RevMexAA (Serie de Conferencias), **42**, 55–57 (2013)

SHARDS: SURVEY FOR HIGH-Z ABSORPTION RED & DEAD SOURCES

P. G. Pérez-González,[1,2] A. Cava,[1] and the SHARDS Team[3]

RESUMEN

SHARDS (siglas en inglés de la Exploración de galaxias con absorción rojas y muertas a alto desplazamiento al rojo), un ESO/GTC Large Program, es una exploración espectro-fotométrica super-profunda (26.5 mag) realizada con GTC/OSIRIS y diseñada para seleccionar y estudiar galaxias masivas que evolucionan pasivamente a z=1.0–2.3 usando un juego de 24 filtros de anchura media (FWHM∼17 nm) a 500–950 nm y apuntando a GOODS-N. Nuestra estrategia observacional ha sido ideada para detectar la marca espectral conocida como absorción de Mg (a ∼280 nm), que constituye una característica distintiva, necesaria y suficiente de las poblaciones estelares evolucionadas (más viejas que 0.5 Gyr). Nuestras observaciones están siendo analizadas para: (1) construir por primera vez una muestra no sesgada de galaxias quiescentes a alto-z, llegando a magnitudes más débiles de lo conseguido hasta ahora con técnicas espectroscópicas y fotométricas; (2) derivar edades y masas estelares precisas basándonos en medidas robustas de índices espectrales como el de Mg_{UV} o D(4000); (3) estimar desplazamientos al rojo con una precisión de $\Delta z/(1+z)<0.02$; y (4) estudiar galaxias con líneas de emisión (con formación estelar o AGN) hasta altos desplazamientos al rojo. Además, las SEDs ópticas de resolución intermedia proporcionadas por SHARDS serán de gran utilidad para otras exploraciones cosmológicas llevadas a cabo con otros telescopios (p.e., HST, *Spitzer* y *Herschel*).

ABSTRACT

SHARDS, an ESO/GTC Large Program, is an ultra-deep (26.5 mag) spectro-photometric survey with GTC/OSIRIS designed to select and study massive passively evolving galaxies at z=1.0–2.3 in the GOODS-N field using a set of 24 medium-band filters (FWHM∼17 nm) covering the 500–950 nm spectral range. Our observing strategy has been planned to detect, for $z>1$ sources, the prominent Mg absorption feature (at rest-frame ∼280 nm), a distinctive, necessary, and sufficient feature of evolved stellar populations (older than 0.5 Gyr). These observations are being used to: (1) derive for the first time an unbiased sample of high-z quiescent galaxies, which extends to fainter magnitudes the samples selected with color techniques and spectroscopic surveys; (2) derive accurate ages and stellar masses based on robust measurements of spectral features such as the Mg_{UV} or D(4000) indices; (3) measure their redshift with an accuracy $\Delta z/(1+z)<0.02$; and (4) study emission-line galaxies (starbursts and AGN) up to very high redshifts. The well-sampled optical SEDs provided by SHARDS for all sources in the GOODS-N field are a valuable complement for current and future surveys carried out with other telescopes (e.g., *Spitzer*, HST, and *Herschel*).

Key Words: galaxies: high-redshift — galaxies: photometry — galaxies: starburst

1. INTRODUCTION

One of the most interesting results in Extragalactic Astronomy in the last decade is the discovery of a numerous population of massive galaxies ($\mathcal{M}\gtrsim10^{11}$ $\mathcal{M}_\odot$) at high redshift (e.g., Franx et al. 2003). Some of them are already evolving passively (Daddi et al. 2004), being good candidates for the progenitors of massive nearby ellipticals (Hopkins et al. 2009). Even more puzzlingly, these galaxies present very small sizes, and thus large mass densities (Daddi et al. 2005; Trujillo et al. 2007; Toft et al. 2007) comparable to the density of a globular cluster (Buitrago et al. 2008). The existence of very compact massive dead galaxies at high-redshift is extremely challenging for models of galaxy formation, based on the hierarchical ΛCDM paradigm (e.g, Baugh et al. 1996; Cole et al. 2000; de Lucia et al. 2006; Croton et al. 2006).

