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Scanning emission line galaxies through the SHARDS survey

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Abstract

SHARDS (Survey for High-z Absorption Red & Dead Sources; see [12]) is an optical ultra-deep spectro-photometric survey with OSIRIS-GTC aimed at selecting and studying massive passively evolving galaxies at $z = 1.0$–2.3 in GOODS-North. Nonetheless, the data quality allow a plethora of studies on galaxy populations, including Emission Line Galaxies (ELGs) about which we have started our first science verification project. The selection procedure, measurement and first analysis of ELGs in SHARDS, demonstrate the huge capability of the survey in providing physical information for a large sample of emitters, spanning from local Hα to high-z AGN and Lyman-α emitters.

1 Introduction

The analysis of emission lines in the spectra of star-forming galaxies (SFGs) and objects hosting AGN is one of the main tools to understand galaxy evolution. Emission lines can be used to select both SFGs and AGN, and then to obtain estimations of relevant physical parameters, being redshift, SFR, metallicity, or black hole mass some of the most interesting (see, e.g., [2, 6, 3, 21]).

Although the most straight-forward way of getting emission-line identifications and fluxes is through spectroscopic observations, these data are hard to obtain for large number of objects and very time consuming. Moreover, current spectrographs on the largest telescopes are only able to reach continuum magnitudes around $RI\sim$24-25 mag. This results in a scarcity of spectroscopic data for faint objects, especially at z$\gtrsim$1.5, and a bias of spectroscopic surveys towards bright emission-line galaxies at z$\lesssim$1.

A powerful alternative to spectroscopic surveys can be found in (ultra-)deep narrow-band imaging observations, which have been demonstrated to be useful to select emission-line galaxies (ELGs) with the faintest magnitudes, and measure important quantities such as equivalent widths (EWs) and line fluxes (see, among many, [18, 11, 10, 17, 19, 15, 4, 8]). In addition, although imaging data cannot directly provide robust identifications and precise observed wavelengths for emission-lines, they certainly help determine accurate photometric redshifts, even for very high redshift sources, based on the detection of both emission and absorption features or breaks.

2 ELGs at intermediate redshift

Imaging surveys in the optical aimed at selecting ELGs usually employ narrow-band filters, with narrow meaning widths around 10 nm. The SHARDS filters are wider, the typical FWHM is 15 nm, but the depth, photometric accuracy, and imaging quality of the GTC data can compensate the lower spectral resolution ($R \sim 50$), compared to more classical narrow-band surveys.

Figure 1 (left panel) shows an example of the selection of ELGs with SHARDS data for one of our 24 filters, the one centered at 687 nm (filter F687W17). The method is similar to that used by narrow-band surveys such as the ones referenced above: the flux in a given photometric band at wavelength $\lambda_{\rm line}$ is compared with the average flux around that wavelength. Sources with emission-lines lying inside the central filter would present an excess of flux compared to the average around it, with the latter corresponding to the spectrum continuum next to the line. In this particular example, we would expect to identify a population of galaxies at z$\sim$0.80-0.84 featuring an excess in the flux seen by the F687W17 filter due to [OII] emission. Note that the redshift interval is governed by the width of the filter as well as by the CWL variation of the pass-band along the FOV. Other lines could provide samples at different redshifts (e.g., Ly-α at z$\sim$4.6).

Typical narrow-band surveys use a broad-band filter to determine the continuum (e.g., [19, 17, 15, 5, 16]) , or one or several narrow- or medium-band filters around a given one [7]. In our case, the contiguous spectral coverage of the optical window allows us to obtain a continuum determination by using the adjacent filters to a given one, or even several filters around the central pass-band. This measurement is very robust, since it takes into account the intrinsic color of each galaxy in a close region around the spectral region of interest, rather than providing an average continuum value in a wide wavelength range. Moreover, the continuum determination is not affected by the emission line itself (for a typical line such as [OII]λ3727), as would be the case for surveys using broad-band filters).

Sources whose emission in the F687W17 filter is brighter than the average for the adjacent filters with more than the 3-σ confidence are located above the dashed red line. This is the expected locus for emission-line galaxies. Note that the color to detect a line with medium-band filters such as ours ranges between 0.1 and 0.5 mag, approximately. For filters with larger widths (e.g., broad-band), emission lines such as the ones we are able to detect would be diluted by the ratio between filter widths, and thus would be very hard to detect

