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VANDELS: a deep VIMOS survey of the Candels UDS and CDFS fields

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Abstract. VANDELS is a spectroscopic VIMOS public survey of the Candels UDS and CDFS fields aimed at exploring the high-z Universe. VANDELS, contrary to previous spectroscopic surveys, is designed to move beyond redshift acquisition, obtaining spectra with high enough signal-to-noise to derive galaxies' physical parameters e.g. metallicities and velocity offsets, from the very early phases when the Universe was still partly neutral (z∼7) to the epoch when the peak of the star-formation occurred (z∼2). To this end, integration times of 20hrs < t_{int} < 80hrs have been planned.
VANDELS will have an important legacy value to the astronomy community. All raw data will be immediately public on the ESO archive, while the reduced 1D and 2D spectra will be made available ∼9 months after observations.
VANDELS pushes today's instrumentations opening the road towards our understanding of high-z galaxy physics. The findings will drive future observations, e.g. providing z=3-5 targets for detailed IFU observations using E-ELT.

Key words. Galaxy: high-z – Galaxy: abundances – Cosmology: observations

1. Introduction

VANDELS (PIs: Laura Pentericci & Ross McLure) started as a response to an *"ESO call for public spectroscopic surveys with VIMOS"*, with a letter of intent sent in October 2013 and a full proposal submitted in March 2014. The aim of the project is to study the physical properties of high redshift galaxies.

VANDELS has two main key aspects: (i) the legacy value to the astronomical community; and (ii) the fact that, alike previous spectroscopic surveys, VANDELS is not just a redshift survey.

VANDELS will consists of 912 hours of visitor mode observations, spread over 240 nights, to be carried out in four observing seasons (Aug-Dec) during 2015-2018. All raw data will be immediately public on ESO archive. Data reduction is being carried out in Milan using an updated version of `VIPGI` (Scodeggio et al., 2005) and `Easylife` (Garilli et al., 2012). The fully calibrated 1D and 2D spectra as well as additional data products will be made available ∼9 months after observations.

2. Science goals and targets

The aim of the project is to build a comprehensive scenario of the physical processes regulating star formation and mass assembly in galaxies, from the very early phases when the Universe was still partly neutral (z∼7) to the epoch when the peak of the star-formation oc-

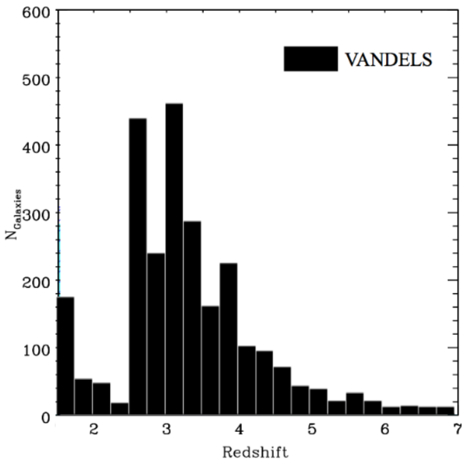

Fig. 1. Expected redshift distribution of the VANDELS survey based on the photometric redshifts derived from the multi-wavelength data available in the UDS and CDFS fields.

curred (z~2). VANDELS will therefore move beyond simple redshift acquisition, obtaining spectra of high-z galaxies with unprecedented high signal-to-noise, enough to derive properties such as metallicity and velocity offset between absorption and emission lines, thus allowing detailed investigation of the physics of galaxies in the early Universe.

The total sample will include a total of 2600 spectra consisting of four main classes:

i) Star-forming galaxies, selected in the range $2.5 < z < 5.5$ ($H_{AB} < 24$);
ii) Massive passive galaxies at $1.5 < z < 2.5$ ($H_{AB} < 22.5$);
iii) Lyman-break galaxies at $3.0 < z < 7.0$ ($H_{AB} < 26.5$);
iv) Faint AGN at $3.0 < z < 5.5$ selected via X-ray, radio, mid-IR Herschel detection and/or variability.