In addition, several works have found compelling evidence of a high formation redshift ($z\gtrsim2$) jointly with a high star formation efficiency for the most massive galaxies (Cimatti et al. 2006; Bundy et al. 2007; Pérez-González et al. 2008a; Ilbert et al. 2010), a scenario known as *downsizing* (Cowie et al. 1996). Furthermore, other studies report the detection of a red sequence up to $z\sim2$, populated by post-

[1]Departamento de Astrofísica, Facultad de CC. Físicas, Universidad Complutense de Madrid, E-28040 Madrid, Spain.
[2]Associate Astronomer, Steward Observatory, UofA, USA.
[3]http://guaix.fis.ucm.es/∼pgperez/SHARDS/team.html.

starburst galaxies (Labbé et al. 2007; Arnouts et al. 2007; Kriek et al. 2008; Fontana et al. 2009). These works have shown that a key epoch for the study of the formation of the red sequence is $1<z<2$.

The SHARDS ESO/GTC Large Program aims at building an unbiased sample of quiescent ETGs at $z>1$ and providing with reliable observational estimations of relevant quantities such as their number density, stellar masses, ages, and sizes. Reproducing these results at high-z constitutes a major tests for the predictions of galaxy formation models (de Lucia et al. 2006; Croton et al. 2006; Hopkins et al. 2008). Therefore, our Large Program will be a significant step forward in our understanding of galaxy formation, shedding light into the early massive star formation events and quenching mechanisms.

In this conference proceedings, we describe the observational strategy of the survey and present the first results obtained by SHARDS concerning the study of emission-line galaxies at various redshifts, and the characterization of red and dead sources at $z>1$. More information about the study of emission-line galaxies with SHARDS can be found in other conference proceedings in this volume (Cava et al. 2012, Rodríguez-Espinosa et al. 2012).

2. SURVEY DESCRIPTION

SHARDS is using OSIRIS on the Spanish 10.4 m telescope, GTC, to obtain medium-band imaging through 24 filters (FWHM∼17 nm), and covering the GOODS-N field down to the 26.5 mag (AB) in each filter. Our goal is to probe the rest-frame UV spectral range (250–350 nm) for galaxies at $z>1.0$, counting with enough spectral resolution (R∼50) to detect and accurately measure the Mg_{UV} absorption. This is a distinctive, necessary and sufficient feature of massive quiescent ETGs at high redshift. A positive detection of the feature with our spectrophotometric technique will confirm that the galaxies are quiescent and provide us with an estimate of the age of the last star formation burst (Daddi et al. 2005) and the galaxy redshift (with an accuracy $\Delta z/(1+z)<0.02$). OSIRIS provides imaging capabilities up to $\lambda\sim950$ nm, which means that we can probe the Mg absorption at $1.0<z<2.3$.

The resolution of this observing strategy is similar to that used by the Grism ACS Program for Extragalactic Science (GRAPES; Daddi et al. 2005) and the Probing Evolution And Reionization Spectroscopically project (PEARS; PI: Malhotra) to study quiescent ETGs through HST grism slitless spectroscopy. Our project covers 10 times more area than the one used in Daddi et al. (who used the UDF), and reach 1.5 mag fainter.