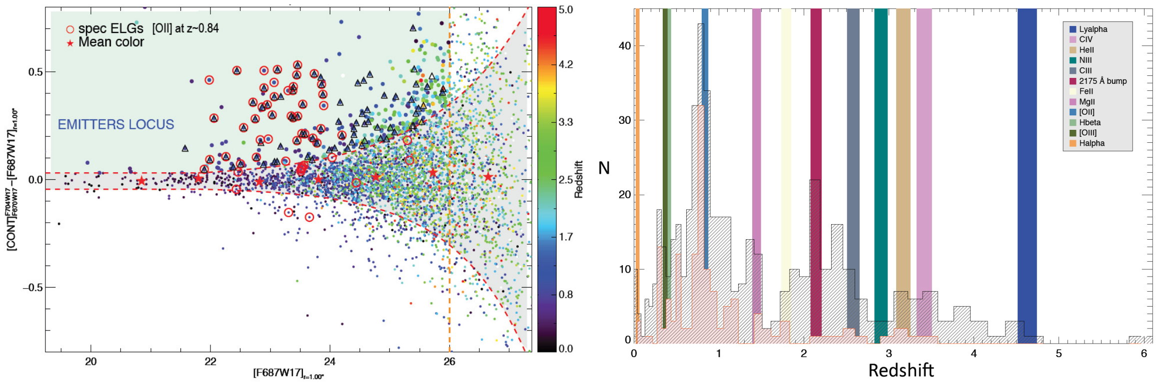

Figure 1: *Left panel:* Color-magnitude diagram showing emission-line galaxy candidates at ∼687 nm in SHARDS pointing #1. Sources with measured spectroscopic redshifts implying that the [OII] line lies within the F687W17 filter are marked in red. Triangles show galaxies with a photo-z between 0.7<z<0.9 [13]. *Right panel:* Spectroscopic (red histogram) and photometric (black) redshift distributions of the sources selected as ELGs with the F687W17 filter. The expected redshifts for emitters with some of the most typical lines (e.g., Lyα, [OII], [OIII], or Hα) are marked with shadowed regions. We also mark spectral features such as the Mg-Fe absorption band at ∼280 nm, or the 2175 Å dust absorption bump (which would imprint an absorption in the galaxy SED).

with broad-band data (typically having widths a factor of 7–8 larger than the SHARDS filters, implying an effect on the broad-band photometry of less than 0.1 mag for the brightest lines).

In order to test how the SHARDS data perform when trying to select ELGs, we have marked in Fig. 1 with red symbols the galaxies with reliable spectroscopic redshifts for which the [OII] line would lie within the F687W17 pass-band[1]. We are able to recover more than 85% of the spectroscopically confirmed galaxies with an [OII] emission-line expected within the F687W17 filter. A visual inspection of the spectra for the non-selected objects (but with z∼0.8) revealed very weak or even absent [OII] emission-lines. Therefore, we conclude that the SHARDS data are very effective in isolating emission-line galaxies at a similar line flux level as deep spectroscopy.

It is also interesting to note that virtually all the spectroscopically confirmed ELGs in Fig. 1 are brighter than R∼24.5. This is the spectroscopic limit of the redshift surveys carried out in the GOODS-N field, and the typical detection threshold for the vast majority of data taken with state-of-the art spectrographs in 10-meter class telescopes. The SHARDS observations reach at least 2 magnitudes fainter, and thus open the possibility to reliably select and study fainter and/or higher redshift ELGs.

Figure 1 (right panel) shows the redshift distribution of the sources selected as ELGs by SHARDS with the F687W17 filter. The red histogram represents galaxies with spectroscopic redshifts, i.e., confirmed ELGs. The open histogram shows the photometric redshifts [13] for all ELG candidates. These redshift distributions demonstrate that the ELGs selected by

[1]Note that these galaxies have been highlighted only because of their redshift, i.e., some of these galaxies may not present [OII] emission, being their spectroscopic redshifts based on some other spectral feature.

SHARDS are preferentially located in the appropriate redshifts corresponding to the most common emission lines detected in intermediate and high redshift galaxies. The majority of the selected sample are [OII] emitters at z∼0.8. The expected redshifts for emitters with some of the most typical lines (e.g., Lyα, [OII], [OIII], or Hα) are marked with shadowed regions. We also mark spectral features such as the Mg+Fe absorption band at ∼280 nm, the Balmer and 4000 Å or the 2175 Å dust absorption bump (which would imprint an absorption in the galaxy SED), which can mimic an emission-line in a color-magnitude diagram such as the one depicted in Fig. 1.