The expected redshift distribution of the whole sample is shown in Fig. 1. Compared to the most notable spectroscopic surveys (see Fig. 24 of Le Fèvre et al., 2015), VANDELS shows a peak at higher redshift ($\gtrsim$3) with a tail at lower redshift populated by the passive galaxies subsample selected to be at $1 < z < 2.5$.

For the primary sample i.e. star-forming galaxies at $2.5 < z < 5$, the aim is to obtain spectra with S/N~10-20 per resolution element, which allow detailed absorption line studies. In this way we will be able to (1) measure the metallicity in galaxies at $2.5 < z < 5.5$ though UV absorption, achieving better constraints on the dust content and star formation rates; and (2) assess (with a spectroscopic sample) the evolving stellar mass function and star formation rate density with unprecedented accuracy, providing a benchmark for future galaxy evolution studies.

We also aim at investigating the assembly of early type galaxies at $1.5 < z < 2.5$ and at identifying the progenitors of massive compact early type galaxies amongst the compact star forming galaxies at z>2. Ages will be contrained from UV breaks (2600/2800Å) using the VANDELS spectra and Balmer breaks from IR HST spectra. Through spectrophotometric fitting we can then therefore derive accurate stellar ages, masses and metallicities of massive quiescent galaxies at z~2.

A further aim of our project is to conduct a more classical redshift survey of galaxies significantly fainter than current samples. For these targets, redshift measurement is the main goal and lower S/N spectra are required since the aim is to detect primarily emission lines (e.g. Lyα). This secondary sample is dominated by Lyman break galaxies at $3.0< z <7.0$. By extending the current redshift surveys to these faint limits, we will be able to measure more accurately luminosity functions, and rest-frame properties of the bulk of galaxy population at high redshift.

Finally, we will be able to assess the physical conditions (metallicities, ionizing fluxes, outflows signatures) of high-z active galaxies and compare them to inactive systems at the same redshifts. Moreover, for unobscured AGN we will detect broad emission lines and estimate black hole masses. This will allow us to constrain the relationship between BH masses and their host galaxies across cosmic time up to high-z.

3. Observational strategy

VANDELS targets two southern fields, i.e. UDS and CDFS, covering a total area of 0.2 deg^2 (Fig. 2). These regions are part of the CANDELS survey (Grogin et al., 2011) and have been observed as deeply as possible at all accessible wavelengths. The CANDELS survey has recently completed its allocation of 902 HST orbits, delivering extremely deep WFC3 and ACS imaging (Koekemoer et al., 2011). In addition they are covered by ultra-deep (50 hrs/filter) Spitzer imaging from the S-CANDELS (Ashby et al., 2015), providing the deepest available 3.6+4.5μm imaging on these angular scales (m_{AB}=26.5, 5σ, at 3.6μm). They also feature deep WFC3/IR grism spectroscopy from the public 3D-HST program (Skelton et al., 2014) and extremely deep Y+K imaging from the large ESO HAWK-I program (PI Fontana). These fields represents the key legacy areas to explore the high redshift Universe and therefore the ideals to follow-up with spectroscopic observations.

All VANDELS pointings will be centered on the CANDELS near-IR HST imaging in the UDS and CDFS fields. Each field will be observed with 8 VIMOS pointings (4 quadrants of 7'x8' each, see Fig. 2) designed to cover the whole HST area. VANDELS aims at studying the physical properties of high redshift galaxies obtaining high signal-to-noise spectra. Long exposures (20-80 hrs) are therefore forseen. In more detail, each pointing will be targeted four times, for 20hrs of integration. Some of the targets, the brightest ones, are included only in one pass while the faintest ones are present in all passes and will therefore be observed for 80hrs. For each field, careful placement of the VIMOS pointings allows 70% of the slits to be allocated to galaxies within the HST imaging area, with the remaining 30% allocated to targets within the wider multi-wavelength imaging area.

