Galaxies at High Redshift and Their Evolution Over Cosmic Time
Proceedings IAU Symposium No. 319, 2015
S. Kaviraj, ed.

doi:10.1017/S1743921315010194

A MUSE View of the HDFS: The Lyα Luminosity Function out to z$\sim$6

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Abstract. We present preliminary results from MUSE on the Lyα luminosity function in the Hubble Deep Field South (HDFS). Using a large homogeneous sample of LAEs selected through blind spectroscopy, we utilise the unprecedented detection power of MUSE to study the progenitors of L* galaxies back to when the Universe was just $\sim$2 Gyr old. We present these results in the context of the current literature, and highlight the importance of the forthcoming Hubble Ultra Deep Field (HUDF) study with MUSE, which will increase the size of our sample by a factor of $\sim$ 10.

Keywords. galaxies: luminosity function, mass function, galaxies: evolution, galaxies: formation, techniques: spectroscopic

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1. Introduction

The study of Lyman Alpha Emitters (LAEs) offers a valuable insight into the very early stages of galaxy formation. The Lyα recombination line of Hydrogen is emitted at a restframe wavelength of $\lambda = 1216$Å, and is produced in abundance wherever new stars form. At redshifts greater than $\sim$3.0 this bright UV emission line is redshifted sufficiently to be observed at optical wavelengths, providing a means by which to detect high-redshift star-forming galaxies with optical telescopes. The intensity of the Lyα line allows us to select galaxies irrespective of their continuum magnitude, and this facilitates the study of galaxies spanning a wide range of stellar masses, including the low-mass star-forming population which form the building blocks of L* galaxies in the local Universe.

With such a representative sample of high-redshift galaxies available, we must assess the demographics and characteristic properties of the population in order to place constraints on models of galaxy formation and evolution. This is commonly accomplished through the determination of the luminosity function for statistical samples of galaxies. For instance, the Schechter luminosity function (Schechter 1976) parametrised by α, ϕ^* and L*, gives characteristic values of the faint-end slope, number density, and luminosity, and can be used to determine the nature of the population at a particular redshift.

2. MUSE Deep Fields

MUSE is a panoramic integral field spectrograph installed at the VLT. While the instrument was designed to address a wide range of science questions, a key goal is to perform deep field observations, working as a kind of detection machine for faint emission line objects. Much time has already been invested in developing observing strategies for MUSE, and it was recently demonstrated in Garel *et al.* 2015b that medium-deep surveys

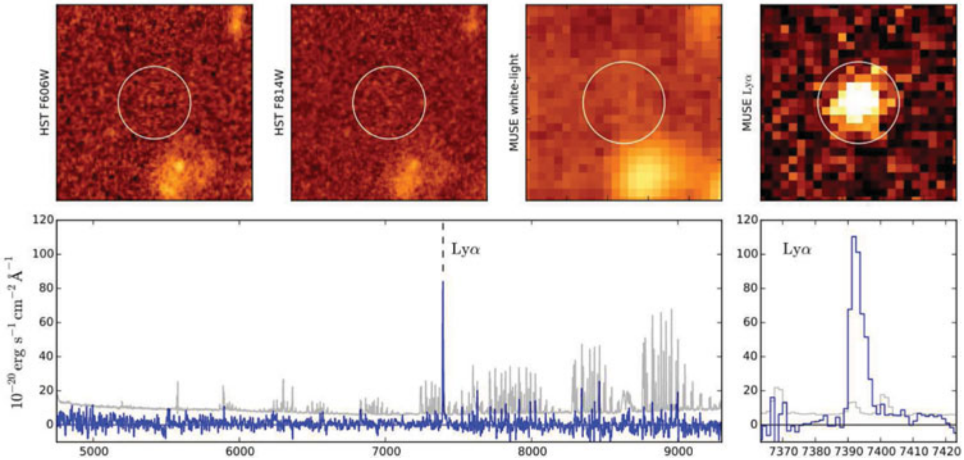

Figure 1. MUSE ID #553. A Lyα emitter at z=5.08 without HST counterpart. The upper panels show (from left to right): HST imaging in band F606W, HST imaging in band F814W, the MUSE white-light image, and finally the MUSE Lyα image (narrow-band with continuum subtraction). The lower panels show (from left to right): the entire MUSE 1-D spectrum for this object, and a zoom-in on the Lyα line. Figure taken from Bacon *et al.* (2015).

of $\sim$ 10 hours integration are ideal for probing the bulk of the LAE population, while the deepest ever selection of LAEs will come from deep field integrations of $\sim$ 80 hours.

During the final commissioning run in July 2014 we performed a deep integration on the Hubble Deep Field South (HDFS) to validate the performance of MUSE, and a wealth of data have now emerged from this patch of sky. We have determined 189 secure redshifts, probing galaxies to very faint magnitudes at high redshift. The power of blind spectroscopy is demonstrated here, as we uncover line emitters completely undetected in the deep HST imaging (I_{814} > 29AB) in just 27 hours. Figure 1 shows an example of such a line-emitter, taken from Bacon *et al.* (2015).

3. Catalogue Construction

To construct our catalogue we employ the software 'MUSELET' (J.Richard), that makes extensive use of the SExtractor package (Bertin & Arnouts 1996) to perform a systematic search through the data cube for emission lines. MUSELET then continues by merging lines co-incident on-sky into single objects, and estimating a best redshift for each of these detections. In the preliminary work presented here we have not implemented an automated rejection of false detections, but instead validate each detection through comparison to the public HDFS catalogue of Bacon *et al.* (2015).