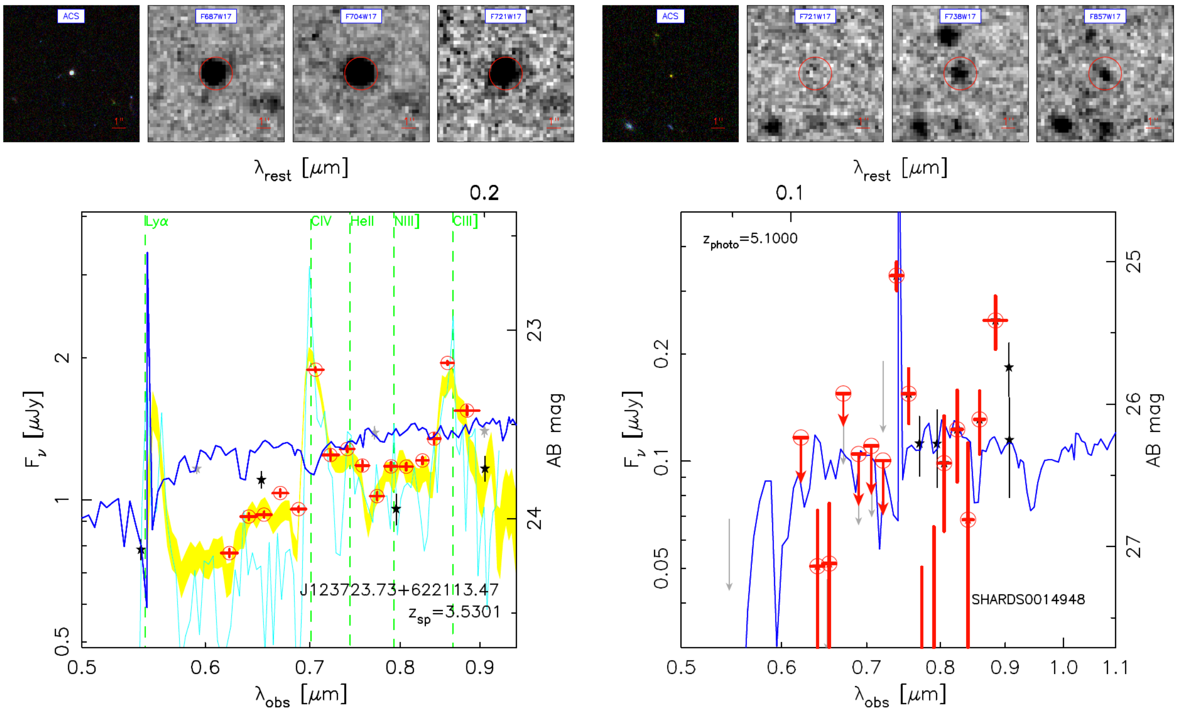

Figure 2: Examples of SEDs constructed with SHARDS data for z>3 galaxies. Broad-band photometric fluxes are depicted with black (ground-based) and gray (HST) filled stars. Red symbols show the SHARDS data, including uncertainties and filter widths. Blue lines represent stellar population synthesis models fitting the broad-band data, which were used to obtain an estimation of the photometric redshift and stellar mass [13]. The cyan lines show ground-based spectra for each source, when available. We also depict with a yellow shaded area the available HST/ACS grism spectrum from PEARS (including uncertainties). The wavelength for several typical emission-lines are marked in green. For each source, postage stamps in several bands are also given. On the left, we show a spectroscopically confirmed AGN at z∼3.5 for which the SHARDS spectro-photometric data provide clear detections of emission-lines such as CIII and CIV. On the right, we show a dropout source which has been selected as a candidate for a LAE at z∼5 with a possible companion (also a LAE at the same redshift) to the NE [14]. The SHARDS data (and the very few detections in broad-band imaging observations) are fitted with a stellar population synthesis model that predicts an intense Ly-α emission at around 740 nm, corresponding to z=5.1.

3 ELGs at very high-z

The ultra-deep imaging data from SHARDS could, in principle, allow us to detect and study sources at very high-z ($z \gtrsim 3$). Indeed, reaching magnitudes as faint as 26.5-27.0 mag in all bands from 500 to 941 nm is deep enough to detect interesting sources such as Lyα emitters (LAEs) at z> 3 and up to z$\sim$6.7. In Fig. 2, we show one example of a spectroscopically confirmed AGN at z>3 where SHARDS data reveal the presence of several emission lines such as CIII]λ1909 or CIVλ1548. The SED of this AGN shows that the spectro-photometric data from SHARDS is completely consistent and provides a similar spectral resolution as the HST grism data from PEARS. Note that SHARDS data are not yet available at wavelengths below $\sim$600 nm, but when our survey is complete we should be able to detect and measure fluxes for Ly-α in this kind of object (AGN or ELGs).

A preliminary analysis of the SHARDS data in four filters from 687 to 738 nm revealed a dozen dropout sources (in one of the four filters) with SEDs consistent with z>4 LAEs and LBGs. Figure 2 shows one of these LAE candidates at z$\sim$5, including postage stamps and a SED. In fact, the postage stamps show two LAE candidates, both appearing in the F738W17 filter (one of them being almost undetected in the ACS bands). The galaxy shown in the SED is a dropout in the F721W17 filter. Its emission is booming in the F738W17 filter, and then becomes fainter again (but detected) in redder filters. This points out to a Lyman break located within the two mentioned SHARDS filters, which would imply a redshift around z=5. This figure demonstrates the potential of the SHARDS ultra-deep medium-band survey to select magnitude 26–27 emission-line galaxies at very high redshifts. We refer the reader to [14] for a more detailed discussion on the detection and properties of the LAEs detected by SHARDS.

4 Summary

Our science verification test has demonstrated that SHARDS is able to detect virtually all the spectroscopically confirmed emission-line galaxies at intermediate redshift. This opens the possibility to extend and reach higher completeness in the samples of ELGs in GOODS-N, and carry out a comprehensive analysis of star-forming galaxies and AGN down to fainter magnitudes ($\sim$26.5 mag) than spectroscopic surveys. SHARDS has also demonstrated to be an excellent tool to detect and characterize higher redshift sources, such as Lyman break and Lyman alpha emitters. A complete analysis of the properties of the emission-line galaxies detected by SHARDS will be presented in a forthcoming paper [1]. Details on the survey definition, data reduction, calibration and general aims of the project can be found in [12].

Acknowledgments

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