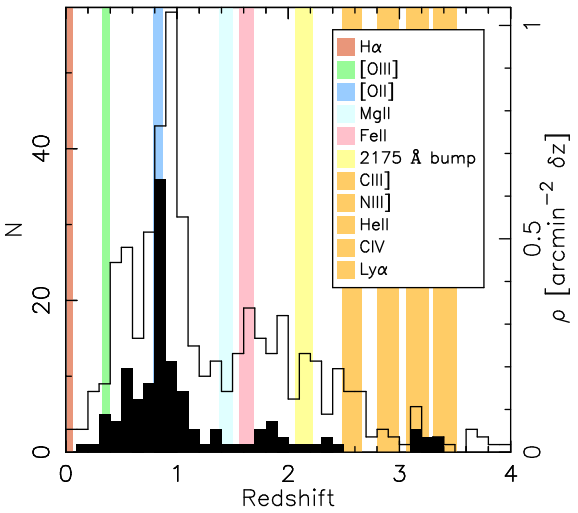

Fig. 1. Redshift distribution of the galaxies selected as emission-line candidates using the SHARDS data at 687 nm. The filled histogram refers to galaxies with confirmed spec-z's; the open histogram shows results based on photo-z's (Pérez-González et al. 2008). Shaded bands depict the expected redshifts for sources with emission in typical lines (e.g., Hα, [OII], Lyα; some absorption features are also shown) lying in the F687W17 filter.

SHARDS has completed 75% of the total 180 hours of observing time awarded to the project, as of January 2012. The data quality is excellent, reaching fainter fluxes than expected (∼27 mag) and virtually all data present sub-arcsecond seeing.

3. EMISSION-LINE GALAXIES IN SHARDS

The comparison of fluxes measured in narrow-band images with those from broad-band data in the same spectral region is a widely used technique to select and study galaxies with emission-lines at low- and intermediate- (e.g., Villar et al. 2008), and high-redshifts (e.g., Ouchi et al. 2008). The technique is based on the detection of a prominent color when an emission-line of a galaxy (at an appropriate redshift) lies within the narrow-band filter pass-band, in comparison with a broad-band filter, whose measurement is dominated by the continuum around that line.

In Cava et al. (2012), we demonstrate that SHARDS data can be used to segregate emission-line galaxies. That paper concentrates in the selection performed with the F687W17 SHARDS filter (central wavelength: 687 nm; width: 17 nm). Here, in Figure 1, we present the redshift histogram for the emission-line galaxies selected in Cava et al. (2012). More than 75% of the spectroscopically confirmed $z\sim0.8$ [OII] emitters in the GOODS-N field are selected with our medium-band data. The resemblance

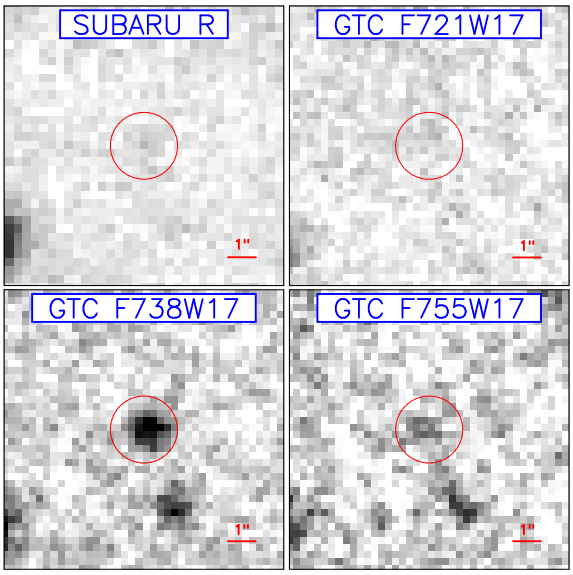

Fig. 2. Postage stamps of a close-pair of Lyman-α emitters (LAEs) at $z\sim5$ in the ultra-deep data taken in the GOODS-N field by Subaru (R-band, resolution R$\sim$7) and GTC (SHARDS data, R$\sim$50).

of the redshift distribution built with photo-z's (open histogram) with that built with spec-z's (filled) is remarkable, and the density peaks are placed where one would expect a peak in the detection efficiency based on the presence of an emission-line or absorption feature in the pass-band of the chosen filter (F687W17, in this example).

Figure 2 shows postage stamps for two Lyα emitter candidates at $z\sim5$. The R-band data and the SHARDS images at wavelengths shorter than 738 nm show blank fields, but the F738W17 filter reveals two bright objects whose Lyα emission is located within the mentioned filter. According to our analysis of the whole SED to obtain photo-z's for both sources, these two galaxies lie at $z\sim5$.