To make a reliable assessment of the luminosity function we rely on a thoroughly understood selection function including detection completeness. In order to make quantitative measures of completeness in our LAE sample we insert fake point-source line emitters distributed randomly on-sky into the real data cube, and evaluate the recovery fraction with MUSELET as a function of the input line luminosity and LAE-redshift. For each fake line-emitter the properties of the Lyα line profile (asymmetry and velocity width) are drawn randomly from the measured profiles of the LAEs presented in Bacon *et al.* (2015). In Figure 2 we present the completeness of LAEs at all wavelengths detected by MUSELET as a function of input line flux. We highlight the 50% and 20% completeness limits at log $F_{Ly\alpha}$ $\sim$-17.45 and $\sim$-17.70 [erg s^{-1} cm^{-2}] respectively. We note that the

https://doi.org/10.1017/S1743921315010194 Published online by Cambridge University Press

Table 1. LAEs per redshift bin found in our study.

Redshift	No. Objects	Median Faintest Bin log $L_{Ly\alpha}$ [erg s^{-1}]	No. Objects in Faintest Bin
$3.0 < z < 4.0$	30	41.172	8
$4.0 < z < 5.0$	27	41.163	1
$5.0 < z < 6.0$	7	42.155	2

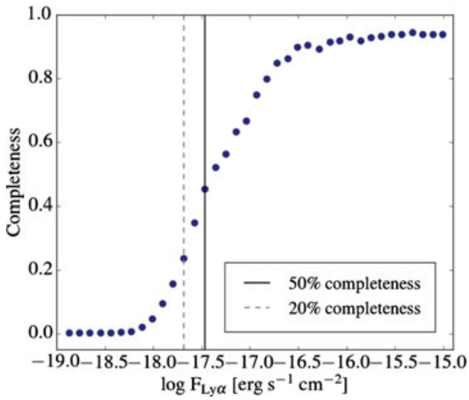

Figure 2. Completeness as a function of input line flux. Analysis carried out for fake point-source LAEs inserted into the HDFS MUSE-cube and recovered using our detection software MUSELET.

plateau at ∼97% completeness results from objects falling on top of bright sources in the field or being coincident in wavelength with strong sky-lines.

4. Results: Luminosity Functions

We apply a Vmax formalism to estimate the Lyα luminosity function per log L bin of width 0.5 dex, in three large redshift bins. We summarise the findings in Table 1, and present the results of this 27-hour integration in the context of previous results in the literature in Figure 3.

Many of the literature samples shown in Figure 3 and compiled in Garel *et al.* (2015) are based on narrow-band selection, but we also include samples from the targeted-plus-serendipitous study of Cassata et al. (2011) (see also VVDS; Le Fèvre et al. 2003) and the deepest sample to date at z∼ 3 from Rauch *et al.* (2008). We detect 30 objects with $3.0 < z < 4.0$, 8 of which fall in our faintest bin. Our data demonstrate that MUSE is able to probe LAEs down to luminosities comparable to the faintest study to date at redshift ∼ 3 (Rauch et al. 2008), but with a much greater efficiency. In the $4.0 < z < 5.0$ bin we see 27 objects, 22 residing at fainter luminosities than seen before at this redshift. Finally in the highest redshift bin, $5.0 < z < 6.0$, we find 7 objects, of number density in good agreement with existing data.

A point of caution is cosmic variance over a field of this size. We refer the reader to the predictions of Garel *et al.* 2015b for quantitative measures of the variation expected for surveys of this kind.

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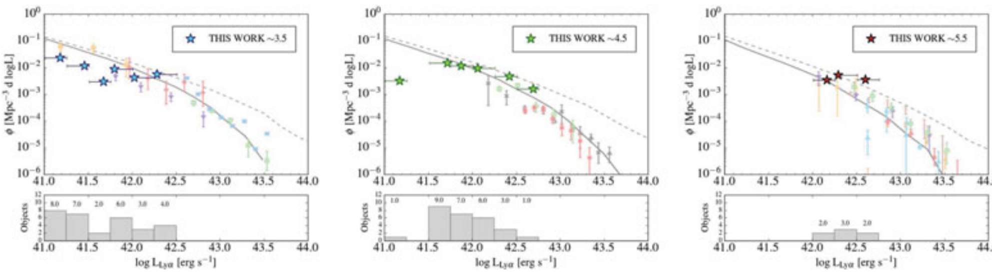

Figure 3. Preliminary Lyα luminosity functions in three redshift bins presented in the context of current literature. The lower panel on each plot shows the number of objects detected in each redshift log-L bin using the software MUSELET.

5. Conclusions

We have demonstrated the efficiency with which MUSE is able to detect emission-line galaxies out to redshift $\sim$ 6, and the great potential that this method holds for constructing samples of emission-line galaxies. We present preliminary constraints from MUSE on the Lyα luminosity function in the HDFS, and using just a 27-hour integration we are already able to help in establishing the faint-end slope out to $z \sim 5.0$.

The advances in our understanding with the study of the Hubble Ultra Deep Field (HUDF) will be great. This 10-hour integration across the 9 square arcminute region of the HUDF will add upwards of $\sim$ 800 objects to our sample of Lyα emitters, allowing a vast improvement in the statistics of our assessment of the luminosity function.

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