4. Target selection and photometric redshift

Targets will be selected using photometric redshifts which are therefore a key aspect for the success of the survey. For the CANDELS areas, accurate photometric redshifts ($\Delta z/z$ = 0.003) are available i.e., Guo et al. (2013) for the CDFS and Galametz et al. (2013) for the UDS field. They are based on 14/15 (for CDFS/UDS) HST homogeneous, aperture matched, photometric bands covering the 0.3-4.5μm range. For the extended area, we have instead collected all the photometric bands available from literature. For the CDFS, 16 bands have been combined, i.e. VIMOS U and R-band (Nonino et al., 2009), 7 medium-band Subaru images (Cardamone et al., 2010), GEMS HST V_{606} and z_{850} (Caldwell et al., 2008), CFHT J and K from TENIS survey (Hsieh et al., 2012), H from VISTA VIDEO Survey (Jarvis et al., 2013) and the IRAC bands from the"supermap" of all CDFS Spitzer programmes. For the UDS, we have collected 13 bands: CFHT U-band (Almaini, private communication), Subaru Suprimecam $BVRi'z'$ (Furusawa et al., 2008), VIDEO Y-band (Jarvis et al., 2013); J, H, and K from UKIDSS (Lawrence et al., 2007), IRAC from SEDS.

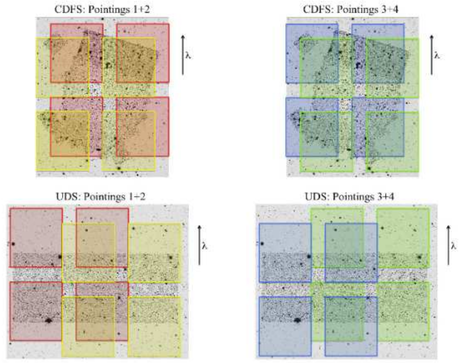

Fig. 2. Survey strategy. Four VIMOS pointings (4x7'x8'=224 arcmin^2 each) for each field i.e., CDFS in the upper panels and UDS in the lower panels, designed to cover the whole HST area.

5. Test observations

In addition to the 912 hrs allocated to the project, we have been allocated two observing runs in November and December 2014 to test the mask preparation and the observing strategy. During these runs we obtained ~10hrs of

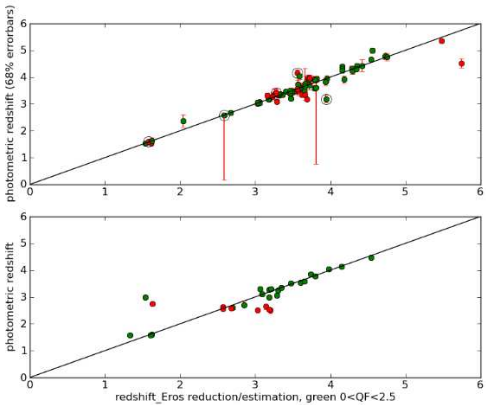

Fig. 3. Comparison between photometric and spectroscopic redshifts for the subsamples of objects observed in the first two test runs (November and December 2014). Upper panel is for the CANDELS areas while the lower panel for the extended areas.

integration in both UDS and CDFS. Already with 10hrs integration (less then the minimum final exposure time per target) we have been able to measure the redshift of 60% (83/135) of the observed targets in CDFS. A comparison between the obtained spectroscopic redshifts with the initial photometric redshifts is shown in Fig. 3. In particular the upper panel is for the CANDELS areas where the photometry is homogeneous and therefore much better for the SED fitting procedure, while the lower panel is for the extended area, which has unhomogenous but still wide photometric coverage. As shown in figure, in both cases, the agreement is very good. This makes us very confident on our target selection.

6. Perspective for future observations with E-ELT

VANDELS represents the last step possible using at their limit our current facilities. The outcome of this project will open the road towards our understanding of high-z galaxy physics and the delivered spectra, of unprecedented depth, will remain a benchmark for astrophysical properties of galaxies until the advent of future facilities such as JWST and E-ELT. In particular, VANDELS galaxies at z=3-5 will be ideal candidates to be studied in details with spatially resolved IFU E-ELT observations.

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