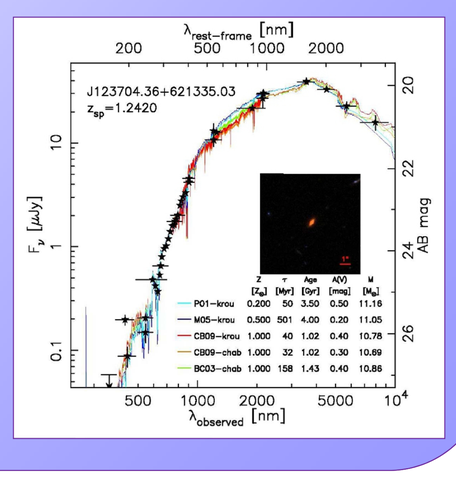


Figure 2



3 – Pre-selection of red galaxies types

We intend to define an unbiased sample of quiescent galaxies at 1.0<z<2.5 by direct measurement of the Mg(UV) index using SHARDS data. We have first used broad-band data from NUV to MIR and SEDs fitting to spectral synthesis models of stellar populations to obtain a initial sample of galaxies on the Red Sequence using the UVJ diagram in GOODS-N up to z=4. We have then identified different spectral types according to the rest-frame broad-band properties of the galaxies (as done in other studies), in order to analyse the relation between these identifications and the characteristic age derived from the Mg(UV), D(4000), and $H\delta_A$ indices obtained with SHARDS. These types are:

1) Quiescent galaxies (according to the criteria by Whitaker et al. 2010).
2) Young post-starbursts (post-SB) without dust (Whitaker et al. 2012).
3) Dusty post-SB: red galaxies that do not fulfill the previous two criteria.

Figure 3 shows the location of our red galaxy sample in the UVJ diagram by mass and redshift bins (circles in red colours). ''Quiescent'' galaxies identified with broad-band data have been marked with a cross, ''young post-SB without dust'' with a green circle. The rest of galaxies on the Red Sequence are ''dusty post-SB''. **Figure 4** analyses the mass completeness of each red galaxy type as a function of the redshift in the sample. Our red sample is complete for $10<\log(M/M_{sun})< 11.5$ at $0.5< z < 2$.

Figure 3

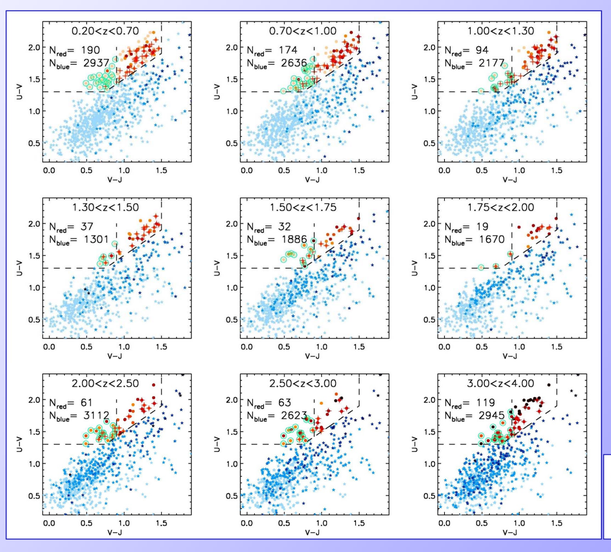
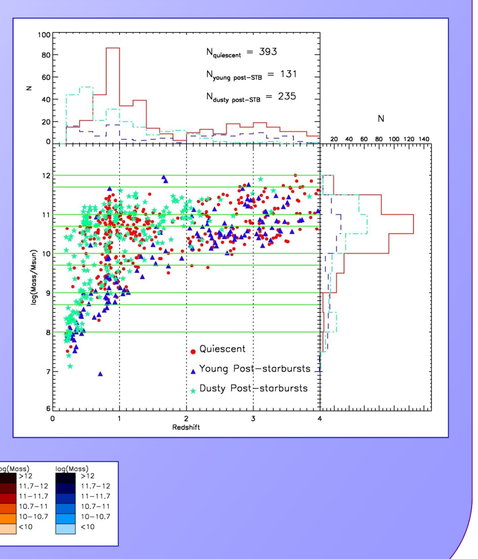