4. HIGH-Z RED & DEAD SOURCES IN SHARDS

Figure 3 shows the SED of one of the few spectroscopically confirmed massive compact galaxies at $z>1$ in the GOODS-N field (Newman et al. 2010). The SHARDS data allow to measure absorption features such as the Mg_{UV} (around 280 nm rest-frame), which can be used to constrain the stellar population models and obtain a robust determination of the age. For this galaxy, the SHARDS fluxes also reveal emission in the [OII] line, probably coming from some residual star formation (the source also counts with a faint detection in the MIPS 24 μm band). So the galaxy is not completely dead, as the broad-band data implied, but maybe in a post-starburst phase.

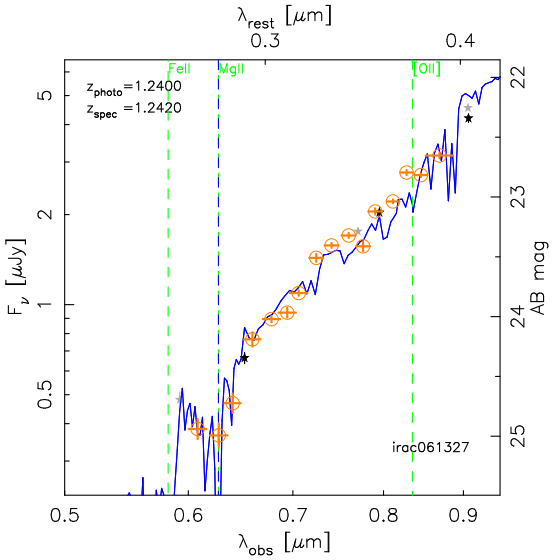

Fig. 3. SED of J123704.36+621335.0, one of the spectroscopically confirmed compact massive spheroidal galaxies in GOODS-N ($10^{11.03\pm0.04}$ $\mathcal{M}_{\odot}$, Pérez-González et al. 2008; see also Newman et al. 2010). The broad-band data (black and gray symbols) have been fitted to a stellar population model (in blue). SHARDS data (depicted in orange jointly with filter widths and errors), and the positions of the Mg absorption feature (also formed by FeII lines) and the [OII] emission-line are marked.

REFERENCES

Arnouts, S., et al. 2007, A&A, 476, 137
Baugh, C. M., et al. 1996, MNRAS, 283, 1361
Buitrago, F., et al. 2008, ApJ, 687, L61
Bundy, K., et al. 2007, ApJ, 665, L5
Cava, A., et al. 2013, RevMexAA (SC), 42, 79
Cimatti, A., et al. 2006, A&A, 453, 29
Cole, S., et al. 2000, MNRAS, 319, 168
Cowie, L. L., et al. 1996, AJ, 112, 839
Croton, D. J., et al. 2006, MNRAS, 365, 11
Daddi, E., et al. 2004, ApJ, 617, 746
Daddi, E., et al. 2005, ApJ, 626, 680
de Lucia, G., et al. 2006, MNRAS, 366, 499
Fontana, A., et al. 2009, A&A, 501, 15
Franx, M., et al. 2003, ApJ, 587, L79
Hopkins, P. F., et al. 2008, ApJS, 175, 390
Hopkins, P. F., et al. 2009, MNRAS, 398, 898
Ilbert, O., et al. 2010, ApJ, 709, 644
Kriek, M., et al. 2008, ApJ, 682, 896
Labbé, I., et al. 2007, ApJ, 665, 944
Newman, A. B., et al. 2010, ApJ, 717, L103
Ouchi, M., et al. 2008, ApJS, 176, 301
Pérez González, P. G., et al. 2008, ApJ, 675, 234
Rodríguez-Espinosa, J. M., et al. 2013, RevMexAA (SC), 42, 58
Toft, S., et al. 2007, ApJ, 671, 285
Trujillo, I., et al. 2007, MNRAS, 382, 109
Villar, V., et al. 2008, ApJ, 677, 169