Figure 4



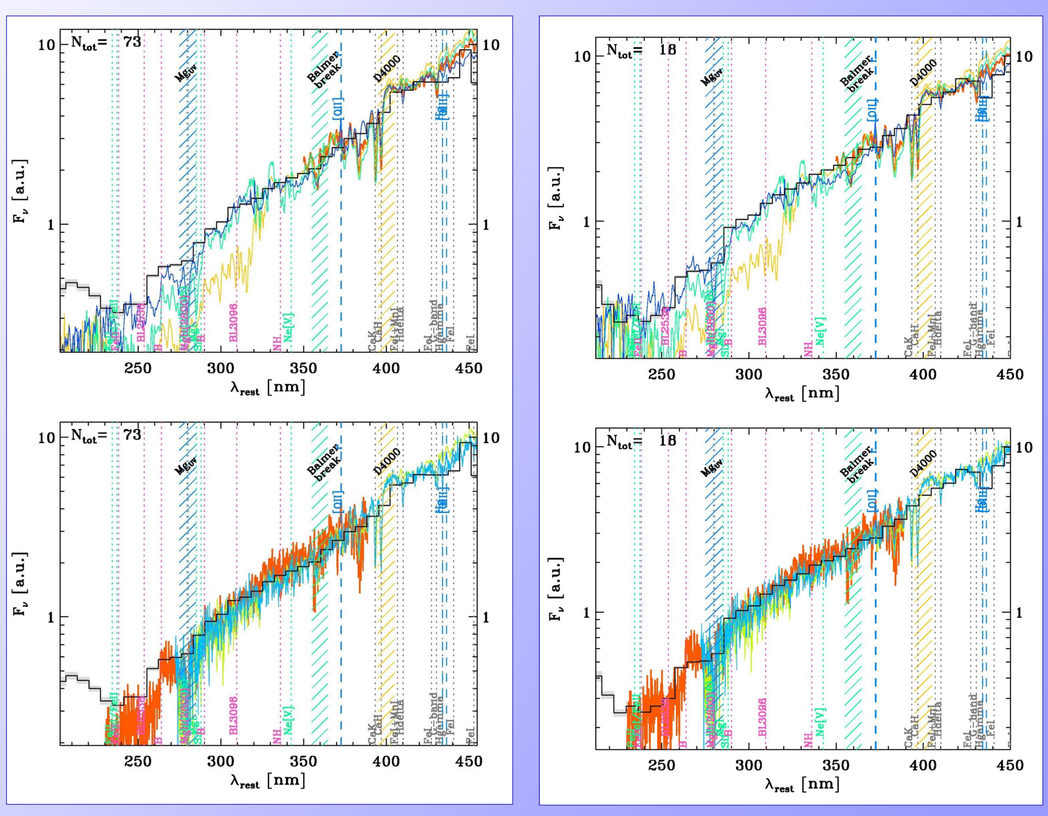
4 – Measuring Mg(UV) in preliminary stacked spectra

The SHARDS pseudo-spectrum of each pre-selected red galaxy has been displaced to rest frame according to its redshift and re-binned. The average rest-frame spectral resolution of the data is ~1 nm. Beside the individual pseudo-spectra, we have obtained stacked spectra by mass and redshift bins according to the procedure described in Pérez-Rafols et al. (2014).

Figure 4 shows some preliminary stacked spectra, obtained for all red galaxies at $1.0<z<1.5$ with $10<\log(M/M_{sun})<11$ (left panels) and $\log(M/M_{sun})>11$ (right panels). The top panels compare the resulting stacked spectra (black lines) with the characteristic spectra of early-type galaxies at z=0 (Kinney et al. 1996) and of luminous red galaxies at z~0.4 (Eisenstein et al. 2003, red line). At $\lambda<350$ nm, the stacked spectra of massive red galaxies at $1.0<z<1.5$ are more similar to local Sa's (blue line) than to local E's and S0's (yellow and green lines, respectively). The bottom panels of the figure compare the stacks with the averaged spectra of passive and post-SB types at $0.6<z<1.2$ (Nastasi et al. 2014, green and blue lines) and with quiescent galaxies at $1.4<z<2$ (Cimatti et al. 2008, red lines), showing a good agreement.

The location of several galaxy spectral features have been marked in **Figure 5**, in particular the **Mg(UV) absorption, Balmer break, and 4000 Å break**. These stacks show the robustness of the detection and measurement of the indices related to these absorption features (characteristic of passively evolving stellar populations) at $1.0<z<2.5$ using SHARDS.

Figure 5



Ongoing work

We are currently working to make robust measurements of these indices in the individual and stacked pseudo-spectra to study the redshift evolution of the characteristic ages of quiescent galaxies up to z=2.5. These results may shed some light into the assembly epoch of these galaxies.